Conceptual frames and research strategies for integrated studies of adaptation to drought

Philippe P. Rozenberg, Anne Griebel, Gregor Sanders

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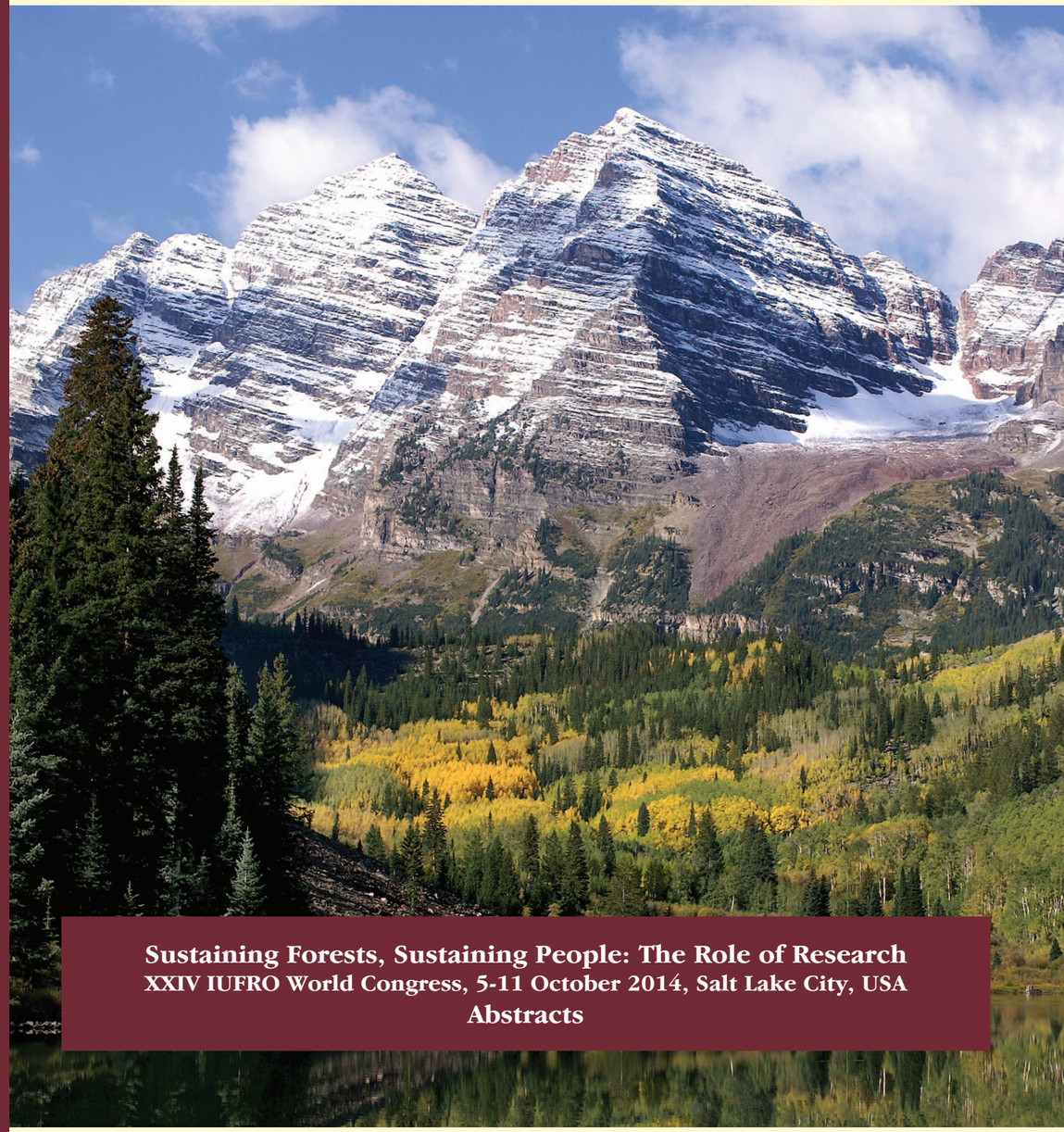

Sustaining Forests, Sustaining People: The Role of Research
XXIV IUFRO World Congress, 5-11 October 2014, Salt Lake City, USA
Abstracts

EDITORS: JOHN A. PARROTTA, CYNTHIA F. MOSER, AMY J. SCHERZER, NANCY E. KOERTH and DARYL R. LEDERLE

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A.A. NAWIR and L. SANTOSO

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The International Forestry Review

Sustaining Forests, Sustaining People: The Role of Research

XXIV IUFRO World Congress, 5–11 October 2014, Salt Lake City, USA

Abstracts

EDITORS

JOHN A. PARROTTA, CYNTHIA F. MOSER, AMY J. SCHERZER,

NANCY E. KOERTH and DARYL R. LEDERLE

Preface

On behalf of the Congress Scientific Committee[1] for the XXIV World Congress of the International Union of Forest Research Organizations (IUFRO) – the world's network of forest science – it is my pleasure to present this collection of abstracts of plenary, sub-plenary, technical, and poster presentations which constitute the Congress scientific program. These 2,430 abstracts represent the results of the latest research of thousands of forest scientists and students from over 100 countries, as well as the significant contributions of the more than 200 colleagues who organized over 170 technical and sub-plenary sessions. We thank all of these colleagues, as well as members of 2014 Congress Organizing Committee and colleagues from IUFRO Headquarters in Vienna for their unstinting support of the Congress Scientific Committee's work since 2011.

The Congress title, *Sustaining Forests, Sustaining People: The Role of Research*, reflects both core values of our profession and the aims of IUFRO, whose mission is to promote global cooperation in forest-related research and to enhance the understanding of the ecological, economic and social aspects for forests and trees; as well as to disseminate scientific knowledge to stakeholders and decision-makers and to contribute to policy and on-the ground forest management.

In its 2010–2014 Strategy, IUFRO committed itself to strengthen forest research for the benefit of forests and people by addressing the changing needs and priorities of forest science and IUFRO's members, The strategy also sought to expand IUFRO's strategic partnerships and cooperation by promoting interdisciplinary scientific cooperation; increasing involvement of students (our future) in IUFRO's activities; expanding partnerships with international organizations, governments and stakeholders; and strengthening communication and linkages with the broader scientific community, policy-makers, and society at large. These objectives are embodied in the seven Congress themes, encompassing the full range of IUFRO's traditional and emerging scientific priorities. These themes, around which the Congress scientific program was built, explore issues of paramount importance for the future of forests and the broad spectrum of environmental, social, cultural, and economic benefits that forests provide to people in both rural and urban societies worldwide: *Forests for People, Forest Biodiversity and Ecosystem Services, Forests and Climate Change, Forest and Water Interactions, Forest Biomass and Bioenergy, Forests and Forest Products for a Greener Future,* and *Forest Health in a Changing World*.

Regardless of your particular areas of interest and scientific expertise, we hope that this volume of abstracts—organized by Congress program structure with its menu of 5 plenary, 19 sub-plenary, and more than 170 technical and poster sessions—will encourage, perhaps inspire, you to explore and expand your interests in a broad array of contemporary topics in forest science.

Dr. John A. Parrotta
U.S. Forest Service, Research & Development
Chair, Congress Scientific Committee

[1] The Congress Scientific Committee includes IUFRO's two vice-Presidents (Mike Wingfield and Su See Lee), representatives of IUFRO's nine Divisions (Jens Peter Skovsgaard, Yousry El-Kassaby, Hans Heinimann, Ron McRoberts, Andrew Wong, Tuija Sievänen, Tod Ramsfield, Robert Jandl and Jim Johnson), and a representative of the International Forestry Students Association (Lisa Hansen).

PLENARY SESSIONS

Modern timber buildings from sustainable forests. Buchanan, A. (*University of Canterbury, New Zealand; andy.buchanan@canterbury.ac.nz*).

This paper describes the huge opportunities for engineered wood to be used for constructing modern timber buildings. This is essential for a greener future on our planet, to reduce world-wide dependence on energy and CO_2 intensive materials like concrete and steel, by moving to engineered wood to construct homes, factories and offices for growing populations. To promote the design and construction of engineered timber buildings, it is necessary to develop new wood-based materials, to manage the wood supply chain, and to encourage research and innovation by design professionals, and to remove institutional barriers. This is not always easy. The paper describes a New Zealand example, where many of the jigsaw pieces were in place for modern timber buildings in the rebuild of Christchurch following the massive 2011 earthquakes. New Zealand has a mature forest industry, largely based on exotic plantations of radiata pine, and a growing wood processing industry, focusing on LVL. Timber engineering is taught and researched in New Zealand universities, and local structural engineers are leading the world in innovative low-damage seismic design. The paper will describe a successful industry-government research partnership supporting modern timber buildings in New Zealand. Demonstration buildings are needed to catch the imagination of investors and to increase the confidence of all players in the supply chain. New timber buildings have been proposed for Chicago (42 stories), Vancouver (30 stories), and design is well underway for a 14-story building in Ottawa, with the support of the Canadian government.

The People and Forests trajectory- 1994–2014 and beyond. Colfer, C.J.P. (*Center for International Forestry Research, Indonesia & Cornell University, USA; cjpcolfer@gmail.com*).

Much progress on the people-forest nexus has occurred within the forestry world. Forestry researchers are taking serious notice of the impacts of forests on people, and people on forests. Encouraging examples include attention to human well-being, attempts to work collaboratively with communities and their subgroups, a focus on power relations (devolution, ethnic and gender studies), and attention to people's knowledge about forests. More controversial topics like swidden agriculture, human health, nutrition, human rights and population have also been addressed. But much remains to be done. We know how dependent people living in forests are upon them and that their influence can be positive or negative. The desire to maximize the positive suggests the need for a greater focus on equity. The female half of forest populations, for example, still tends to be invisible. Yet studies focused on women alone have proven difficult to integrate into forestry. To activate all human capabilities, we need to better understand the relations between men and women as they interact with each other and with the forest. This will require courageously addressing: a) sensitive issues like population, the division of labor within households, religious beliefs and associated ideals, and violence against women; and b) methodologically complex ones like values, norms, and other powerful but intangible cultural topics. The secret to our ultimate success will be effectively integrating the many disciplines involved so that we can expand our understanding of the forests – people nexus.

City forests, forest cities – exploring the complex liaison between the sylvan and the urban. Konijnendijk van den Bosch, C. (*Swedish University of Agricultural Sciences, Sweden & University of Copenhagen, Denmark; cecil.konijnendijk@slu.se*).

Since the rise of the first cities, the relationship between the Sylvan and the Urban has been complex. Although city and forest have often been regarded as enemies, or at least as opposite ends on a continuum between the man-made and the natural, cities have also been heavily dependent on forests, not in the least for their very development. Moreover, some cities have developed as true 'forest cities', integrating trees and woodland into their very fabric and mentality. This presentation analyses the current relationship between forest and city, based on historical insights and present policies, initiatives and projects from across the globe. It emphasises the role of research in strengthening the ties between urban and sylvan, as for example reflected in the advances made by the urban forestry field. Developments such as the rise of green infrastructure thinking and the provision of a range of ecosystem services are critically analysed. Difficulties in assessing cultural ecosystem services are hampering the development of the urban-forest relationship, as forests and trees in urban areas provide a range of cultural services that contribute to the health, wellbeing and happiness of urbanites. Lessons will be drawn for the role of forestry in an urbanising world.

On maintaining cycles and feedbacks in tropical forest ecosystems: some thoughts from basic research. Newbery, D.M. Vegetation (*University of Bern, Switzerland; david.newbery@ips.unibe.ch*).

Despite a long tradition of continued research into the ecology of natural rain forests many insights have still to be acknowledged and applied properly in forest management. Relevant advice continues to be largely ignored, and this has important consequences for conservation and long-term sustainability. I suggest that broad pan-tropical generalizations are not going to be particularly useful, and a focused site-orientated scientific approach is likely to be far more effective. Recognition of ecosystems as *simple* systems, ones in which not more than three or four key components are modelled or altered, may lead to much better progress for forestry. Ecosystems are nevertheless dynamic and contingent, so a middle way is required to steer us out of the current one-versus-many species or factors dichotomy. The need to 'take stock' and re-evaluate our research directions is highly desirable. These ideas will be developed with some theory. They are not all so very new, but their context and immediacy calls for some serious reconsideration. Illustrative examples from two long-term studies in rain forest will be discussed, and some recommendations presented.

SUB-PLENARY SESSIONS

SP-01 Forest foods, medicines and human health

Organizers: Hannu Raitio (Finnish Forest Research Institute, Finland), James Chamberlain (U.S. Forest Service, USA), Carsten Smith-Hall (University of Copenhagen, Denmark) & Tuija Sievänen (Finnish Forest Research Institute, Finland)

Integrating forest foods and medicines into sustainable forest management. Chamberlain, J. (*U.S. Forest Service, USA; jchamberlain@fs.fed.us*).

Multiple-use, ecosystem management, biodiversity conservation, have been strategies for managing the world's forests. Objectives of maximizing timber, conserving wildlife, protecting endangered species, providing recreation are fully embedded in forest management plans. In general, the forestry profession is supported by a wealth of science-based knowledge on producing a sustainable supply of fiber. But, there is little science-based information on how to manage the same forests for food and medicine to sustain the lives of people who depend on the same natural resources for mere sustenance. Trained foresters can estimate with great accuracy the amount of merchantable wood in a forest. Growth and yield models for most temperate trees are developed and used in estimating when and how much to harvest. But those same techniques are not available for forest plants that are harvested for their food or medicinal values. This presentation examines the challenges of integrating food and medicinal plants in forest management. It explores efforts to develop inventory methods for estimating merchantable biomass of plants that are harvested for their roots. The author urges the forestry profession to expand the management paradigm to include products that are used to feed and cure people.

Food security, food sovereignty, and urban forests. Emery, M. (*U.S. Forest Service, USA; marla.r.emery@gmail.com*).

In Syracuse, New York, Bhutanese refugees harvest lambs quarters (*Chenopodium* sp.) in vacant lots and around the edges of community garden plots. Gingkos (*Gingko biloba*) planted as street trees in Philadelphia attract foragers seeking ingredients for a special soup made at lunar New Year. Learn about results from multi-city research in the United States on the contributions of edible urban non-wood forest products (NWFPs) to human health and wellbeing. Hundreds of plant and mushroom species are foraged from city green spaces that run the gamut from formal parks to stoop yards and street medians. The prospect of finding edible urban NWFPs gives purpose to outings and a motivation for exercise. It also provides fresh produce at no cost for urbanites who often live in food deserts. However, there may also be human health risks associated with contaminated soils and misidentification of species. Further, the diversity of land ownerships makes it difficult to negotiate access and know what rules do and do not apply. Understanding urban NWFPs suggests opportunities for new urban forest policy and design to increase food security and sovereignty for city residents.

Wildlife: a forgotten and threatened forest food resource. Nasi, R. (*Center for International Forestry Research (CIFOR), Indonesia; r.nasi@cgiar.org*), Pinedo-Vasquez, M. (*Columbia University, USA; map57@columbia.edu*), Van Vliet, N. (*ONFi and Center for International Forestry Research (CIFOR), Indonesia; vanvlietnathalie@yahoo.com*).

Protein from forest wildlife (including fish) is crucial to food security, nutrition and health across the tropics. The harvest of duikers, antelopes, pigs, primates, rodents, birds, reptiles and fish provides invaluable benefits to local people both in terms of income and of improved nutritious diets. It also creates, often linked with commercialization, some very important health issues with the spread of several life-threatening diseases (Ebola, SARS). Vulnerability of the resource to harvest varies, with some species sustaining populations in heavily hunted secondary habitats, while others require intact forests with minimal harvesting to maintain healthy populations. Global attention has been drawn to biodiversity loss through debates regarding bushmeat, the "empty forest" syndrome and their ecological importance. However, information on the harvest and the trade remains fragmentary, along with understanding of their ecological, socioeconomic and cultural dimensions. Here we assess the consequences, both for ecosystems and local livelihoods, of the loss of these important resources and propose alternative management options.

A global-comparative analysis of household-level incomes from environmental food products. Smith-Hall, C., Pouliot, M., Larsen, H., Thorsen, R. (*University of Copenhagen, Denmark; cso@ifro.ku.dk; mapo@ifro.ku.dk; hol@ifro.ku.dk; rith@ifro.ku.dk*), Angelsen, A. (*Norwegian University of Life Sciences, Norway; arild.angelsen@umb.no*), Wunder, S. (*Center for International Forestry Research (Center for International Forestry Research (CIFOR)), Brazil; swunder@cgiar.org*).

How important is environmental food extraction to rural household incomes? Orthodox knowledge portrays environmental foods as a resource of last resort to tropical households: famine foods for the hungry, and fallback subsistence sources for women and the poorest. However, the available evidence, typically from smaller-scale case studies, is inconclusive. Using income data from approximately 8000 households in 24 developing countries across three continents, collected by the Poverty Environment Network (PEN), we investigate absolute and relative household-level incomes from environmental food products and analyze the relative importance of forest and non-forest environments as supply sources. We use multivariate analyses to identify the determinants of household-level environmental food incomes. Environmental foods constitute the most important non-forest environmental income source and the second-most important forest income product group. In absolute terms, environmental food forest income is triple that from non-forest environments. Environmental food income is found across all household income quintiles, but poorer households have higher shares, in particular from subsistence products. Environmental foods also serve an income gap filling function.

From forest to pharmacy — drug development from nature based molecules. Wähälä Hase, K. (*University of Helsinki, Finland; kristiina.wahala@helsinki.fi*).

Natural products maintain their importance in drug discovery alongside the advances in computational work. They serve most often as starting points for discovery work on the computer screen. This presentation will show examples particularly in the area of forest-derived bioactive chemical compounds, their effects and use as sources for new or modified drugs, as well as future challenges in the area. The possibilities seem almost endless — just think of nature itself which has been able to synthesize more than 600,000 bioactive organic compounds from isoprene, the plant and forest derived hydrocarbon of just five carbon atoms.

SP-02 Integrating the economics of ecosystem services into sustainable forest management

Organizers: Donald Hodges (University of Tennessee, USA), Donald Grebner (Mississippi State University, USA) & Lidija Zadnik-Stirn (University of Ljubljana, Slovenia)

The role of bioenergy as an ecosystem service. Grebner, D. (*Mississippi State University, USA; dgrebner@CFR.MsState.Edu*), Hodges, D. (*University of Tennessee, USA; dhodges2@utk.edu*), Henderson, J., Grala, R. (*Mississippi State University, USA; jhenderson@cfr.msstate.edu; rgrala@cfr.msstate.edu*).

As human populations expand around the globe, there is an increasing need for benefits and services provided by forested ecosystems. These services include traditional products such as sawn wood and pulpwood, but also wildlife habitat, water quality, biodiversity, carbon sequestration among many others. An old ecosystem service that has re-emerged as a topic of interest in recent years is the use of wood as a feedstock for bioenergy generation. This paper will discuss the linkages of using woody biomass for bioenergy generation to sustainable forest management as well as some of the limitations and drawbacks of incorporation into forest management operations. In addition, potential research needs will be identified as well as the optimal scale for these types of analysis will be discussed.

Current status and future research directions for assessing water as an ecosystem service. Hodges, D., Chapagain, B. (*University of Tennessee, USA; dhodges2@utk.edu; bchapaga@utk.edu*), Hale, S. (*ecoReata, USA; stuart@ecoreata.com*).

Water and forested watersheds continue to be a major emphasis for ecosystem service markets, capitalizing on both the ability of watersheds to regulate the flow as well as the quality of water. This paper presents the current status of these markets for a variety of cases globally, highlighting several recent innovations in measurement and applications of market mechanisms. Special emphasis is placed on identifying those features that enhance the likelihood of success for market development and function, as well as major barriers to implementation. The paper concludes by discussing some of the methodological issues for future research efforts.

Valuation of ecosystem services using the life satisfaction approach. Kant, S. (*University of Toronto, Canada; shashi.kant@utoronto.ca*), Vertinsky, I. (*University of British Columbia, Canada; Ilan.Vertinsky@sauder.ubc.ca*), Zheng, B. (*University of Toronto, Canada; zhengbi@auburn.edu*).

Stated- and revealed-preference valuation methods suffer from many limitations and are inappropriate for situations where markets for private goods associated with ecosystem services (ES) do not exist or are not perfectly competitive. Such situations exist in all countries. We propose a life-satisfaction-based approach for ES valuation. In this approach, a multi-domain model of the determinants of life satisfaction explores the linkages between activities that contribute to satisfaction with key life domains (i.e. Income, Housing, Health, and Social, Cultural, and Land Use (SCLU)), and contributions of domains to the general satisfaction (GS). We used the model to value social, cultural, and land use activities that incorporate multiple ecosystem services. The model is estimated using primary data from two First Nations of Canada. In terms of GS, one unit change in the SCLU, Health, and Housing domains are equal to 2.31, 2.27, and 2.05 units change in Income domain, respectively. The mean elasticity of GS with respect to traditional diet (provisioning services), social ties, and land use activities laws, health services, and gathering quality (cultural services) are 5.46, 8.00, 9.42, 10.73 and 31.12 times the elasticity with respect to income, respectively. These results reflect the central role of ecosystem services in life satisfaction.

Influence of the TEEB DE study on forest reporting and management. Kindler, E., Möhring, B. (*Georg-August-Universität Göttingen, Germany; elisabeth.kindler@forst.uni-goettingen.de; bmoehri@gwdg.de*).

Forests and the ecosystem services they provide have been part of the scientific discussion in the German forest sector for more than one hundred years. Besides the valuation of these services their integration into the forest management was and is of major interest. Irrespective of forest science the number of environmental studies concerning ecosystems, their services and values, has increased during the last years; e.g. the TEEB (The Economics of Ecosystems & Biodiversity) study which is mainly driven by nature conservation actors. The idea behind this initiative is to value ecosystems or ecosystem services monetarily so planners can also consider the severe economic loss for society in the case of ecosystem damage and degradation. The state forestry service of Lower-Saxony (NLF) manages about 330,000 ha of woodlands in northern Germany that provide multiple forest services. In our study we investigate how useful the outcomes of the TEEB study – especially its national implementation TEEB DE ("Naturkapital Deutschland") – are from a forest enterprise's perspective, with reference to the NLF. In this process we examine if, and how, the TEEB results can be used in the NLF reporting system as well as how they can be incorporated into forest management decisions.

SP-03 Forest health in a changing world

Organizers: Tod Ramsfield (NRCan-Canadian Forest Service) & Eckehard Brockerhoff (Scion, New Zealand)

Synergies, feedbacks and tipping points: mountain pine beetle's rapid range expansion threatens invasion of North American boreal pine forests. Carroll, A. (*University of British Columbia, Canada; allan.carroll@ubc.ca*).

The mountain pine beetle is an aggressive bark beetle that is native to the pine forests of western North America. When environmental conditions suitable for survival coincide with abundant susceptible host trees, landscape-level outbreaks result. Although there have been 4 outbreaks during the past century, the ongoing epidemic is unprecedented in its size and severity – causing the mortality of mature pines across »18 million hectares since 1999. Historically, the mountain pine beetle was restricted to western North America by non-forested prairies in the South, and the high elevations of the Rocky Mountains in the North. However, in recent years, it has successfully breached the geo-climatic barrier posed by the northern Rocky Mountains, and small populations are now established in pure jack pine stands within the western margins of the boreal forest. Given predictions of increasingly suitable climate for the mountain pine beetle, together with accumulating evidence for reduced defensive potential by evolutionarily naïve pines, there is concern that full-scale invasion of boreal pine and expansion across northern North America is a plausible threat. This paper will examine the causes and consequences of rapid range expansion by the mountain pine beetle, and consider the risk to the transcontinental boreal forest.

Forest biodiversity and forest health. Okabe, K. (*Forestry and Forest Products Research Institute, Japan; kimikook@ffpri.affrc.go.jp*).

The relationship between biodiversity and ecosystem services (ES) in terrestrial ecosystems has been summarized at the species diversity level: while ES of which processes highly depend on organisms (e.g. pollination, biological control and seed dispersal) tend to be strongly related with species richness, the others such as regulation of erosion and air purification are weakly to not related with species diversity but well related with ecosystems. Among non-biodiversity related ES, some are suspected to be more related to biodiversity than may be currently understood: for example, the production service (increasing biomass) that is highly related to the carbon sink in natural forests may be positively correlated with species diversity of trees, depending on scale and the ecosystem type. Forest types such as monocultural plantations and young/old natural forest, forest age/successional stage and forest area have influence on biodiversity depending ES because they are also habitat characteristics of ES agents. Forest resilience and resistance are also related to biodiversity, and these characteristics strongly influence forest health. Hence, biodiversity directly and indirectly contributes to maintaining forest health although the mechanisms may differ with scale and the particular aspect of health considered.

Loss of resilience leads to low productivity in a Chilean hardwood forest. Thompson, I. (*Canadian Forest Service, Canada; ian.thompson@nrcan.gc.ca*), Bahamondez, C. (*Instituto Forestal (INFOR), Chile; cbahamon@infor.cl*).

Forest resilience is an emergent ecosystem property conferred at multiple levels by genes, species, and landscapes. Forests are naturally resilient to environmental change and management within bounds. These bounds reflect the capacity of the system to recover its normally recognized species composition and reflects the inherent stability of the system in ecological time. In poorly managed or 'unhealthy' ecosystems, thresholds may be passed resulting in a change in state, where a different vegetation community assembles that may or may not be stable, and where the ecosystem services derived from the system are altered. A threshold is a change in the forest ecosystem state over a critical boundary value, related to the dynamic behaviour of systems, below which the ecosystem production changes in an unpredictable fashion. One measure of such a change is ecosystem productivity, which can be measured for trees as mean annual increment. Here, we illustrate the concept of loss of resilience. We discuss how improper management of a Chilean forest has resulted in a change in state with consequent low productivity and altered tree species composition. We developed a model using differential equations on stand-level data to illustrate the unpredictable outcome of overcoming the natural resilience of this forest. The model is widely applicable and can be used to predict a threshold for managers.

International trade in live plants: rationale for mitigating a high-risk pathway for the introduction of forest pests and pathogens. Wingfield, M. (*FABI, University of Pretoria, South Africa; mike.wingfield@fabi.up.ac.za*), Liebhold, A. (*U.S. Forest Service, USA; aliebhold@gmail.com*), Brockerhoff, E. (*Scion, New Zealand; eckehard.brockerhoff@scionresearch.com*), Slippers, B. (*FABI, University of Pretoria, South Africa; Bernard.Slippers@fabi.up.ac.za*).

New biological invasions by invasive alien tree pests and pathogens are increasing in number for every country of the world where data are being accurately assembled. This represents a global crisis with signifant costs to world economies and negative impacts to natural ecosystems and biological diversity. Various measures have been implemented to reduce the movement of pests and pathogens across global boundaries and some, such as treatment standards for trade in wood and wood packaging material, appear to have positive effects. Yet, there is significant evidence to show that one of the most important pathways for the global movement of unwanted pests and pathogens lies in the transfer of living plant material. Sadly, there is also evidence of illegal movement of plant material. Ironically, legally sanctioned trade in plants is increasing globally with growing numbers of examples of this pathway of introduction leading to tree disease and insect epidemics. Initiatives such as the Montesclaros Declaration suggest strong controls for the trade living plants are promoting improvement. But much more work is required, including economic assessments that allow balancing the benefits of live plant trade with the costs associated with introduced tee pests and pathogens.

SP-05 Biodiversity and ecosystem services in planted forests

Organizers: Eckehard Brockerhoff (Scion, New Zealand), Hervé Jactel (INRA, France) & Peter Freer-Smith (Forest Research, UK).

The impacts of pests and diseases on future delivery of ecosystem services. Freer-Smith, P., Webber, J. (*Forest Research, United Kingdom; peter.freer-smith@forestry.gsi.gov.uk; joan.webber@forestry.gsi.gov.uk*).

The increasing numbers of invasive pests and pathogens entering the United States, Europe and Africa indicate that the threat to forests is increasing concurrently with climate change and globalisation. To date research has mainly focused on trees of economic importance. However in recent years a number of major epidemics have devastated natural ecosystems and landscapes valued both for timber and by the general public. It is helpful to consider explicitly the consequences of pests and pathogens for the full range of ecosystem services. Pests and diseases can affect the ability of forests to store carbon, to reduce flooding, to maintain water supplies, conserve biodiversity and to support recreation and culture. Many of these benefits are uncosted and enjoyed by a range of stakeholders; raising important questions about who is responsible for measures to protect tree health. There are a number of research priorities including to understand: 1) why some pathogens and insects become significant, 2) the molecular basis of pathogenicity, 3) why some species reach epidemic prevalence or abundance. It will also help to identify which species are most likely to be problematic if they are transported to new geographical regions, recombine with other organisms, or experience new climatic conditions.

Biodiversity and resistance to pests and pathogens of planted forests. Jactel, H. (*French National Institute for Agricultural Research (INRA), France; herve.jactel@pierroton.inra.fr*), Brockerhoff, E. (*Scion, New Zealand; eckehard.brockerhoff@scionresearch.com*), Castagneyrol, B. (*French National Institute for Agricultural Research* (*INRA), France; bastien.castagneyrol@pierroton.inra.fr*).

Pest and pathogen regulation is an increasingly recognized service provided by biodiversity in forest ecosystems. Specific tree species associations can lead to reduced biotic damage, i.e. associational resistance. Here we report the outcomes of meta-analyses that allowed quantifying the magnitude of this resistance. We show that resistance of mixed forests is greater against host-specific than generalist pests and pathogens. Furthermore, a review of experimental evidence revealed that associational resistance is driven by two key ecological mechanisms occurring in mixed forests: (1) a reduction in colonization probability through reduced host tree density and apparency, (2) an increase in top down regulation by natural enemies that can benefit from more diverse resources and shelters. Both processes depend more on the composition of tree species assemblages than on the number of associated tree species. In particular, mixtures of phylogenetically contrasting tree species display more resistance than mixtures of congeneric tree species. These findings pave the way for an improvement in the design of planted forests that are less vulnerable to impacts of pests and diseases.

Assessing biodiversity effects on forest multi-functionality using a global network of tree diversity experiments. Scherer-Lorenzen, M. (*University of Freiburg, Germany; michael.scherer@biologie.uni-freiburg.de*), Bruelheide, H. (*University of Halle, Germany; helge.bruelheide@botanik.uni-halle.de*), Paquette, A. (*Université du Québec à Montréal, Canada; paquette.alain@uqam.ca*), Ponette, Q. (*Universite Catholique de Louvain, Belgium; quentin.ponette@uclouvain.be*), Hector, A. (*University of Oxford, United Kingdom; andrew.hector@plants.ox.ac.uk*), Messier, C. (*Université du Québec en Outaouais, Canada; ch.messier@gmail.com*), Jactel, H. (*French National Institute for Agricultural Research (INRA), France; herve.jactel@pierroton.inra.fr*), Verheyen, K. (*University of Ghent, Belgium; Kris.Verheyen@UGent.be*), Reich, P. (*University of Minnesota, USA; preich@umn.edu*), Koricheva, J. (*Royal Holloway University London, United Kingdom; Julia.Koricheva@rhul.ac.uk*), Huxham, M. (*Edinburgh Napier University, United Kingdom; M.Huxham@napier.ac.uk*), Godbold, D. (*University of Natural Resources and Life Sciences (BOKU), Austria; douglas.godbold@boku.ac.at*), Perring, M. (*University of Western Australia, Australia; michael.perring@uwa.edu.au*), Barsoum, N. (*Forest Research, United Kingdom; nadia.barsoum@forestry.gsi.gov.uk*), Hulvey, K. (*University of Western Australia, Australia; kris.hulvey@uwa.edu.au*), Potvin, C. (*McGill University Montreal, Canada; catherine.potvin@mcgill.ca*).

Plantation forests deliver many ecosystem services, but are often depauperate in biodiversity compared with natural forests. To overcome this deficit, several measures have been suggested, including the use of multi-species mixtures instead of planting monocultures. The rationale behind such suggestions do also stem from findings of functional biodiversity research, which has shown that increasing plant diversity may have many positive effects on ecosystem functions and services. Most results have been obtained from fast-growing model systems such as grasslands, and evidence from forests remains scarce. Here, I review results from the global network of tree diversity experiments (TreeDivNet), where new forests stands differing in tree species diversity were established by different research groups. At sixteen locations around the globe covering all major biomes, tree communities of differing species diversity have been established since 1999, covering now more than 800 hectares of experimental area. Over 760,000 tree individuals have been manually planted in a predefined design. First results show that increasing tree diversity in even-aged plantations affects tree growth, mortality, biomass production or infection by pests and pathogens. Hence, biodiversity might not only be seen as a good to monitor and to preserve, but also as a tool to optimise and stabilise multiple functions in plantation forestry.

The challenge of climate resilient biodiversity enrichment in planted forests in post-tenure reform China. Wu, S. (*Chinese Academy of Forestry, China; shuirongwu@126.com*).

The forest cover of China has increased from barely 8% in 1950 to about 20.4% now through massive tree planting across the country. Most of these plantations are of single tree species or, at best, have two or three species, and the government's efforts to make these planted forests as biodiverse as possible through various programs have met with limited success. The two biggest challenges faced are the large scale change in forest ownership following the land tenure reform and the warming climate. Many

new small-scale forest owners are reluctant to switch from economically viable short-rotation plantations of single species to more diverse forests of doubtful economic viability. Also, the changing climate is altering the nature and the dynamics of biodiversity itself, which introduces considerable uncertainty. This paper uses climate projections for the year 2030 to propose a range of climate resilient and economically viable forest species in all eco-climatic zones of China and suggests a range of market development activities, fiscal support, and regulatory policies that could persuade the forest owners and managers to adopt measures to enhance biodiversity.

SP-06 Cultural values, quality of life and forest landscapes

Organizer: Mauro Agnoletti (University of Florence, Italy)

Cultural values, forest policies and sustainable development. Agnoletti, M. (*University of Florence, Italy; mauro.agnoletti@unifi.it*).

European forests have been shaped by millennia of human influence that have affected all their features. They represent a fundamental part of the cultural heritage of the continent, and their values and functions cannot be maintained without considering the role of culture. Socioeconomic development, the abandonment of marginal lands and inappropriate policies are rapidly erasing cultural values and contributing to the globalization of cultural forest landscapes, often simplified into areas either managed for commercial exploitation or left to natural evolution. The fact that cultural values are not preserved by specific European initiatives indicates the scant consideration given to the role of culture and history in the overall valuation of forests within the paradigm of sustainable development. Failure to effectively and coherently address culture and history is an emerging weakness that needs be reconciled, suggesting the need for better cooperation between science and humanities in research. The European Landscape Convention and the UNESCO-CBD Joint Program on Biocultural Diversity offer the political tool and an appropriate scientific approach for integrating nature and culture, contributing to improve the competitiveness of rural economies, the ecological status of the countryside and the quality of life of the population. Cultural heritage and landscape are clearly indicated in the new EU agricultural policy (2014–20) while some political initiatives have been developed at the national level for preserving these values.

Understanding role of traditional forest knowledge and culture in landscape restoration in China. Liu, J. (*Renmin University of China, China; liujinlong@ruc.edu.cn*).

Traditional forest-related knowledge and culture has played and continue to play an outstanding role in livelihoods of rural communities and landscape maintenance and restorations in spite of significant political, social and economic obstacles. This paper overviews historically contributions of these knowledge and culture to integration of natural resource management, biodiversity conservation, agriculture, medicine, and sustainability management of unique social-ecological landscape. It has testified that through few cases studies, that traditional knowledge and associated culture are of importance to quality of community livelihood and better landscape with complexity of integration of various physical components, including forests, farming, grazing, biodiversity conservation, and residences, and social components, including customary regulation, social capital, network. These knowledge and culture improve resilience of community and landscape confronted to climate change, globalization, and urbanization. While traditional forest-related knowledge is under threat worldwide, efforts to preserve and enhance it are increasing. It required cross-sectoral cooperation, and stakeholder participation, in particular to engaging the holders and users of traditional knowledge to develop enable policy to support the preservation, development and application of traditional knowledge to enhance quality of life, and culture forest landscape reservation.

The UNESCO-CBD Joint Programme on the Links between Biological and Cultural Diversity. Persic, A. (*UNESCO, USA; a.persic@unesco.org*).

Recognizing the inextricable link between biological and cultural diversity, the United Nations Education Science and Cultural Organization (UNESCO) and the Secretariat of the Convention on Biological Diversity (SCBD) joined forces to understand and address the interactions between, and common challenges of, contemporary changes in diversity trends. The two institutions launched a Joint Programme in 2010 to strengthen the linkages between biological and cultural diversity initiatives, and enhance synergies between interlinked provisions of Conventions and programmes dealing with biological and cultural diversity at relevant scales. Cultural values and traditional knowledge are central to the Joint Programme as they both embody the key linkages between biological and cultural diversity. These are particularly relevant in the context of the much needed integrated sustainable forest management practices which reflect the economic, environmental and socio-cultural values of forests and build on participatory management approaches. Considerable progress has therefore been made in the framework of the Programme in terms of reviewing the current knowledge and practices relating to the contribution of cultural values and traditional knowledge to sustainable use and management of biodiversity, including into planning and management of forest ecosystems at different scales.

Wilderness or cultural landscapes? A perspective from Central Europe. Woitsch, J. (*Institute of Ethnology, Academy of Sciences of the Czech Republic; jiri.woitsch@post.cz*).

The Bohemian Forest (Sumava, Boehmerwald) is nowadays considered to be the most valuable part of nature in the Czech Republic, depicted in tourist brochures as the only Central-European forest wilderness. However the history of these forests tells a different story. Firstly is important to stress the history of human impact on the nature in the region resulting in the creation of cultural landscape consisting of pastures, wood pastures, arable land and managed secondary forests during the 19th century. Secondly, during the 1800s, the "social construction" of nature in the Bohemian Forest had begun. Thanks to writers, poets and heritage organizations, the cultural landscape of the region began to be depicted as a unique natural landscape in industrialized Bohemia. Third was the very exceptional period in the history of during the period from 1950 to 1989, when the area was part of

the so-called "iron curtain" between Eastern and Western world. Nearly all settlements were abandoned and the landscape and cultural heritage of the Bohemian Forest started reverting back to nature, coniferous forests back to primeval. Nowadays Sumava National Park, established in 1991, is a battlefield of different conceptions of forest management and conservation policies. Unfortunately the point of view of forest historians is missing in these discussions.

SP-07 The Importance of quantifying uncertainty in managing forests

Organizers: Ruth Yanai (State University of New York-ESF, USA), David Paré (Canadian Forest Service), Peter Clinton (Scion, New Zealand) & Bogdan Strimbu (Louisiana Tech University, USA)

Uncertainty in forest management planning: why it will not go away and what should we do about it. Bernier, P. (*Canadian Forest Service, Canada; pbernier@rncan.gc.ca*).

Forest management is an activity that plans and operates across a range of spatial and temporal scales. At the operational scale and over modest forest landscapes, forest management operates on short time frames. In that context, uncertainties are dominated by sampling and modelling errors. By contrast, at the strategic scale, and over large areas, forest management takes the "long view" so as to capture the repercussion of actions on the forest environment over one or many rotations. In the boreal forest, the long view often spans a century or more. At such a level, sampling and forecasting are only one of many sources of uncertainty. Other sources specific to the long view include stand-replacing natural disturbances, climate change and external factors linked to social and economic forces. Changes linked to the climate and to socio-economic values and forces are not random, but rather incorporate trends that impose a future different from the past. Most of the associated uncertainties are, in addition, irreducible. The presentation describes forces at play in the generation of such uncertainties within strategic-level forest management planning, identifies elements that differentiate the past status quo from a potentially new forest management framework, and proposes a precautionary approach for dealing with these considerations.

Forest carbon stock change uncertainty estimation in Mexico. Carrillo Negrete, O. (*Comision Nacional Forestal, Mexico; oswaldisma@gmail.com*), Wayson, C. (*SilvaCarbon, USA; cwayson.silvacarbon@gmail.com*), Vaquera, H. (*Colegio de Postgraduados, Mexico; hvaquerah@gmail.com*), Olguín Alvarez, M., Morfin, J., Muñoz, M., Santos, L. (*Comision Nacional Forestal, Mexico; olguin.conafor@gmail.com; jemorfinr@gmail.com; miguelmrv.munoz@gmail.com*; *lucio.conafor@gmail.com*).

Mexico's government is making efforts to implement a monitoring, reporting and verification system to generate highly precise estimates (low uncertainty) of changes in forest carbon stocks, based on a transparent and cost-effective approach consistent with international guidelines. In this paper, we present the results on national estimates of changes in carbon content biomass, including uncertainties associated with the estimates of emission factors (EF), activity data (AD) and their combination using the Monte Carlo method (MCM) according to 2006 IPCC Guidelines. We calculated uncertainties for EF with data from Mexico's national forest inventory using the MCM in "R", while the uncertainties for AD were obtained from forest inventory data and recent national vegetation maps, according to the methodology proposed by Olofsson et al. (2013). Future validation will include comparisons of results with uncertainties calculated using carbon dynamics models and intensive monitoring sites (Tier3 focus) in strategic forests in Mexico.

Improving forestry decision making by accounting for uncertainty. Kangas, A., Eyvindson, K. (*University of Helsinki, Department of Forest Sciences, Finland; annika.kangas@helsinki.fi*; *kyle.eyvindson@helsinki.fi*), Hartikainen, M., Miettinen, K. (*University of Jyväskylä, Finland; markus.hartikainen@jyu.fi; kaisa.miettinen@jyu.fi*).

All forest decisions are made under conditions of uncertainty. These uncertainties may be rather predictable, such as measurement errors, but they can also be more serious like the effects of climate change. Irrespective of the source of uncertainty, ignoring it is the poorest way to deal with it. Deterministic optimization produces solutions that are optimal for one specific scenario, but can be very poor under some other scenario. Explicitly accounting for the uncertainty with stochastic optimization produces more robust solutions and better expected outcomes. It also enables minimizing the risks for very poor outcomes. Thus, information on uncertainty is valuable information in itself, and it should be utilized in decision making. Stochastic optimization also allows us to consider the value of acquiring additional information to further improve the decisions. Estimating VOI allows for the portrayal of collection of new information as an investment, rather than just expenditure. In this presentation, we will show examples of how decisions are improved using stochastic optimization in forest management problems under measurement error uncertainty and climate change uncertainty. We show how the stochastic solution affects to the risks the decision maker faces. We will also discuss the value of acquiring additional information in these problems.

Uncertainty in forest carbon and nutrient budgets. Yanai, R. (*State University of New York-Syracuse, USA; rdyanai@syr.edu*), Campbell, J. (*U.S. Forest Service, USA; jlcampbell@fs.fed.us*), Green, M. (*Plymouth State University, USA; mbgreen@plymouth.edu*).

Ecosystem nutrient budgets are difficult to construct and even more difficult to replicate. As a result, uncertainty in the estimates of pools and fluxes are rarely reported, and opportunities to assess confidence through replicated measurements are rare. Uncertainty analysis can help direct research effort to best improve confidence, while providing estimates of confidence in our results. We demonstrate the propagation of measurement error and uncertainty in allometric equations and nutrient concentrations in estimating pools of carbon and nutrients in forest biomass, using data from the Hubbard Brook and Bartlett Experimental Forests, New Hampshire, USA. We also constructed nutrient cycling budgets and evaluated uncertainty in ecosystem fluxes. Uncertainty in inputs and outputs is small compared to uncertainty in change in storage in soils. QUEST (Quantifying Uncertainty in Ecosystem Studies) is a research coordination network that aims to promote the use of uncertainty analysis, provide guidance to researchers interested in uncertainty analysis, and support both developers and users of uncertainty analyses. QUEST has a web site (http://www.quantifyinguncertainty.org) with news feed, relevant papers, and examples of code in SAS, R, STATA, and Excel.

SP-08 The future of our forests

Organizers: William Nikolakis & John Innes (University of British Columbia, Canada)

Drivers of future forest use. Cohen, D., Nikolakis, W. (*University of British Columbia, Canada; david.cohen@ubc.ca; william.nikolakis@ubc.ca*).

Global forces are changing not only our global environment but also the global business environment for forest products. This presentation briefly summarizes some of these forces focussing on population growth, the restructuring of economic power, and the growth of the global middle class. These trigger increases in consumption that lead to long term resource scarcity. This creates the conditions for the emerging bioeconomy that fundamentally seeks to replace non-renewable resources with well managed renewable resources. Concurrently, the growth of information computer technology (ICT) and digital media has led to a long decline in the use of some paper types. This created the need for many forest products companies to transform as they respond to new threats (due to ITC) and opportunities (due to the emerging bioeconomy).

European forests: facing the challenges of the coming 50 years. Nabuurs, G., Schelhaas, M. (*Wageningen University and Research Center, Netherlands; gert-jan.nabuurs@wur.nl; MartJan.Schelhaas@wur.nl*), Lindner, M., Verkerk, H. (*European Forest Institute, Finland; marcus.lindner@efi.int; hans.verkerk@efi.int*), Hengeveld, G. (*Wageningen University and Research Center, Netherlands; geerten.hengeveld@wur.nl*).

European forests (177 Mha of forest and other wooded land in EU27) are mostly characterised as semi-natural, multi functional forests. European forests are highly diverse through centuries of management; each country with its own cultural historical objectives, and regional specific demands. These forests provide multiple goods (wood and non-wood) and services (capturing 10% of the European Union's CO_2 emissions, being the main host for biodiversity, providing high-quality water) to rural communities and society in general. Often, the current management trend is towards nature oriented management, aimed only partly at wood production, and hardly aimed at other services. For many of the 16 million small private owners, income from wood production is only a small part of their total income including other sources. These circumstances, plus a sluggish demand under the current economic crisis hamper any investment, or more rational forest operations, despite signals of the forest sector having to play a role in the green economy with new demands for bioenergy and biorefineries' specialised products. Here we project the state of forest resources and wood supply with the EFISCEN (European Forest Information Scenario) model for the all EU forests. The analyses pay attention to provisioning functions as well as regulating services. We conclude with policy recommendations.

New Generation Plantations: what future role towards sustainability? Neves Silva, L. (*WWF International, Portugal; lnsilva@wwfint.org*).

In the longer term, as population and incomes grow, zero forest loss will require forestry and farming practices that produce more with less land, water and pollution, and new consumption. Even with more frugal use and greater efficiencies, demand for wood is likely to grow. WWF projects that maintaining zero loss of natural forests after 2020, without significant reductions in consumption, would require up to 250 million hectares of new tree plantations by 2050. Therefore, well-managed plantations, particularly on currently degraded land, and restored ecosystems will play an increasingly important role. Plantations use less land to produce a given volume of fibre than logging natural forests and if New Generation Plantations (NGP) concept is applied, plantations can have positive environmental and social impacts. The NGP concept describes an ideal form of plantation that maintains ecosystem integrity, protects high conservation values and is developed through stakeholder engagement, while contributing to economic growth. The NGP is a learning and influencing platform of WWF, companies and governments, in dialogue to develop sustainable solutions for better plantations. The platform advocates for better plantations in key regions by learning from real-world experiences of participants, showing and sharing practical examples of how plantations can be done.

Carbon, fossil fuel, and biodiversity mitigation using both wood products and forests. Oliver, C. (*Yale University, USA; chad.oliver@yale.edu*).

Life cycle, energy, and utilization analyses determined the carbon dioxide (CO_2) and fossil fuel saved by various solid wood products, wood energy, and unharvested forests. Some products proved very efficient in CO_2 and fossil fuel savings, while others did not. Efficient products save much more CO_2 than the standing forest or wood used only for energy. Using wood in place of steel and concrete contributes the most to CO_2 and fossil fuel savings, and burning parts of the harvested logs not used for products creates an additional savings. Using wood substitutes could save 14% to 31% of global CO_2 emissions and 12% to 19% of global fossil fuel consumption by using 34% to 100% of the world's sustainable wood growth. More CO_2 can be sequestered synergistically in the products or wood energy and landscape together than in the unharvested landscape—and more biodiversity could be provided in the managed forests. Innovative wood products such as cross laminated timber can meet the anticipated demand for an increased infrastructure in sustainable way in many parts of the world.

SP-09 Forests for people: ecosystem services under pressure?

Organizers: Ulrike Pröbstl-Haider (University of Natural Resources and Life Sciences, Austria) & Perry Brown (University of Montana, USA)

Reforestation in the Anthropocene: biological and societal perspectives on genetic decisions. Aitken, S. (*University of British Columbia, Canada; Sally.Aitken@ubc.ca*), Hamann, A. (*University of Alberta, Canada; andreas.hamann@ualberta.ca*), Kozak, R., Hajjar, R., McGuigan, E., Moshofsky, M. (*University of British Columbia, Canada; rob.kozak@ubc.ca*; *reem.hajjar@gmail.com*; *erin.mcguigan@ubc.ca; m.moshofsky@gmail.com*), Jones, K. (*University of Alberta, Canada; kjones4@ualberta.ca*).

Forest management decisions on species and seed sources for reforestation will impact the productivity, health, and provision of ecosystem services in future climates. Policy decisions for seed transfer have until now been informed by traditional, field-based provenance testing, which takes decades and substantial resources to complete. Technological advances in climate modeling and downscaling of climatic data can be used to select seed sources for future conditions for climate-based seed transfer, and to identify new geographic areas where species may thrive through assisted migration. The technological revolution in genetics and genomics has also provided new tools that can be used to understand genetic variation and local adaptation of populations to climate, and to predict the health, productivity and resilience of trees under different climatic conditions. Climate-based seed transfer, informed by both genomic knowledge of adaptive variation in natural populations and by climate models, should be more biologically robust than the status quo of reforestation using local populations. However, our research in western Canada suggests the acceptability of climate-based changes to forest management practices to stakeholders, forestry professionals, and the general public depends in part on familiarity with new technologies that inform decisions, as well as on general perspectives about climate change and interventions in nature.

The future of outdoor recreation, society and forests in the United States. Cordell, K. (*U.S. Forest Service, USA; kcordell@fs.fed.us*).

Total days of US forest recreation is projected to increase by 8.7 percent by 2015. In this same period, population will increase 6.2 percent. With recreation projected to increase faster than population, the effect on forests is greater demand. As well, the activity makeup of demand is projected to change. Among activities rising fastest are gathering mushrooms/berries, walking, visiting historic sites, and mountain and rock climbing. Projected to decline were mountain biking and snowmobiling. Because of increasing demand for forest-based goods and services and because of land development, total forest is in decline, and is forecast to continue declining. Less forest land for outdoor recreation in the face of rising population will mean declines in per capita supply. Also, a downward trend is seen in non-industrial forest access, in particular individual and family-owned forest lands. Per-capita forest acres are projected to decline steeply in all regions of the U.S. to between 50 and 74 percent of the 2010 level by 2060. Societal change makes this picture yet more complex. Population age, ethnic makeup, lifestyle, and technology use are changing rapidly. This presentation will examine recreation, forest access, and societal change and likely effects on the future of forests.

The role of forest provisioning ecosystem services in coping with household stresses and shocks in Miombo woodlands of Zambia. Kalaba, F. (*Copperbelt University, Zambia; kanungwe@gmail.com*).

This paper examines the contribution of forest provisioning ecosystem services (FPES) to rural livelihoods in Africa's Miombo woodlands. It examines the use of FPES in coping with stresses and shocks, and assesses the influence of wealth and gender in households' coping decisions. The study employed a mixed methods approach by combining focus groups meetings, in-depth interviews, and household interviews in Copperbelt province, Zambia. FPES are an important source of food, medicine, construction material and fodder, and provides 43.9% of average household income. Results show that households face multiple shocks which negatively affect their livelihood options. FPES are the most widely used coping strategy used by households facing income shocks. With respect to coping with household food stresses, charcoal production is the most widely used strategy which degrades the woodlands and negatively affects the flow of other ecosystem services. Reducing charcoal production has the potential to increase the flow of ecosystem services and contribute to livelihoods. In designing forest management strategies aimed at reconciling forest conservation and rural development, such as reduction of emissions from deforestation and forest degradation (REDD+) schemes, it is vitally important that alternate coping strategies are made available to rural households to reduce pressure on forests.

Introduction to the IUFRO Forests for People strategy. Pröbstl-Haider, U. (*University of Natural Resources and Life Sciences (BOKU), Vienna, Austria; Uproebst@groupwise.boku.ac.at*).

The presentation summarizes the main trends presented at the Forests for People conferences over the past four years, and discusses the need to support the IUFRO strategy which aims to provide a platform for subjects of societal relevance and build bridges between thematic fields. Firstly, it was found that poverty alleviation studies, focusing on non-timber-forest-products, were perceived as underrepresented in past IUFRO endeavors, underlining the importance of the new strategy. Secondly, the field of health, recreation, and tourism increasingly applies the new ecosystem (cultural) service approach. Due to an aging society and unhealthy lifestyles, particularly in developed countries, the focus of these studies mostly lies on therapeutic aspects and on interdisciplinary approaches on health and well-being. Thirdly, the trade-offs between diverse land use opportunities in rural areas worldwide form the basis for a growing and challenging research field. The task of societies' acceptance of new developments, such as increased use of biomass, modification of plants, and introduction of new species, requires the incorporation of social science, especially under the condition climate change adaptation.

Stretching community-based ecosystem management to protect Indigenous livelihoods: The Beardy's and Okemasis First Nation and the Prince Albert Model Forest. Reed, M. (*University of Saskatchewan, Canada; m.reed@usask.ca*), Gamble, A. (*Beardy's and Okemasis First Nation, Canada; algamble@hotmail.com)*, Welter, S. (*University of Saskatchewan, Canada; srw099@mail.usask.ca*).

Community-based ecosystem management (CBEM) is a management approach that seeks to maintain the integrity of natural systems and services at the landscape scale while supporting human communities to collaborate, seek consensus, and adapt to changing and uncertain conditions. Identifying the best strategies for addressing social and biophysical concerns simultaneously remains challenging. This paper reports on initiatives of the Prince Albert Model Forest and the Beardy's and Okemasis First Nation in Saskatchewan, Canada. Together, they have undertaken several initiatives to strengthen the adaptive capacity of the First Nation. Their work reveals that CBEM must be conducted in a manner that is sensitive to Indigenous *and* Western cultural traditions, social norms, taken-for-granted assumptions. For example, projects include the establishment of community gardens,

work in flood hazards prevention and mitigation, provision of alternative energy supplies, programs for youth engagement as well as more conventional (in the western sense) initiatives geared to "sustainable forest management". CBEM can indeed be stretched to meet social and cultural requirements. However, doing so successfully requires an openness by all participants to learn from one another and to re-think longstanding paradigms about forestry, land use, and ecological and social knowledge.

SP-10 Resilience of forest ecosystem services to changing disturbance regimes

Organizers: Rupert Seidl (University of Natural Resources and Life Sciences, Austria) & Tom Spies (U.S.Forest Service)

Climate change and disturbance regimes in western North America: pathways for building resilience. Peterson, D. (*U.S. Forest Service, USA; wild@uw.edu*).

The frequency and magnitude of extreme climatological events, ecological disturbances, and stressor interactions will drive climate-induced changes in the structure and function of forest ecosystems in western North America. However, the following climate-informed management strategies can effectively reduce loss of functionality and assist a transition to a permanently warmer climate (adaptation). First, create science-management partnerships that will develop climate change vulnerability assessments and adaptation plans. Second, reduce existing sources of stress (e.g., high stand density) to improve physiological vigor. Third, reduce fuel loading in dry forests to lessen the severity of wildfires, thus enhancing retention of key ecosystem components (e.g., large trees). Fourth, create structural and age diversity across large landscapes to maintain a mosaic in which at least some components will persist in the face of increasing disturbances. These efforts will require collaboration among public and private landowners and other stakeholders at large spatial scales and will be successful only if stress complexes are accurately described, restoration is reframed as resilience building, and climate-informed management is implemented soon, during the next 20–30 years.

Risks for ecosystem services provisioning from natural disturbance: A European perspective. Schelhaas, M. (*Wageningen University and Research Center, Netherlands; MartJan.Schelhaas@wur.nl*), Seidl, R., Rammer, W. (*University of Natural Resources and Life Sciences (BOKU), Austria; rupert.seidl@boku.ac.at*) (*University of Natural Resources and Life Sciences, Vienna, Austria; werner.rammer@boku.ac.at*), Gardiner, B. (*French National Institute for Agricultural Research (INRA), France; barry.gardiner@bordeaux.inra.fr*), Verkerk, H. (*European Forest Institute, Finland; hans.verkerk@efi.int*).

The amount of wood affected by natural disturbances in Europe has been increasing steadily over the last century. Climate change and changes in the state of the forest due to management have contributed equally to the observed increase in disturbance levels. Projected trends in climate change and forest development indicate that damage levels are likely to increase further in future. Furthermore, disturbance types are expected to expand their range as a consequence of changes in the climate. An increase in disturbance level, and changes in expected disturbance types, can have a large impact on forest service provisioning. Currently, natural disturbances are usually not incorporated into forest management planning and simulation models. Future projections should therefore be evaluated not only for their impact on various forest services, but also on their risks for natural disturbances. Carbon sequestration in forest biomass is the most obvious service under risk of disturbance, but also other services can be severely affected. Evaluating future disturbance risks across Europe calls for more generally applicable, mechanistic models than current (often deterministic and region-specific) models. A few examples of possible approaches will be demonstrated.

Disturbance regimes and ecosystem services in a changing world. Seidl, R. (*University of Natural Resources and Life Sciences (BOKU), Austria; rupert.seidl@boku.ac.at*), Spies, T. (*U.S. Forest Service, USA; tspies@fs.fed.us*).

Disturbance regimes have intensified considerably around the globe in recent decades, and climate change is expected to further increase the frequency and severity of wildfires, insect outbreaks, and wind damage in many forest ecosystems. Disturbances are an integral part of natural ecosystem dynamics, yet the expected intensification could result in a departure from the historical range of variability, with potentially adverse consequences for ecosystem services. Considering their sensitivity to disturbance, the sustainable and uninterrupted provisioning of ecosystem services such as carbon storage and other values such as biodiversity are at considerable risk from altered disturbance regimes. To set the stage for the session "Resilience of forest ecosystem services to changing disturbance regimes" we will briefly review current and potential future trends in forest disturbance regimes. We will present evidence that disturbance frequency and severity has increased in many parts of the world recently, and review predictions on the expected trajectories under future climate change. We will contrast this development with the growing societal demand for an increasing number of ecosystem services. Subsequently, the talks in this session will report examples of disturbance-related threats to ecosystem services, and will discuss ways forward of how to address them in ecosystem management.

Resilience of forest ecosystem services to changing disturbance regimes: a synthesis. Spies, T. (*U.S. Forest Service, USA; tom.spies@oregonstate.edu*), Seidl, R. (*University of Natural Resources and Life Sciences (BOKU), Austria; rupert.seidl@boku.ac.at*).

In the face of changing disturbance regimes managing for resilience becomes increasingly important in ecosystem management. Here we synthesize the contributions to the IUFRO Congress session "Resilience of forest ecosystem services to changing disturbance regimes", and provide an outlook on possible future research directions and hitherto unresolved issues. From the contributions to this session it is clear that changing disturbance regimes are an increasing issue for forest ecosystem management. Yet, we are just beginning to understand the implications of these changes, and our knowledge of disturbance effects on ecosystem services beyond timber and carbon is still limited. To address both the known and unknown effects of changing disturbance regimes, the studies presented here document the potential of resilience-based management, focusing on the capacity to recover or adjust to new regimes rather than on rapid recovery to historical conditions. Adopting resilience thinking into

ecosystem management thus could be a promising way forward for addressing changing disturbance regimes. However, an improved understanding of disturbance regimes and ecosystem dynamics is needed. In addition, application of resilience approaches must be put in the context of social-ecological systems because management and policy responses to altered disturbance regimes require learning and decision making with tradeoffs and uncertainty.

Resilience in forest ecosystem management – an introduction from the western U.S. and northwestern Mexico. Stephens, S. (*University of California, Berkeley, USA; sstephens@berkeley.edu*).

Increasing forest resiliency has become a common management goal. Research suggests that heterogeneity in spatial patterns of forest structure and fuels are critical for a resilient forest which allows the long term delivery of ecosystem services. High variability characterizes all live tree, snag, fuel, and coarse woody debris structures in the forests of the Northwestern Mexico. Spatial forest structure was random to slightly clumped pre and post wildfire and pine dominance increased after fire. Wildfire enhanced or maintained a patchy forest structure that lead to high resiliency; similar spatial heterogeneity should be included in U.S. forest restoration plans. Most U.S. forest restoration plans include thinning from below to separate tree crowns and attain a narrow range for residual basal area/ha. This essentially produces uniform forest conditions over broad areas that are in strong contrast to resilient Sierra San Pedro Mártir forests in Baja California, Mexico. In addition to producing more spatial heterogeneity in restoration plans of forests that once experienced frequent, low-moderate intensity fire regimes, increased use of managed wildfire could also be implemented at broader spatial scales to increase forest resiliency.

SP-11 Advances in large-scale forest inventories to support the monitoring and the assessment of forest biodiversity and ecosystem services

Organizers: Anna Barbati (University of Tuscia, Italy), Piermaria Corona (Consiglio per la Ricerca e la sperimentazione in Agricoltura, Arezzo, Italy), Frédéric Gosselin (Irstea, France) & Ronald E. McRoberts (U.S. Forest Service)

Inference on diversity indexes from large-scale forest inventories. Fattorini, L. (*University of Siena, Italy; lorenzo.fattorini@unisi.it*), Corona, P. (*University of Tuscia, Italy; piermaria.corona@unitus.it*).

Large-scale forest inventories usually involve two sampling phases. In the first phase, sampling points are selected for the study area using systematic or stratified designs and are classified as forest or non-forest. In the second phase, a sample of forest points is selected using probabilistic sampling, and the points are visited on the ground. Tree-level attributes are recorded for all trees on fixed-radius plots centered on these points. If all the first phase points are visited on the ground, previous results have shown the asymptotic unbiasedness, normality and consistency of design-based estimators of indexes of tree-level ecological diversity such as the Shannon and Simpson indexes or diversity profiles. However, these properties of the estimators do not follow when the diversity indexes are estimated from the two-phase samples often used by forest inventories. The presentation demonstrates the asymptotic unbiasedness, normality and consistency of the second-phase estimators of diversity indexes. A simulation study was conducted using an artificial population of trees and a case study application was considered.

Assessing information for indicators for sustainable forest management: potentials and pitfalls. Koehl, M. (*University of Hamburg, Germany; michael.koehl@uni-hamburg.de*), Inhaizer, H. (*European Forest Institute, Germany; hubert.inhaizer@efi.int*).

Criteria and indicators (C&I) have emerged as a powerful tool to promote sustainable forest management (SFM). Several international programs and initiatives have developed sets of criteria and indicators as a policy instrument to promote and safeguard SFM. In 2003 Forestry Europe adopted a set of 35 quantitative indicators, for most of which information is provided by forest resource assessments. In practical applications many indicators are caught between political significance and informative value. We present the Pan-European indicators for the criteria health and vitality, biodiversity, and forest resources and elaborate on the respective data supply by national and international data providers. The political intention behind the indicators is confronted with the underlying data quality, data availability and validity. We identify information gaps and recommend adjustments for data assessment and data analysis.

Development of innovative models for multi-scale monitoring of ecosystem services indicators in Mediterranean forests Marchetti, M., Lombardi, F., Chirici, G. Sallustio, L., Vizzarri, M. (*University of Molise, Italy; marchettimarco@unimol.it; fabio.lombardi@unimol.it*; *gherardo.chirici@unimol.it; lorenzo.sallustio@studenti.unimol.it; matteo.vizzarri@unimol.it*), Barbati, A. (*University of Tuscia, Italy; barbati.sisfor@unitus.it*), Travaglini, D. (*University of Florence, Italy; davide.travaglini@unifi.it*), Lafortezza, R. (*University of Bari, Italy; raffaele.lafortezza@uniba.it*), Cullotta, S., La Mela Veca, D. (*University of Palermo, Italy; sebastiano.cullotta@unipa.it; donato.lamelaveca@unipa.it*), Secondi, L. (*University of Tuscia, Italy; secondi@unitus.it*), Pesola, L. (*University of Bari, Italy; lucia.pesola@uniba.it*), Maetzke, F. (*University of Palermo, Italy; federico.maetzke@unipa.it*), Corona, P. (*University of Tuscia, Italy; piermaria.corona@unitus.it*).

In this study, ecosystem services (ES) are considered in natural resource management, developing tools for their estimation, mapping and provision in Mediterranean forest habitats. A set of indicators for assessing forest ES was selected and benchmarked, then data layers for each ecosystem function were standardized for mapping purposes, using existing expert advice and data quantiling, considering multiple spatial scales. Cutting-edge statistical methods were applied for the spatial estimation of the indicators, deriving wall-to-wall maps on ES provision across a range of spatial domains. The InVEST model was applied for these purposes. The main results are connected to the aggregation of the indicators for the different ES, creating a system for trade-off analysis to resolve possible conflicts in alternative forest management scenarios aimed at maximizing the overall ES provisioning in different forest management scenarios. These results can help in incorporating ES into land, environment and forest management decisions, thus providing an unparalleled opportunity for understanding the congruence between the different

ES in forest ecosystems and landscapes. The approaches and tools applied were implemented with specific reference to ES in Mediterranean forests, but were developed in a way that they could be theoretically applied to any ecological region across the globe.

Contribution of the Floristic and Forest Inventory of Santa Catarina to large scale forest biodiversity assessment. Vibrans, A., Moser, P., Gasper, A., Lingner, D., Oliveira, L., Maçaneiro, J. (*Universidade Regional de Blumenau, Brazil; acv@furb.br*); *paolo.moser@gmail.com; algasper@gmail.com; deboravanessa.ef@gmail.com; laiozoliveira@gmail.com; jpmacaneiro@hotmail.com*), Rezende, V. (*Universidade Federal de Minas Gerais, Brazil; vanessa.leite.rezende@gmail.com*).

Systematic forest inventories are a powerful means to assess biodiversity, especially in tropical regions. Floristic and dendrometric data from the Santa Catarina Floristic and Forest Inventory (IFFSC) in Southern Brazil provide a unique and unprecedented opportunity to explore quantitative and qualitative aspects of the highly diverse Atlantic Forests in a regional scale, based on a systematic sample, measured between 2007 and 2010 at 418 equal probability sample points. Statistical analyses of primary data were performed to evaluate data variability, representativeness, reliability of information and generate estimates by forest type. Floristic richness, diversity and similarity between forest types were examined. Vascular plant richness was assessed by rarefaction curves. Unlike most other tropical regions, Santa Catarina's flora has been relatively well known since the 1960s, and species richness estimators (Chao 1/2, Jackknife 1/2, ACE, ICE, boostrap, Michaelis-Menten) could therefore be validated. Differences in their performance are related to significant forest type variations. Spatial autocorrelation of variables, patchiness and naturalness of forest vegetation were analyzed. Large scale gradient analysis were performed based on binary and abundance matrix in order to evidence patterns of floristic differentiation and driving forces among vegetation types and improvement of local distribution models (GWR) compared to global ones (OLS).

SP-12 Policy learning for multi-level governance

Organizers: Daniela Kleinschmit (Swedish University of Agricultural Sciences) & Ben Cashore (Yale University, USA)

Can policy learning improve strategic insights for practitioners and policy makers? Lessons from collaborative research on legality verification in Brazil. Bueno, G. (*University of Massachusetts-Boston, USA; gabriela.bueno001@umb.edu*), Cashore, B. (*Yale School of Forestry & Environmental Studies, USA; benjamin.cashore@yale.edu*), Micol, L. (*Instituto Centro de Vida, Brazil; laurent.micol@icv.org.br*).

One of the most important questions of policy learning is to understand the processes through which "causal" knowledge might be generated across scholarly and practitioner communities. We intend to shed light on these processes through our collaborative project about efforts to curb illegal logging in Brazil. By integrating pathways research (Bernstein and Cashore) with learning (Gohler, Rayner and Cashore) we intend to analyze more deeply the ways in which strategic insights might be developed, and inform, the practice of forest resources stewardship. We are curious about whether, and how, current international efforts to curb deforestation may help reduce forest cover loss and promote good forest governance in the country, especially through legality verification instruments. In order to analyze how transnational actors can influence domestic policy-making, we use Cashore and Bernstein's four pathways framework, namely: 1) international rules, 2) international norms and discourses, 3) creation of or interventions in markets and, 4) direct access to domestic policy processes. We draw on lessons learned from legality verification policies in Indonesia and Malaysia, and examine which ones, if any, are relevant to the Brazilian case. We are mindful of the importance of contextual analysis in policy learning from research across different countries when providing a comparative examination of case studies.

The role of policy learning in shaping pathways of influence: lessons from multi-level forest governance for designing an effective learning architecture. Cashore, B. (*Yale School of Forestry & Environmental Studies, USA; benjamin.cashore@yale.edu*), Rayner, J. (*University of Saskatchewan, Canada; raynerjd@gmail.com*), Gohler, D. (*World Bank, Germany; Daniela.Goehler@bmu.bund.de*), Bernstein, S. (*University of Toronto, Canada; steven.bernstein@utoronto.ca*), Glueck, P., Lim, T. (*Yale School of Forestry & Environmental Studies, USA; tseyang.lim@yale.edu*).

Two scholarly literatures address seemingly distinct questions: 1) How and why do international institutions influence domestic policy making? 2) How does policy learning shape policy outputs? The former has consumed the attention of the global environmental politics community while the latter has been addressed by comparative public policy scholars. This paper reflects on how to better integrate complementary approaches: four pathways of influence developed by Bernstein and Cashore, and policy learning directed towards building coalitions around instrument choice. We call for a narrower focus on policy learning on "causal knowledge" regarding policy interventions. We define "policy learning" as "the phenomenon in which policy makers and relevant stakeholders devote attention to understanding, assessing, and hypothesizing about, the cause and effect of policy interventions across multiple levels for ameliorating specified problems." This narrower approach allows us to look for, and identify, a "learning architecture" and practical tools for generating, and promoting, collective knowledge.

Science-policy advocacy: creating new social institutions for policy learning. Shannon, M. (*State University of New York-Buffalo Law School, USA; mshannon@buffalo.edu*).

Surprise and uncertainty are certain in times of complex change. While scientists work to understand the complexity sufficiently to provide evidence for action, policy makers usually simply have to act to address immediate problems. Both scientists and policy makers are advocates for their way of thinking, understanding, and legitimating choices. Policy learning is a concept that proposes modes of interaction between scientists and policy makers that can fulfill the needs of policy makers for rapid information and evidence based choices as well as keep scientists in a critical inquiry mode that seeks to falsify the evidence even as it is being applied. This paradox can be understood by thinking of both scientists and policy makers as advocates for different world

views and ways of organizing for action. This paper will explore this paradox and provide a basis for critical guidelines for policy learning among scientists and policy makers within complex social problems. The paper demonstates that new social institutions for science-policy interaction have been emerging over the last 30 years and that lessons can be developed from this experience to create improved institutions for policy learning.

SP-13 Forest biodiversity, ecosystem services and human well-being – harnessing biodiversity for adaptation to global change

Organizers: Bryan Finegan (CATIE, Costa Rica), Robert Jandl (Research and Training Centre for Forests, Natural Hazards and Landscape, Austria), Eckehard Brockerhoff (Scion, New Zealand), & J.P. Skovsgaard (Swedish University of Agricultural Sciences)

Biodiversity, ecosystem services and resistance to invasion of planted forests. Brockerhoff, E. (*Scion, New Zealand; eckehard.brockerhoff@scionresearch.com*), Jactel, H. (*French National Institute for Agricultural Research (INRA), France herve.jactel@pierroton.inra.fr*), Kimberley, M., Meurisse, N. (*Scion, New Zealand; Mark.Kimberley@scionresearch.com; Nicolas.Meurisse@scionresearch.com*).

Biodiversity plays an important role in the functioning of ecosystems and the provision of ecosystem services. Planted forests, which are typically managed as single-species stands, represent a growing proportion of the world's forests, and demands for planted forests' contributions to the provision of vital ecosystem services is likely to grow. But are planted forests up to the task, given their relatively lower levels of biodiversity compared with natural forests? In this presentation, relationships between biodiversity and some important forest ecosystem services will be reviewed in the context of plantation forestry. Examples will include effects of forest diversity on resistance to pests and diseases, resistance to biological invaders, as well as associated direct and indirect economic impacts. Relevant mechanisms by which biodiversity can influence the delivery of these ecosystem services will be summarised. There are various opportunities for enhancing biodiversity of planted forests and their capacity to deliver particular ecosystem services. Suggestions for the diversification of planted forests will be discussed including the use of species mixtures at the stand and landscape scales and the planting of species-rich buffer zones surrounding planted stands.

Effective territorial governance for the maintenance and restoration of ecosystem services: analysis of experiences. De Camino, R. (*Red Iberoaméricana de Bosques Modelo, CATIE, Costa Rica; rcamino@catie.ac.cr*).

To be successful in reaching its objectives any socio-environmental system needs a context of enabling conditions, one of which is good governance. Additionally in order to give motivation to the society in the territory to be maintained and restored, the actions taken and their impacts need to have practical value for the communities affected: improve their livelihoods, improve the access to production and markets, provide solutions to contingent, urgent problems faced by the community (environmental vulnerability, water supply, food security, employment), etc. Thus maintenance and restoration is a trade-off between ES and social objectives and between the time preferences and time frames of the global and the local communities. In this paper cases will be presented and analyzed of ecosystems maintenance and restoration with different degrees of success, related with the structure and quality of the governance, defined with different variables based in the experience of some Model Forests and other territories.

On beyond S: why other metrics of biodiversity can tell more about ecosystem services than species richness. Hooper, D. (*Western Washington University, USA; hooper@biol.wwu.edu*).

Much research on biodiversity and ecosystem functioning has focused on the effects of species richness on ecosystem properties. However, applying the insights from this research to management of ecosystem services has been difficult for several reasons. Here, I argue that we need to move beyond the focus on species richness to understand how ecosystem composition, diversity, and location at the landscape scale are just as important as species diversity within communities as a management tool for several key ecosystem processes and services. First, a recent literature review suggests that evidence for the role of species richness *per se* as a driver of several key functions and ecosystem services is mixed. Second, documented trade-offs among multiple services in a single community can make it difficult to maximize several services at once on any given area of land. Third, the particular location of ecosystem types in a landscape (e.g., riparian buffers, wetlands, areas of cultivation, etc.) can be more important for actualized ecosystem services than the number of different ecosystem types. Understanding mechanisms underlying ecosystem processes and services provides more robust management information than regressions with species richness.

Forest landscape heterogeneity and local plant species richness effects: A proxy for biodiversity monitoring. Luque, S., Redon, M., Cordonnier, T., Berges, L. (*National Research Institute of Science and Technology for Environment and Agriculture (IRSTEA), France; sandra.luque@irstea.fr; mathilde.redon@irstea.fr*; *thomas.cordonnier@irstea.fr*; *Laurent.berges@irstea.fr*).

The spatial distribution of resources can be a key element in determining habitat quality, and that in turn is directly related to the level of heterogeneity in the system. In this sense, forest habitat mosaics may be more affected by lack of heterogeneity than by structural fragmentation. Nonetheless, increasing spatial heterogeneity at a given spatial scale can also decrease habitat patches size, with potential negative consequences for specialist species. Such dual effect may lead to hump-backed shape relationships between species diversity and heterogeneity, leading to three related assumptions: (i) at low levels of heterogeneity, an increase in heterogeneity favours local and regional species richness, (ii) there is an optimum heterogeneity level at which a maximum number of species is reached, (iii) further increase in spatial heterogeneity have a negative effect on local and regional species richness, due to increasing adverse effects of habitat fragmentation. In this study, we investigated the existence of a hump-shaped relationship between local plant species richness and increasing forest landscape heterogeneity on a complex mosaic in the French Alps.

SP-14 Energy from trees: Technology, opportunities, and challenges

Organizers: Woodam Chung (Oregon State University, USA) & Hans Heinimann (Swiss Federal Institute of Technology in Zurich, Switzerland)

Economics and logistics of forest biomass supply: Integrated supply chain research to reduce costs, increase value and quantify uncertainty. Anderson, N. (*U.S. Forest Service, USA; nathanielmanderson@fs.fed.us*).

Forest biomass supply chains have been the subject of intensifying research in response to the growing use of biomass from silvicultural treatments and primary wood processing in bioenergy and bioproducts production. A wide range of multi-scale approaches and tools have been developed to assist stakeholders in understanding how biomass production, logistics, infrastructure, conversion technology, and market forces can impact the flow of forest biomass across networks to specific facilities. Much of the existing work has focused on using the best available science to inform the size and location of new facilities, as well as estimate the potential scale of emerging industries and anticipate both complementary and competitive interactions among new and existing sectors of the forest economy. Using western North America as a backdrop, the authors present recent developments in spatial supply chain analysis that integrate high resolution above ground biomass models with operations research and forest management data to improve logistics and increase supply chain efficiency. In addition to addressing core questions surrounding the costs and value of biomass from natural forests and associated primary industry, the authors also examine the impact of specific environmental and social values on forest biomass flow, especially from managed public lands.

The global footprint of traditional woodfuels: a spatially explicit assessment of supply, demand, and sustainability. Bailis, R. (*Yale School of Forestry and Environmental Studies, USA; robert.bailis@yale.edu*), Ghilardi, A., Masera, O. (*Centro de Investigaciones en Geografía Ambiental, Mexico; aghilardi@ciga.unam.mx; omasera@gmail.com*), Drigo, R. (*Independent consultant, USA; rudi.drigo@tin.it*).

Worldwide, 2–3 billion people rely on woodfuels to meet their energy needs. Woodfuels are common across the developing world and represent the *single largest use of harvested wood worldwide.* For decades, forest and energy planners have feared a "fuelwood crisis" would lead to rapid decline of forest resources in developing countries. We now understand that woodfuels do not necessarily lead to widespread forest degradation or deforestation, but forests do face many other threats. Indeed, in many places, woodfuel demand continues to grow even as forests decline, but there is little understanding of how well demand for woodfuels can be met by existing supplies. To fill this knowledge gap, we present the first systematic mapping of global woodfuel supply, demand, and sustainability. Our assessment integrates the latest tropical forest stock data with forest growth estimates. These are combined with maps of woodfuel-dependent populations and, accounting for accessibility constraints, we create spatially explicit maps of supply-demand balances. These maps reveal the degree of sustainability of woodfuel exploitation and identify specific locations that are likely to experience scarcity and/or suffer from forest degradation. With these estimates of unsustainable harvesting, we calculate greenhouse gas emissions from woodfuel harvest and use in the developing world.

Social processes, challenges and opportunities for forest bioenergy harvesting. Edwards, P. (*Swedish University of Agricultural Sciences, Sweden; peter.edwards@slu.se*), Lacey, J. (*CSIRO, Australia; Justine.Lacey@csiro.au*).

The nexus of increasing forested area in Europe and the demand for renewable and/or bioenergy presents opportunities and challenges in the social realm that are often overlooked in the quest for woody biomass. In Sweden, in particular, the environmental and economic challenges and opportunities have been and continue to be explored, especially with respect to whole stump removal. However, what social opportunities and challenges are present? There are opportunities to improve the viability of rural communities, however there are challenges too. One of the most substantial challenges is whether communities are willing to grant the practice of whole stump removal (and the use of other technologies for bioenergy harvesting) a social licence to operate (SLO). SLO reflects the approval communities provide to the development of forest resources and the potential reluctance to grant an SLO can stem from numerous reasons, e.g. landscape values or recreation. In drawing on empirical insights from Sweden, based on theoretical work from Australia, this paper presents a discussion on whether or how these social challenges and opportunities can be brought to the attention of policy-makers, and be reconciled within the social realm alongside environmental and economic challenges and opportunities of bioenergy production.

Feedstock production practices and challenges in Sweden. Egnell, G. (*Swedish University of Agricultural Sciences, Sweden; Gustaf.Egnell@slu.se*).

Here current feedstock production practices in Sweden are presented together with future challenges in order to procure more biomass for a growing market in an economically feasible way with low environmental impacts. When residues from the forest industry were fully used logging residues, conventionally left in the forest, has become an important source for a growing combined heat and power sector based on biomass. Initially focus was on branches and tops together with damaged wood. Beyond that assortment, small diameter trees and stumps offer a substantial contribution – but with economic constraints. Typically the procurement systems used are based on slightly modified systems for conventional round wood harvest. Large technical steps require systems developed for full tree harvest. The market for that kind of technology is however still to small to attract investors. Other future developments include silvicultural systems focusing on valuable biomass production rather than valuable volume production.

Life-cycle assessment LCA of biomass fuels – state and perspectives. Heinimann, H. (*ETH Zurich, Switzerland; hans.heinimann@env.ethz.ch*).

Biomass fuel supply has been of high priority as one path to future energy systems to be based on renewable resources. Current research has been mainly addressing the problem of designing and improving systems that are operationally efficient and economically competitive compared to non-biomass-based systems, such as wind, or photovoltaic. Environmental performance, as

proposed by the ISO 14000 standards, has become an additional operational performance metric along with economic efficiency. However, there are only few studies that addressed this issue. The contribution aims (1) to critically review the state-of-the-art methodology of performing life-cycle-assessment LCA studies in biomass supply systems, (2) to review environmental performance results for biomass energy supply systems of available studies, and (3) to identify the future challenges of LCA studies in forest operations.

Environmental impacts and site sustainability of biomass-for-bioenergy harvest operations. Page-Dumroese, D. (*U.S. Forest Service, USA; ddumroese@fs.fed.us*), Jurgensen, M. (*Michigan Technological University, USA; mfjurgen@mtu.edu*).

Forest biomass thinning operations used to promote forest health, reduce wildfire risk, or for energy production can be accomplished with few negative impacts on long-term soil quality and have the potential to increase soil quality if biochar is added back to the soil. For example, many forest stands in the western U.S. are in need of restoration for a variety of attributes because of fire suppression or lack of harvesting activities. Increased interest in harvesting both large and small trees to fuel biomass energy plants or to use woody feed stock for in-wood energy processing could cause severe impacts on soil quality through changes in physical, chemical, or biological properties. However, efforts to maintain soil function and sequester carbon in the soil profile can be successful by following several best management practices: 1) Thinning operations should use forest slash in traffic lanes to minimize machine trafficking impacts, 2) Develop site-specific risk rating systems to identify soil conditions that might be altered, 3) Re-use existing traffic lanes, 4) Leave woody residue, branches, twigs, stumps, and needles on low-fertility sites to reduce excess nutrient removals, and 5) emerging technologies for biomass-to-energy production create biochar which can enhance carbon sequestration, soil water holding capacity, build soil organic matter, reduce nutrient leaching, and enhance nutrient cycling.

SP-15 Historical responses of research to global forestry issues

Organizer: Jeffery Burley (University of Oxford, UK)

Research responses to major forestry and forest products challenges over the past quarter century. Burley, J. (*Past-President, IUFRO, United Kingdom; jeff.burley@plants.ox.ac.uk*), Lee, D.K. (*Past-President, IUFRO, Seoul National University, Republic of Korea; leedk@snu.ac.kr*), Salleh, M.N. (*Past-President, IUFRO, Malaysia; sallehmohd.nor@gmail.com*), Seppälä, R. (*Past-President, IUFRO, Finland; ristojseppala@gmail.com*).

Four IUFRO Past-Presidents reviewed responses by the research sector to the challenges described in the presentation by Gregersen, Blaser and El-Lakany; these challenges included enhanced production of forest goods, social benefits and environmental services through sustainable management of trees and forests. Globally the growth, processing and demand for forest products, especially from plantations, moved from boreal and temperate countries to tropical and emerging economies. Changes in the forest sector included globalization, governance reform, multisectoral relations, diversified products, and the demand for greater social and environmental focus. These encouraged parallel changes in research towards interdisciplinary cooperation and the sharing of new technologies especially information and communication. Responses have comprised two groups – (1) Provision of timely proactive and reactive research and (2) Impact on international and national policy processes. Through its Divisional organization IUFRO scientists organized many conferences and published thousands of papers. IUFRO also established projects expanding support for developing countries and creating a highly visible presence in the Collaborative Partnership on Forests. It also broadened contacts with non-governmental organizations and sought to enhance the role of the private sector. However, a major continuing issue is transferring research results to policy processes to ensure capture of the value of research.

Historical responses of research to global forestry challenges, 1996–2000: into the third millennium. Burley, J. (*Past-President, IUFRO, United Kingdom; jeff.burley@plants.ox.ac.uk*).

The period required modification of forest research for the needs and technologies of the 21st century. Key elements included:- inter-disciplinary approaches to problem-solving; availability of information technologies for dissemination of research results; need to present results in formats that policy-makers, media and general public could understand. IUFRO responded by:- creating Task Forces; increasing inter-disciplinary meetings and projects; participating in inter-Agency policy processes; publishing books on major subjects. Relatively new subjects included:- social forestry; climate change; land degradation; biodiversity evaluation; new wood and non-wood products and processes; ecological services; sustainability criteria; private sector. These required new professional specialities yet support for research declined and several organizations terminated their membership. Forestry often became subsumed within non-traditional university and government departments unfamiliar with the coherence of the forestry profession. IUFRO strengthened its Special Programme for Developing Countries and the Global Forest Information Service. It recognized good research through awards and nominated scientists for other organizations, e.g. Marcus Wallenberg Prize. These activities were pursued under my successors; they will require the skills of future Presidents and members if we are to ensure the sustainability of forest benefits.

Global forest challenges over the past quarter century. Gregersen, H. (*University of Minnesota, USA; hans@walk-about.net*), Blaser, J. (*Bern University of Applied Sciences, Switzerland; juergen.blaser@bfh.ch*), El-Lakany, H. (*University of British Columbia, Canada; lakany@mail.ubc.ca*).

The purpose of this paper is to identify the main global forest challenges – issues and opportunities – that society and researchers needed to address over the past quarter century. We used a nested approach. Thus, within the over-arching challenge of meeting the growing need for forest goods and ecosystem services in a more efficient, effective and sustainable manner, we identified three strategic challenges that needed to be faced: (1) reduce loss of existing natural forests, (2) create new, productive planted forests, including in the process of restoring degraded lands, and (3) improve the efficiency and effectiveness of management,

processing and utilization of both natural and planted forests and trees outside forests. Within each of these, we identified a number of operational challenges. These operational challenges arise and evolve within the context of the main trends taking place in the forest-based sector over the past quarter century. These relate inter alia to globalization, relocation of forest industry activity, forest governance reform, growing importance of inter-sectoral relations, rapidly advancing developments in ICT, which relate closely to the expanding knowledge of the links between forests, climate change, biodiversity, watershed protection, forest products development and livelihoods of forest dwellers. Finally implications for the future are briefly reviewed.

Historical responses of research to global forestry challenges, 2006–2010: continuity and strengthening. Lee, D.K. (*Past-President, IUFRO, Seoul National University, Republic of Korea; leedk@snu.ac.kr*).

All Past-Presidents of IUFRO were challenged by different forestry issues especially in meeting the over-arching demands for forest goods and services. During the period 2006–2010, deep concern was given to the lack of expertise in forestry, particularly in developing countries. The same also applies to institutional support and development in forestry which had not progressed in pace with other fields. Meanwhile, strong advocacy for capacity building from collaborative research projects was emphasized. Since research is the primary activity of member institutions, strengthening research groups in IUFRO was mainly undertaken. A network of information exchange among scientists around the world was also enhanced through conferences, symposia and workshops. IUFRO played active roles in UNFCCC and UNCBD but not in UNCCD despite the fact that land degradation is closely linked to the loss or degradation of forests. There has been a lot of talk about biotechnology and nanotechnology on cellular levels. Moreover plantations with fast-growing species including Eucalyptus and Acacia have spread widely in Africa, Asia and Latin America, and there use of traditional knowledge, i.e. medicinal herbs, for improving people's health has not been given much attention. These are some of the challenges that brought changes to improve research globally.

Historical responses of research to global forestry challenges, 1991–1995: forestry research from a tropical perspective. Salleh, M.N. (*Past-President, IUFRO, Malaysia; sallehmohd.nor@gmail.com*),

Tropical rainforests exhibit high levels of biodiversity with half of all the living animal and plant species on the planet. Tropical rainforests have been called the "world's largest pharmacy". Unfortunately, tropical rainforests are highly threatened ecosystems. As the first IUFRO President from outside Europe and America, I considered one of the foremost concerns to be the low level of forestry research in developing countries. The lack of political support, funding and qualified human resources were barriers to effective research. Thus, with support from the Food and Agriculture Organization (FAO) of the United Nations and several bilateral donor agencies, IUFRO formed the Special Programme for Developing Countries (SPDC) to address these. The SPDC developed various programmes in developing countries, especially in Africa and Latin America. In Asia, the Asia Pacific Association of Forest Research Institutes (APAFRI) was formed with support from the FAO Regional Office in Bangkok. APAFRI is still active headquartered permanently in the grounds of the Forest Research Institute of Malaysia. In the period, with IUFRO support, the Consultative Group on International Agriculture Research (CGIAR) established the Centre for International Forestry Research (CIFOR) in Indonesia.

Historical responses of research to global forestry challenges, 2001–2005: contributions to international and national policy processes. Seppälä, R. (*Past-President, IUFRO, Finland; ristojseppala@gmail.com*).

It became evident that the most serious problem in forest-related research is not lack or quality of research but rather how to transfer existing scientific knowledge to decision makers and other clients so that it can be incorporated into forest policy and practice. Consequently, during the first years of this millennium IUFRO took several steps to improve the global science-policy interface. A milestone was reached in 2003 when IUFRO became the only NGO member of the Collaborative Partnership on Forests (CPF). Based on this membership, IUFRO contributed actively to the United Nations Forum on Forests (UNFF) and other international policy processes by bringing scientific aspects to discussions and resolutions. IUFRO was the driving force behind establishing CPF's Global Forest Expert Panels (GFEP) to support decision-making by providing independent scientific assessments. So far, the Union has led and coordinated three successful assessments. IUFRO had earlier initiated the Global Forest Information Service (GFIS), an Internet gateway to forest information resources, and has been coordinating this service on behalf of CPF since 2004. GFEP, GFIS and some other global activities of IUFRO represent a breakthrough in spreading forest-related scientific knowledge. They have also efficiently enhanced communication within the scientific community across disciplines.

SP-16 Triumphs, tribulations and transitions – the graduate research experience from the Student IUFRO Award winners

Organizers: Shirong Liu (Chinese Academy of Forestry, China) & Lisa Hansen (IFSA/University of British Columbia, Canada)

IUFRO Outstanding Doctoral Research Awards (ODRA)

Dynamics and Restoration of *Pilgerodendron uviferum* forests on Chiloé Island, North Patagonia, Chile. Bannister, J.R (*University of Freiburg, Germany & Instituto Forestal (INFOR), Chile; jbannister@infor.cl*).

Southern bog forests dominated by the conifer *Pilgerodendron uviferum* in Northern Patagonia are a typical case of ecosystems with low resilience to fire disturbance. Using a multi-scaled approach, this doctoral thesis focussed on the following questions: a) whether *P. uviferum* forests can persist in the absence of large-scale disturbances; b) to what extent natural regeneration from seeds of remnant *P. uviferum* trees may facilitate recolonization of disturbed forests? and c) how important microsite conditions are for successful restoration planting of *P. uviferum* forests? The results show that *P. uviferum* is a stress-tolerant conifer that can regenerate and grow under conditions of low light and low fertility. In disturbed forests, natural regeneration from dispersed seeds

of remnant trees can effectively facilitate forest restoration. However, at the landscape scale, after high-severity fires, there are vast areas without seed trees of the species. Based on these results, a mixed passive-active restoration approach, relying on scattered seed trees complemented through low-density planting, can be recommended as a low-cost, effective and efficient option to restore these disturbed forests. The approach used here may be adopted for other ecosystems with low resilience and high degradation, where restoration is likely to be extremely expensive and the outcome uncertain.

A forest simulation tool for assessing impacts of management strategies and climate changes on *Eucalyptus* wood production in Portugal. Barreiro, S. (*Technical University of Lisbon, Portugal; smb@isa.utl.pt*).

In a context of uncertainty in global markets redefining national policies for the forest sector became a need. SIMPLOT, a large-scale regional scenario simulator, was developed to allow evaluating the impacts of wood demand on wood production and the subsequent supply of the Portuguese pulp and paper industries. This simulator, mainly driven by wood demand (for pulp) and secondary driven by biomass demand (for energy), uses forest inventory information combined with forest growth models to project the long-term development of eucalyptus forests. Projections are made under assumptions of future wood and biomass demands, fire occurrence, land use changes and management. A methodology for integrating process-based models at regional level into SIMPLOT was developed to allow simulating the effects of climate changes. Its output runs provide several forest characteristics and a wide set of sustainability indicators. Because SIMPLOT was developed to assist and support in decision making processes, its projections were evaluated proving the tools' for making reliable large-scale projections for standing volume and forest area by age classes (with the exception of the area of uneven-aged forests). The results obtained led this tool to be chosen for a national study about the Portuguese forest sector.

Fungal diseases of eucalypts in P.R. China. Chen, S.F. (*University of Pretoria, South Africa & Chinese Academy of Forestry, China; shuaifei.chen@gmail.com).*

The eucalypt industry in P.R. China is expanding significantly, but information on the species identity, origin and impact of fungal pathogens in the country remains very limited. The aims of this dissertation were to identify common fungal pathogens from eucalypt plantations and nurseries in South China, to test and evaluate the pathogenicity of the fungal pathogens on commercial eucalypt hybrids/clones, and to understand the biology of selected important eucalypt pathogen populations and their structure. The causal agents of common eucalypt diseases were characterized using morphology and DNA sequence data. Seventeen species of eucalypt pathogens in eight genera were identified, including nine new species which were described and named. The pathogenicity of the identified fungi on the most popular Chinese commercial eucalypt hybrids/clones was tested. Species in two genera of Cryphonectriaceae, *Chrysoporthe* and *Celoporthe*, and species in the Botryosphaeriaceae, *Calonectria* spp. and *T. zuluensis,* were identified as pathogens to eucalypts in South China. In addition, the population diversity and structure of *Teratosphaeria zuluensis* was investigated using microsatellite markers, with results results showing that *T. zuluensis* had a very high genetic diversity in P.R. China, and presented of sexual recombination, indicating *T. zuluensis* need to be monitored carefully in the region.

Abatement cost of wood-based electricity and ethanol at production and consumption levels. Dwivedi, P. (*University of Georgia, USA; puneetd@uga.edu*).

Woody feedstocks will play a critical role in meeting the demand for biomass-based energy products in the United States. An integrated model was developed using comparable system boundaries and common set of assumptions to ascertain unit cost and greenhouse gas (GHG) intensity of electricity and ethanol derived from slash pine (*Pinus elliottii*) at the production and consumption levels by considering existing automobile technologies. Relative GHG abatement cost was also calculated with respect to comparable energy products derived from fossilized fuels. Production cost of electricity derived using wood chips was cheaper by about 2 ¢ MJ^{-1} over electricity derived from wood pellets. Production cost of ethanol without any income from cogenerated electricity was costlier by about 1 ¢ MJ^{-1} over ethanol with income from cogenerated electricity. Production cost of electricity derived from wood chips was cheaper by about 1 ¢ MJ^{-1} over ethanol with income from cogenerated electricity. However, cost of using ethanol as a fuel in a flex-fuel vehicle was at least higher by 6 ¢ km^{-1} than a comparable electric vehicle. A carbon tax of at least $ 10 Mg CO_2e^{-1} and $ 30 Mg CO_2e^{-1} is needed to promote wood-based electricity and ethanol production in the United States, respectively.

Temporal and spatial modeling of root reinforcement in montane and subalpine forests. Mao, Z. (*National Research Institute of Science and Technology for Environment and Agriculture (IRSTEA), France; maozhun04@126.com*).

It is widely recognized that vegetation can mechanically stabilize artificial and natural slopes against shallow landslides due to plant roots, which reinforce soil on a slope by providing an additional cohesion. My PhD thesis aimed to characterize, quantify and model the spatial and temporal patterns in root dynamics and their impact on the estimation of root reinforcement. Tree root distribution, growth and mortality were measured using monoliths and rhizotrons installed at two altitudes in naturally regenerated mixed forests in the French Alps. I found that (i) in highly heterogeneous montane and subalpine forest ecosystems, root quantity influenced the reinforcement more than root mechanical properties; (ii) root reinforcement could be spatially and seasonally heterogeneous according to altitude, type of vegetation patch, soil depth and month; (iii) root growth could be active even during the coldest months, maintaining the protective role; (iv) the finest roots, i.e. those of ≤1 mm in diameter, which are considered the most important for nutrient and carbon cycling, contributed little to mechanical reinforcement of the soil. My PhD thesis highlights the importance of taking into account the three-dimensional spatial and temporal patterns of tree roots in future ecological engineering models of slope stability when managing mountain forests against shallow landslides.

On the modeling of carbon sequestration in fast growing tree plantations established over former pasture lands. Pérez-Cruzado, C. (*Georg-August-Universiät Göttingen, Germany; cperez@gwdg.de*), Merino, A., Rodríguez-Soalleiro, R. (*University of Santiago de Compostela; agustin.merino@usc.es*; *roque.rodriguez@usc.es*).

In spite the trend observed in the tropics, forest area increased in the northern hemisphere in the last decades. This trend was favored in Europe by the implementation of the EU Common Agricultural Policy, which supposed large area of pasture land transformed to forest plantation. Even though it is widely agreed that afforestation of arable land supposes an increase in C stocks, the effect of pastures afforestation is still not clear because the large C content and stability in pasture soils. The objective of this research is to model the C evolution in pastures afforested with fast-growing tree species by considering: i) all compartments where C can be stored, ii) tree, stand and landscape estimation levels, and iii) empirical and mechanistic models. The results showed that afforestation affected soil organic matter stability, and drives a decreasing pattern in soil C after afforestation which can be corrected with a proper stand management. Sampling design for biomass equations was seen to be a key factor for C monitoring. Bioenergy use and products had a large effect on mitigation. The developed models will allow to simulate different management schemes and to optimize the management when C sequestration is a major goal.

The role of analysis and deliberation in changing community preferences for strategies and indicators of sustainable forest management. Rodríguez-Piñeros, S. (*Universidad Autónoma de Chihuahua, México; sandra_osu@yahoo.com*).

The objectives of the study were to incorporate stakeholders' perceptions of forest management into the management plans; and to investigate changes in preferences for indicators of SFM, while a forest management plan is discussed in a participatory process of analysis and deliberation (A&D). Q-methodology provided the basis for understanding subjective perspectives; and indicators of SFM were summarized in a survey to capture the difference in preferences. A community of 200 families in the State of Puebla, Mexico provided the venue for this research. The study revealed that A&D serves as a mechanism to incorporate values and preferences during planning; A&D assures that the final outcome, as reflected by the adoption of a forest management plan, meets people's preferences, includes their values, and ensures that the indicators for SFM are fully understood and embraced. Forest owners have a holistic view of the forest, which is associated with the condition of the forest and cultural, spiritual, and traditional values. How indicators are perceived and implemented rest on the understanding of forestry concepts and the goals of management associated to the benefits obtain from the forest. If the goals of management meet people's values and needs, SFM goals are more likely to be pursued.

Personal networks and private forestry: exploring extension's role in landowner education. Sagor, E. *(University of Minnesota Extension, USA; esagor@umn.edu*).

Despite public investments to educate and assist landowners, enrollment remains low. I investigated the role of personal networks in the flow of information and adoption of sustainable forest management behavior. Based on a written survey, 90% of 1767 owners of Minnesota forest land have received forestry information from at least one source, including 65% from a peer and 53% from a professional forester. Personal forestry information network size ranged from 0 to 14 with a mean of 2.92. Landowner network results confirm the important role of public sector foresters, but also suggest opportunities for increased use of peer learning techniques to engage landowners as learners. A related study investigated the ways that Extension Forestry programs leverage peer networks for education. The managers of 39 forestry-related peer learning programs train volunteers and use other peer learning techniques. Relative to state-level Extension forestry programs, peer learning programs target smaller, often underserved, landowner groups. Although program outputs and demands for service are increasing, many program managers face reduced budgets and are turning to new technologies and techniques to maintain or grow their programs. The results of these studies present both opportunities and challenges for the future of the nation's Extension forestry programs.

A study of the physical and mechanical properties of rubberwood lumber processed by high temperature treatment. Sik, H.-S. (*Forest Research Institute Malaysia; sik@frim.gov.my*).

This study was initiated in direct response to calls by the European Union (EU) Directive, for certain wood treatment chemicals, particularly borates, to be assigned to the "Repro-toxic Category" under the Dangerous Substance Directive 67/548. The aim of this study was to develop a method of accelerated drying-cum-high temperature treatment for rubberwood processing. The first stage of drying assessment was a simulation process study using a laboratory experimental dryer. The second stage of drying assessment was conducted using a commercial size prototype high temperature drying (HTD) system developed at Forest Research Institute Malaysia. This technology offers a unique solution to counter concerns on chemical treatment, particularly in the rubberwood furniture industry. It eliminates the application of standard Bethell treatment process which impregnates borates into the rubberwood prior to conventional drying. The operation of HTD technology involves only a single-step procedure and the process cycle time is reduced from 2 weeks to less than 2 days. The quality of HTD processed lumber is generally enhanced, with improved dimensional stability over lumber processed by conventional methods. Patents were granted for HTD technology from the United States in March and Malaysia in October 2013 (Patent No. US8397400B2 and MY149935). Patents were also filed in six other countries of interest.

IUFRO Student Awards for Excellence in Forest Sciences (ISA)

Effects of heat-treatment on the mechanical properties of loblolly pine, sweetgum, and red oak. Adewopo, J.B. (*University of Florida, USA; adewopo@ufl.edu*), Patterson D.W. (*University of Arkansas-Monticello, USA; pattersond@uamont.edu*).

Heat-treatment has been assessed as an eco-friendly means to reduce wood's dimensional instability and biodeterioration under varying ambient conditions. However, irreversible losses in mechanical properties have been reported to occur when wood is subjected to elevated temperatures. In this study, we assessed the effect of heat-treatment on strength properties (flexural strengths, compression strengths, shear strength, and hardness) of loblolly pine (*Pinus taeda*), sweetgum (*Liquidambar styraciflua*), and water oak (*Quercus nigra*). A total of ~270 wood samples were prepared for each strength test, and heat-treated at 3 temperature levels (93, 149, 204°C) and three durations (2, 5, and 8 h). Samples were placed in a conditioning chamber for 1–4 months, depending on sample dimension, and subsequently subjected to different standard testing procedures. Results showed

that the strength properties for the three species were optimally preserved, or mostly improved in specimens treated at 149°C for 8 hours. However, heat-treatment at peak level (204°C, 8 h) had most deleterious effect on the shear strength which reduced by 42% in pine, 72% in sweetgum, and 55% in oak, compared to kiln-dried control samples. Despite the decline of modulus of rupture in pine (~39% reduction) at peak treatment levels, improvements in modulus of elasticity (8% increase) and compression parallel to grain (25% increase) in sweetgum and oak, respectively, suggests potential opportunity for enhancing wood strength by optimizing heat-treatment conditions. These research findings are important for improved product development that may further encourage the usage of heat-treated wood for structural applications.

Assessment of nitrogen fertilization on growth, yield and carbon storage in above-ground biomass of a managed Douglas fir forest stand in the Pacific Northwest and application in sub-Saharan Africa. Daramola, T.M. (*University of British Columbia Okanagan, Canada*; t.daramola@yahoo.com).

This study investigated growth yield and carbon sequestration of a nitrogen fertilized Douglas fir forest stand in the Pacific Northwest and explored the potentials of replicating such treatment and management practice for restoration of degraded lands in the sub-Saharan Africa. The study utilized three fertilized thinned plots and three unfertilized thinned plots and compared their growth yield and carbon stock from 1987 to 2011. The result shows substantial amount of higher growth yield and carbon stocks on individual fertilized plots than unfertilized plots, but there was drastic decline in the growth rates after the end of fertilization period. The outcome leaves two parallel questions that demand further studies in the future on factors most responsible for the drastic decline in growth rates of the fertilized plots and the edaphic elements that stimulates growth rates of unfertilized plots. In addition, further studies are required to help register the contribution of the changes in biomass after fertilization. Overall, application of nitrogen fertilizer remain most viable option to restore soil nutrients for tree growths in the sub-Saharan region. The findings demonstrates that fertilization response correlate to various soil properties and worth the extra financial costs towards the restoration efforts in the sub-Saharan Africa.

Water erosion vulnerability of upland watersheds under different forest covers in the Chittagong Hill Tracts, Bangladesh. Hossain, M.M. (*University of Freiburg, Germany; mohitulh@yahoo.com*), Haque, S.M.S. (*University of Chittagong, Bangladesh; sms_haque@yahoo.com*), Olarieta, J.R. (*Universitat de Lleida, Spain; jramon.olarieta@macs.udl.cat*), Hossain, M.N. (*University of Chittagong, Bangladesh; noorhossain28@gmail.com*).

Water erosion is the most serious environmental problem in hilly watersheds of Bangladesh, and is a major concern for forestry and agricultural productivity. It is therefore necessary to identify land use practices that will control this problem in order to establish sustainable watershed management strategies. In this connection, the study was carried out in 21 different sites in the Chittagong Hill Tracts by conducting direct field assessments of soil loss under various land uses using erosion pins and pedestals measurement during the period 2009–2010. The results showed that average soil loss was highest (64 t $ha^{-1}yr^{-1}$) in deeply-tilled agricultural slopes, followed by *Tectona grandis* plantations (47 t $ha^{-1}yr^{-1}$), while the lowest soil losses (13 t $ha^{-1}yr^{-1}$) were recorded in bamboo plantations. Among the other forest plantations studied, soil loss rates were comparatively smaller under mixed-plantations (17 t $ha^{-1}yr^{-1}$) and *Gmelina arborea* plantations (30 t $ha^{-1}yr^{-1}$). Land use was the most significant factor explaining these erosion rates compared to slope and soil characteristics. This study can be useful to identify areas with high erosion risk and to develop adequate soil conservation measures in the hilly watershed of the Chittagong Hill Tracts.

Swidden cultivation among two *Chepang* communities in the central hill districts of Nepal: local perceptions and factors influencing change. Mukul, S.A (*University of Queensland, Australia; s.mukul@uq.edu.au*), Byg, A. (*James Hutton Institute; anja.byg@hutton.ac.uk*), Herbohn, J. (*University of Queensland, Australia; j.herbohn@uq.edu.au*)**.**

Swidden or shifting cultivation is one of the prominent land-use practices, and often criticized for their perceived negative impact on environment. On contrary, nowadays it has widely been recognized amid scientists that, swidden is not as detrimental as believed. Nepal, being situated in the Himalayas and highly vulnerable to climate change has been experiencing rapid land-use changes in recent years due to changing policy, local developments and growing concern on environmental issues. Swidden – locally known as *bhasme* **–** has been a common land-use practice in the mountains of Nepal. Despite decades of policy disputes, ignorance and misunderstanding on that age-old system, swidden is still the mainstay of livelihoods of many people. We performed an exploratory study amongst the rural *Chepang* farmers who lives traditionally on swiddening in two central hill districts of Nepal, to investigates the changes so far been taken place in the area, local understanding and perceptions on swidden. We found that, although swidden practice is declining rapidly and been replaced by cash crop based sedentary agriculture, the role of swidden in food security is still crucial. The main reasons why farmers practice swidden were: lack of secure tenure, poverty, unemployment, cultural identity, absence of alternative land-use options etc. A more equitable land-use options, tenure security, and access to government support could enhance swidden farmers to shift towards more environment friendly land-uses.

Skidding and chipping systems for the utilization of forest biomass. Yoshida, M. (*University of Tokyo, yoshida@fr.a.u-tokyo.ac.jp*).

To establish stable biomass chip supply chain, the effect of capital cost on chipping cost reduction was analysed. The productivity and price of introduced chippers currently were not synchronized in Japan, but the investigated small mobile chipper encouraged efficient chip supply chain establishment because of its low capital cost. The reduction of capital cost of chippers will keep chip production efficient especially in small scale forestry because it does not require vast amounts of forest material to realize lower cost. Thus, it is deemed easy for small scale forestry to implement a cheap chipper while the produced chip amount can be arranged by mobilizing and changing the number of chippers in a specific region.

Winch skidding productivity was investigated by time study as a basic whole tree harvesting system to primarily gather chip materials. The harvested volume was the most effective factors influencing productivity, and the method of attaching plural trees one-by-one within a cycle was effective to reduce fuel consumption. The reason for this result was that the wire tension while skidding was kept lower compared to the conventional winching method extracting trees all together at once.

The perception of decision-makers to climate change adaptation in urban and peri-urban forests of Belgrade.
Ivana Živojinović, I. (*European Forest Institute, Austria; ivana.zivojinovic@boku.ac.at*).

Climate change has become a main driver of an environmental change. Its negative effects of are reflected on urban and peri-urban forest (UPF) resources, which at the same time have an important role in combating climate change at local level, both through adaptation and mitigation measures. Existing literature demonstrate that understanding climate change mitigation measures is much better compared to adaptation. Therefore, this master thesis is aiming to analyse the current integration of climate change adaptation issues in UPF policies and management plans in Belgrade (Serbia). By analysing policy and management documents, conducting in-depth interviews and a Q-methodology questionnaire, this study reveals current state-of-the-art in this respect. Analysis of UPF-related documents has shown very weak integration of climate change issues. It can be noted that a comprehensive and systematic approach to this challenge does not exist. Awareness of managers is present to a certain extent, but it is influenced by many assumptions and uncertainties, which are the result of poor knowledge, lack of data on the local impact, and lack of communication between various actors. Therefore, institutional and human capacities are one of the most important factors that should be developed and strengthened in order to better adapt urban and peri-urban forests to climate change.

SP-17 Forests, water, and people

Organizers: Shirong Liu (Chinese Academy of Forestry); Ge Sun (U.S. Forest Service) & Tony Simons (World Agroforestry Centre, Kenya)

Forest watershed management policies and practices meeting increasing multiple needs in a changing world.
Bren, L. (*University of Melbourne, Australia; lbren@ncable.net.au*), Nettles, J. (*Weyerhaeuser Company, USA; jami.nettles@weyerhaeuser.com*).

For managers of watersheds carrying stable, mature forest, the forest may be a double-edged sword. On the one hand the watershed provides a sustained, heavily buffered flow of quality water. On the other, a range of natural perturbations may impact on the forest beyond its natural limits of resilience at scales ranging from small to landscape. This may lead to changes in the watershed yield, efficiency, and conservation value. Externally-sourced perturbations include fire, wind-throw, and insect attack. For conservation forests, forest age and climate change may become potent agents of change. Management options involving cutting, particularly of older trees, may be stridently resisted by the public. The interplay of these factors is presented using case studies from around the world. It is assumed that a major policy aim is to maintain the outflow of forest watersheds as "stable" or, for newly acquired areas, to move towards "stability." This can be achieved by manipulating stands (planting, thinning, cutting) to achieve desired levels of resilience and/or watershed outflow. Implications of this for watershed policy are explored; in particular whether managers should continually manipulate the forest to move towards a truly stable state or have long periods of quasi-stability punctuated by irregular but statistically predictable episodic disasters.

Forest and water relations under a changing environment: worldwide evidences at multiple spatial scales.
Liu, S. (*Chinese Academy of Forestry, China; liusr@caf.ac.cn*), Wei, X. (*University of British Columbia, Canada; adam.wei@ubc.ca*).

Forest and water interactions have long been recognized as one of the most important ecosystem processes and play a vital role in biogeochemical and hydrological cycles. Thus, understanding the forest and water relations is essential for managing forest ecosystems to sustain water supply and aquatic ecological functions. However, their complex and non-linear nature over multiple spatial and temporal scales under a changing environment often produce inconsistent results. Increasing of world-wide evidences from paired watersheds studies has greatly improved our knowledge of forest and water relations at small watersheds, but there has been little information at large heterogeneous landscapes and watersheds because of limited research at this scale and the challenges in scaling up and spatial extrapolation. At larger watersheds, forest and water relations are difficult to study due to complicated interactions among climate, land uses and watershed properties. There is a clear need to explore new approaches to assess forests and water relations at large watersheds or landscapes. This talk will provide a summary on what we have learned on the forests and water relations over different spatial scales, and identify research priorities to further advance our understanding.

From forests to the faucets: water supply functions of forests under global change.
Sun, G., Caldwell, P., McNulty, S. (*U.S. Forest Service, USA; gesun@ncsu.edu; pvcaldwe@ncsu.edu; steve_mcnulty@ncsu.edu*).

The world's remaining natural forests are generally found in headwater watersheds, often characterized as hilly terrains on high elevations, receiving relatively higher precipitation but lower evaporative energy than the surrounding areas, thus these forests are naturally important sources for water supply providing disproportionately more water for human and downstream ecosystems. Both unmanaged and managed forests provide the best water quality among other landuses. Forests do consume large amount of water to realize the ecosystem functions (e.g., carbon and nutrient cycling) and services such as stormflow mitigation, climate moderation, and carbon sequestration. Global climate change, energy development, air pollution, urbanization and landuse change, and increased water demand all threaten forests' water supply service functions by affecting the basic forest hydrologic cycles at multiple scales. This paper reviews our current understanding about the interactive relations among global change, forests, and water service functions. The paper discusses potential tradeoffs between water supply and biological carbon sequestration, water quantity and quality, and ecological restoration and water supply in developing mitigation and adaption strategies and measures in confronting a warming climate and water-stressed environment.

SP-18 Stemming invasions of forest insects and pathogens: research supporting pathway risk management and phytosanitary policy

Organizers: Andrew Liebhold (U.S. Forest Service) & Eckehard Brockerhoff (Scion, New Zealand)

Pathway level analysis of trade policy for reducing invasive species risk. Leung, B. (*McGill University, Canada; brian.leung2@mcgill.ca*), Springborn, M. (*University of California, Davis, USA; mspringborn@ucdavis.edu*), Turner, J. (*AgResearch, New Zealand; James.Turner@agresearch.co.nz*), Brockerhoff, E. (*Scion, New Zealand; eckehard.brockerhoff@scionresearch.com*).

Invasive species policies are often directed at pathways of introduction, yet few analyses have examined risk at the pathway level. We synthesize the best available economic and ecological information surrounding an international phytosanitary pathway level policy (ISPM 15). We highlight temporal factors for calculation of net benefits, emphasizing that while we cannot stop invasions, even delaying new arrivals results in substantial economic benefits. We show that even though policy implementation is costly and yields only moderate protection, it can yield >$11 billion in cumulative net benefits by 2050, averting as many pests as currently exists in the USA. However, this projection has high uncertainty, given available data, and we discuss the relative magnitude of effect of different sources of uncertainty and identify the most crucial data needs.

Forest insect invasion pathways in Europe. Roques, A. (*French National Institute for Agricultural Research (INRA), France; alain.roques@orleans.inra.fr*).

A total of 385 alien insect species established on woody plants in Europe since 1800. Along with globalization, the rate of arrival of new species exponentially increased from 1.8 /yr during the first half of the 20th century to 6.2/yr during 2000–2012. The mean annual number of new alien insects establishing on broadleaved has increased more rapidly than on conifers, on which it appeared to decrease during the last period. This trend mirrors the rapid increase in the import of live plants for planting. At present, the trade of ornamentals, including bonsais, constitutes the major pathway of invasion by forest insects whereas timber trade and wood packaging contributes less. A comparison between interceptions and establishments of aliens during 1995–2010 revealed only six common species out of the 117 newly established ones. More variation was found across insect genera or families in interceptions than in establishments, which is presumably due to the focus of inspections on a small number of known pests, and on particular consignments. Once arrived in a EU country, the release of custom barriers allows a number of species to quickly expand through human- mediated pathways and/or natural corridors but also as stowaways. Several examples will be detailed.

Global forest pathogen invasion pathways. Santini, A. (*Institute of Plant Protection, Italy; a.santini@ipp.cnr.it*).

Human-driven species expansion has increased tremendously in the last century, as a consequence of the unprecedented growth of international travel and trade, resulting in huge disturbance to ecosystems and severe socio-economic impact. In plants, emerging infectious diseases (EIDs) are linked to biological invasions. More than half of the world plant EIDs in the last few decades have resulted from the arrival of previously unrecognized pathogens. Many studies confirm that the main pathway of entrance of pathogens was the trade of living plants. In particular, the trade of ornamental woody plants plays a role of primary concern. These observations should serve to focus attention on the risk inherent in the trade of ornamental plants for planting in soil, which also constitutes the main pathway of introduction of pests. This pathway is particularly insidious as invasive harmful organisms are not easily detectable in soil, and they are, in addition, almost unknown and neglected in their native ranges. Several unexpected pathways are becoming of increasing importance. Eradication seems to be impossible, and so prevention by early detection of new introductions seems the only reliable measure, although it is difficult in the face of global mobility.

TECHNICAL SESSIONS

Theme A: Forests for People

A-01 Forests and human wellbeing: Life satisfaction and behavioral approaches

Organizers: Shashi Kant (University of Toronto, Canada), Sen Wang (NRC-Canadian Forest Service), Martin Hostettler (Cycad Inc., Switzerland) & Peter Deegen (Technische Universität Dresden, Germany)

Farmers' woodlots management and sustainable livelihood development: a case study in southern Sri Lanka. De Zoysa, M. (*University of Ruhuna, Sri Lanka, Sri Lanka; mangalaxyz@yahoo.com*), Inoue, M. (*University of Tokyo, Japan, Japan; mkinoue@fr.a.u-tokyo.ac.jp*), Kalansuriya, N. (*University of Ruhuna, Sri Lanka, Sri Lanka; kalansuriya@agri.ruh.ac.lk*).

Participatory forestry approaches are popular due to their rural development efforts improving livelihood opportunities. Sustainable livelihoods enhance rural capabilities and assets by not undermining the natural resource base. The paper based on field study analyzed the contribution of the farmers' woodlots program in Nidahas Gama on livelihood development in terms of human capital, natural capital, physical capital, financial capital, social capital, and governance. The program has developed human capital through skills development and training of the participants while natural capital through land development of farmers woodlots; and improvement of agricultural and other lands, and homegardens. Increased household facilities, alternative sources of energy for cooking, and improvement of infrastructure are identified as physical capital as well as increased household income; and popularize banking transactions are identified as financial capital developed by the program. Main strategies used for social capital development are the development of groups and networks; trust and solidarity development; promotion of collective action and cooperation; development of social cohesion and inclusion; empowerment of participants; and information and communication improvement. The program addresses governance through popular participation, promotion of equity, and the creation of information flow. The program, incorporated with rural development strategies, has made very important contributions to livelihood development.

How farmers adapt to co-management of land as sustainable development platform – a study of community forestry programs in the Philippines. Jarzebski, M., Yamamoto, H. (*University of Tokyo, Japan; marcin.jarzebski@yahoo.com; yama@k.u-tokyo.ac.jp*).

Community level resilience building is very important for sustainability up-scaling to the regional or national level. Advocating the role of community resilience, which support farmers in adapting to resource co-management and help to adopt system of social forestry as a sustainable development platform, becomes critical in globalized times. Social capital, which encompasses not only social networks but also attachments to the forest, spirituality and beliefs, traditional knowledge, and subjective well-being, could be an alternative component of sustainable forestry, complementing natural and economic capital, when local resources are limiting the local socio-ecological system. The research consists of four case studies Community Based Forest Management (CBFM) in the Philippines: two areas with different indigenous people groups and two with non-indigenous people. Qualitative and quantitative data on community and government gathered between years 2011 and 2014, supported by satellite analysis, revealed actual situation and community resilience drivers within CBFM projects, 15 years after these projects started. Enhancing the resilience of people who practice traditional methods could drive long-term sustainable development, as these people are more concerned with nature and livelihood subsistence. However, other groups of non-indigenous people find forest resources attractive, and favor them despite a modern life style expansion.

Job habitat – an index of the socio-economic potential of forest stands. Soucy, M. (*Université de Moncton, Canada; michel.soucy@umoncton.ca*).

Forests provide many benefits to society such as employment. However, those benefits are also dependent on highly variable factors such as technology, markets and regulations. Thus, we cannot rely on the current level of benefits to infer on the state of the forest or that of its sustainability. In that context, an index of the socio-economic potential of forest stands inspired by the concept of wildlife habitat is proposed to isolate the capacity of the forest to support benefits from the actual level of benefits observed. A case study over 3.3 million hectares was performed to test the feasibility of the approach and to identify the main challenges. Employment factors for different sectors (silviculture, logging, different wood products manufacturing sectors, maple sap production) were developed and related to stand characteristics. The resulting model made it possible to spatially represent the employment potential that every stand could theoretically support in its current state. The index allows us to monitor the amplitude and location of changes in potential with time, technology, markets and regulations. The spatial nature of the index also allows us to identify areas of conflicting potential and provides a powerful tool for communicating the effects of policy changes.

Impact of health care provisions on the contribution of medicinal plants to health and livelihoods in the Peruvian Amazon. Toda, M., Masuda, M. (*University of Tsukuba, Japan; miki@elstyle.jp; masuda.misa.gm@u.tsukuba.ac.jp*).

The purpose of this research is to evaluate the impact of health care provisions on the contribution of medicinal plants to the health and livelihoods of people living in the Peruvian Amazon. While the role of medicinal plants as complementary primary health care and supplementary income sources are highly expected in developing countries, possible facilitators and hindrances to the expected role have rarely been studied. A household survey based on a structured and semi-structured questionnaire as well as interviews with key persons in health care facilities in the area of the survey was used to gather data. The survey was conducted in an indigenous community and will also be conducted in a mestizo village in the central part of Peruvian Amazon. Besides

socio-economic background, use and knowledge of medicinal plants as well as use and perception of the health care system are asked in the survey. The resulting data was qualitatively and quantitatively analyzed. Comparing the households between different socio-cultural backgrounds, the conditions to facilitate and hinder the expectations of the role of medicinal plants in a tropical rain forest will be identified and its socio-economic dynamism will be discussed.

Evidence for health benefits of urban green motivates a "green" public health indicator – results from a systematic review and GIS-analyses. van den Bosch, M. (*Swedish University of Agricultural Sciences, Sweden; Matilda.Van.Den.Bosch@slu.se*).

Past research has demonstrated varied health effects of forests and other natural environments. In times of urbanisation urban forests, woodlands, and parks are particularly important, in order to prevent many lifestyle related disorders. A systematic review was made to investigate and assess the evidence for different health effects from urban parks. The included papers demonstrated a high evidence grade for urban parks as promoters of physical activity and moderate evidence for the capacity to reduce obesity. The results provide arguments for establishing public health indicators based on urban citizens' access to green spaces. This was tested by combining GIS-data with population data at census level for a mid-sized Swedish city. The GIS-analysis demonstrated that 82% of the population lives within 300 m from a green urban area. By using publically available data from open sources, such as Urban Atlas, standardised comparisons between different cities can be performed. This could, for example, be used to investigate whether regional variances in public health may be related to varied access to urban green spaces. Such urban green space indicators may be used by authorities, planners, and decision makers in order to improve public health and promote urban green establishments.

Forest incomes in the vicinity of a restoration concession – a case study from Harapan Rainforest, Indonesia. Widianingsih, N. (*University of Copenhagen, Denmark; nayu@foi.ku.dk*), David, W. (*Universitas Bakrie, Indonesia; wahyudi.david@bakrie.ac.id*).

It is estimated that only 2–3% of the original Sumatran Lowland Rainforest remain and since 2010, 20% of the remaining areas are under restoration concession called Harapan Rainforest. Unfortunately, Landsat images indicate that, in total, the Harapan concession holder is struggling to minimize land encroachment by a mostly immigrant community that reaches 19 214 ha within the last 7 years. They are interested in removing wood and converting forested areas into plantation cash crops (rubber and palm oil). Little deforestation occurs in the areas where non-timber forest products (NTFPs) are collected by local and indigenous communities. This study will examine the importance of selected NTFPs on various levels of degraded forest area to indigenous, local, and immigrant's livelihoods. It looks at the actual production levels and their economic contribution to forest households' income in total. The results from the socioeconomic survey will be combined with spatial distribution information on forest degradation levels to establish zoned restoration priority areas that could accommodate the restoration purpose and communities' needs. Quantitative data will be collected with Poverty and Environment Network (PEN) prototype questionnaires between October 2013–October 2014. Group and key informant interviews were conducted in January and September 2013.

A-02 Forests and human health: The role of research towards evidence-based practice

Organizers: Takahide Kagawa (Forestry and Forest Products Research Institute, Japan) & Liisa Tyrväinen (Finnish Forest Research Institute, Finland)

Physiological effects of wooden odors on humans: evidence from laboratory experiments. Hishiyama, Y. (*Forestry and Forest Products Research Institute, Japan; yukot@ffpri.affrc.go.jp*), Miyazaki, Y. (*Chiba University, Japan; ymiyazaki@faculty.chiba-u.jp*), Kagawa, T. (*Forestry and Forest Products Research Institute, Japan; kagawa@ffpri.affrc.go.jp*).

This research aims to elucidate the effects of wooden odors on human physiology by conducting laboratory experiments. The physiological measurements we use are cerebral hemodynamics to assess activity in the prefrontal area, blood pressure, and pulse rate. We also use heart rate and heart rate variability as indicators of autonomic nervous activity. Each experiment was conducted in a room with controlled settings, with 10 to 20 participants. Examples of the results include: (i) the smell of Japanese cedar wood chips significantly decreased systolic blood pressure and cerebral activity in adults, (ii) the smell of α-pinene and limonene (odorous components of conifer trees) significantly decreased systolic blood pressure in adults, and (iii) the smell of α-pinene significantly decreased infants' heart rate. These results suggest that the odor of wood chips of certain species or wooden extracts have physiological soothing effects. We consider that a physiological approach, as presented in this paper, will be invaluable for elucidating the relationship between forests and human well-being, and implementing evidence-based practice.

The spread of forest therapy in Japan. Kagawa, T. (*Forestry and Forest Products Research Institute, Japan; kagawa@ffpri.affrc.go.jp*).

In recent years, people living in urban settings have been exposed to heavy techno stresses on a daily basis, hence the increasing attention focused on the role of the forest environment to promote human health and well-being. This is because humans have adapted to the forest environment over millions of years, and are still not familiar with the current urban environment. In Japan, there are currently 53 forest therapy bases and trails. Since we introduced the certification system in 2005, forest therapy has been widely used in municipalities nationwide. Recent field studies have provided many scientific benchmarks for the physiological effect of forest bathing, including sympathetic and parasympathetic nerve activity by heart rate variability (HRV), blood pressure, pulse rate, adrenaline and noradrenaline and salivary cortisol concentration, natural killer (NK) cell activity and the number of NK cells. Moreover, the present study showed how the forest environment is effective in terms of cardiovascular and metabolic parameters. In addition, forest bathing also reduces oxidative stress and boosts antioxidant capacity. Conversely, when comparing the therapeutic effect of natural environments, the forest relaxation effect exceeds that of farm land and sea coast.

A study on the healing effect of Korean forestry. Lee, J., Park, S., Jeong, M., Yoo, R., Kim, J. (*Korea Forest Research Institute, Republic of Korea; jeong86@forest.go.kr; sjpark@forest.go.kr; miaejeong630@gmail.com; cham0505@forest.go.kr; jjkim@forest.go.kr*).

In recent Korean society, the number of healing industries, which connect the Lifestyles of Health and Sustainability (LOHAS) with well-being, is rapidly increasing and the major activities in forests have also been changed to the walking on the forest roads or the real healing through forests, sublating those activities like simple climbing for achievement purpose. In order to respond to the people's demand for forests, the Korea Forest Service is attempting the scientific approach to real healing, namely, the psychological and physiological healing effects of forests. The research on the healing effect of forests started in earnest in 2007 and it is still continuing in 2013. In this study, the scientific results of seven years on the healing effects of forests will be analyzed and forest healing in Korea will be introduced. The forest healing in Korea imitated the forest therapy of Japan at the early stage of its research, but currently, Korea's own direction of forest healing has been established and the relevant research is being conducted based on continuous evidence.

Forests for wood production and human wellbeing – what are the trade-offs in long-term forest management planning? Nordström, I., Lundell, Y., Stoltz, J., Skärbäck, E., van den Bosch, M., Grahn, P., Dolling, A. (*Swedish University of Agricultural Sciences, Sweden; eva-maria.nordstrom@slu.se; Ylva.Lundell@slu.se; jonst309@gmail.com; Erik.Skarback@slu.se; Matilda.Van.Den.Bosch@slu.se; Patrik.Grahn@slu.se; Ann.Dolling@slu.se*).

Social values of forests are increasingly recognized as important objectives in forest management planning. For instance, forests contribute to human health and wellbeing by providing a suitable environment for recreation and rehabilitation. However, it remains a challenge to define and measure these values in terms of forest variables and to incorporate them into forest planning. The objective of this study is to quantify rehabilitation forest characteristics and analyze trade-offs between wood production and rehabilitation forests. The study builds on previous studies of preferences for different forest types among participants in a stress rehabilitation program. For three forest estates in northern, middle and southern Sweden, correlation analysis indicated that the five most important stand-level variables were age, stems/ha, height, diameter and standing volume. Threshold values were set for these variables as well as spatial criteria to define rehabilitation forest. The Heureka decision support system was used to analyze the relation between maintaining different shares of rehabilitation forest and the loss in net present value (NPV) for forestry over a 100 year period. Preliminary results show that 15–25% can be maintained as rehabilitation forest without considerable decrease in NPV. Age and spatial restrictions seems to be important limiting factors.

The Nature, Health & Design Lab – research on nature qualities. Stigsdotter, U., Refshauge, A (*University of Copenhagen, Denmark; uks@life.ku.dk; adre@ign.ku.dk*).

An increasing amount of research suggests that nature is a resource to human health. Studies indicate health benefits at cellular, individual, and population level, and that natural environments have positive impacts in three main ways by encouraging physical activity and social contact, and by providing psychological and physiological restoration. Evidence further suggests that there may be synergies between the three. There is sufficient evidence to support the assertion that natural environments promote health and can act as supportive environments for therapies. This is often stated in Danish health and nature policies. But how can research results be used in practice? Our hypothesis is that everything marked green on a city map cannot promote health or serve as a setting for therapies *per se*. More knowledge concerning nature qualities and evidence-based health design is needed. Therefore the University of Copenhagen has established the Nature, Health & Design Laboratory that consists of two settings; the Health Forest (health promotion), and the Healing Forest Garden Nacadia (treatment of stress). Different nature characteristics' impact on health is being tested using both physiological tests and psychological, validated assessments. In a randomized clinical trial the effect of nature-based therapy in Nacadia and the impact of nature experiences are being studied. Preliminary results will be presented.

The influence of urban nature environments on stress relief — a field experiment. Tyrväinen, L., Ojala, A. (*Finnish Forest Research Institute, Finland; liisa.tyrvainen@metla.fi; ann.ojala@metla.fi*), Korpela, K. (*University of Tampere, Finland; kalevi.korpela@uta.fi*), Lanki, T. (*National Institute for Health and Welfare, Finland; timo.lanki@thl.fi*).

More evidence and systematic research is needed on the psychological and physiological health effects of urban nature areas. This presentation is about the psychological and physiological stress reducing effects of different urban green areas based on an experimental study. We chose three different experimental sites within Helsinki city, the capital of Finland. The study sites were a constructed urban park, large urban woodland and the city centre of Helsinki. We used several psychological and physiological measures for measuring stress relief such as the Restorative Outcome Scale and Perceived Restorativeness Scale physiological measures including salivary cortisol concentration, blood pressure and heart rate variability. The experiment consisted of a 15-minutes viewing session which was followed by a 30-minute walking session on a given course. The final sample consisted of 77 healthy, non-smoking participants between 30–61 years of age. The data were analysed in SPSS, using repeated-measure ANOVA. Our results showed that there was a clear difference between the city centre and urban nature areas. The participants felt more restored after visiting green areas, compared to the city centre. The differences between the urban green areas were smaller. However, the urban woodland had somewhat more restorative qualities than urban park.

Long-term monitoring of health effects of urban forests in Hangzhou, China. Ye, B. (*Chinese Academy of Forestry, China; yb70@caf.ac.cn*), Zhang, T. (*Forestry Bureau of Guangan City, China, China; zhangyanli_qinyu@163.com*), Zhang, Z. (*Beijing Forestry University, China; zzy100083@163.com*), He, Q. (*Hangzhou Forestry Academy, China; heqijiang@21cn.com*).

Various researchers have shown that urban forests can help to improve the health of urban residents. However, it is still very difficult to quantify the magnitude of the health benefits and use the information to guide the planting and maintenance of urban forests. In this study, a long-term monitoring approach was developed to track the dynamic of the health benefit of urban forests. Seven environmental variables that are closely associated with urban forests were selected as measurable indexes of health effects that urban forests can produce. Their spatial-temporal variations in a sub-tropical city in China were monitored by using six automated monitoring platforms. In this report, the rationale of the monitoring protocol, set-up of the platform, and the initial results are reported. Some recommendations on enhancing the health effects of the urban forest are suggested.

Posters

A study of Japanese attitudes toward coniferous forests and pollen allergy. Kawase, M. (*Kyoto University, Japan; kawase.mari.75x@st.kyoto-u.ac.jp*).

In Japan, the forestry policy during the 1960s was to cut down broadleaf trees and plant coniferous trees in order to produce construction wood. Now, approximately 40% of Japanese forest is plantation forest. However, reduced harvesting has resulted in these plantations producing much pollen. Allergy to Japanese cedar (*Cryptomeria japonica*) and Japanese cypress (*Chamaecyparis obtusa*) pollen is a serious health problem in Japan. The first case of Japanese cedar pollen allergy was recognized in 1964. Now, it is thought that 10~30% of people in Japan have pollen allergies. This study investigated Japanese people's attitudes toward plantation forests and their opinions regarding the pollen allergy problem. Understanding their attitudes and opinions is important for developing forest management strategies. The study administered a questionnaire about the pollen allergy problem in three cities. The people surveyed were of the opinion that several factors cause pollen allergy: pollen, which is the main factor, and air pollution, caused by smoke and gases. Opinions about the pollen allergy problem differ between those with and without pollen allergy.

Green spaces at the work place and allergic sensitization of office workers in the city and forest. Lee, J., Park, S., Jeong, M., Yoo, R., Kim, J. (*Korea Forest Research Institute, Republic of Korea; jeong86@forest.go.kr; sjpark@forest.go.kr*; *miaejeong630@gmail.com*; *cham0505@forest.go.kr*; *jjkim@forest.go.kr*).

The prevalence of asthma, allergic rhinitis and atopic dermatitis has increased in recent decades globally. Previous studies suggested that environmental factors may influence the development of allergic diseases, but the relationship between environmental factors and allergic diseases remains unclear. Green spaces are also known as one of the factors that can affect allergic diseases. It has been suggested that green spaces could improve both perceived and objective physical, mental health and well-being. It is associated with increased physical activity, decreased stress level and improved people's life quality. Although we spent at least 40 hours per week in the work place, there is little evidence on the impact of green space on office workers. The objective of our study is to identify an impact between green spaces at the work place and worker's allergic sensitization. For this study, a modified International Study of Asthma and Allergies in Childhood (ISAAC) was used to survey two different work places in Korea in September and October, 2013. We performed a questionnaire survey and skin prick test with 29 common allergens. To analyze, we measured work place indoor and outdoor air quality and individual factors like smoking patterns and medical history.

Analyzing the willingness for cooperation between forest and health experts in improving people's health in Germany. Meyer, K. (*University of Göttingen, Germany; katharina.meyer@forst.uni-goettingen.de*).

As a result of sedentary lifestyles and continuously growing stressors, the number of people suffering from civilization diseases has increased, particularly in developed countries. Concerning forest visits, experiences and their health benefits, especially with respect to the reduction of stress, Germany has hardly conducted any explicit projects. The objective of this study is to gain information about forest and health experts' willingness to cooperate in order to analyze the effect of forest exposures and people's health improvement in Germany. The methodology approach will be built on guideline-based interviews with experts representing both sectors. At first, foresters and forest supervisors on one side and general practitioners and psychologists on the other will be asked for their judgments concerning the importance of forest exposures for people's health. Furthermore they will be asked to estimate the willingness for cooperation of their respective sector in general. Respondents will also be asked what kind of cooperation between the forest and medicine sectors are imaginable, to what extent, and what kind of barriers have to be overcome to realize them. Data will be collected and analyzed during the first quarter of 2014. The results will help to establish a frame for potential cooperation projects in prospective research.

A cost-benefit framework for urban green areas in the case of intensifying urban development. Rekola, M. (*University of Helsinki, Finland; mika.rekola@helsinki.fi*).

Intensifying urban and suburban development is a target in several cities around Europe. The benefits of intensified development include, among others, housing services and reduced travel costs. Costs are related to losses in urban green areas: their potential for recreation and thus reducing health benefits. The paper proposes a cost-benefit framework for urban green areas in the case of intensifying urban development. The Health Economic Assessment Tool (HEAT) model by the World Health Organization (WHO) can be used to measure the benefits of walking and bicycling. The model is used to inform cost-benefit analysis in planning cases for a new piece of cycling or walking infrastructure. The model is based on research on the relationship between physical activity and health and economic estimates of value of statistical life. First, the population incurred is estimated and relative risks of those doing recreation frequently are compared to those doing infrequently. The time of intervention, rate of return and the statistical value of life are then used as parameters. Other benefits of urban areas are taken into account as well. For instance, aesthetic values can be estimated using hedonic pricing. The comprehensive cost-benefit framework is needed to properly account different benefits and avoid double-accounting.

The effects of forest therapy utilizing regional abandoned forests in Japan. Uehara, I. (*Tokyo University of Agriculture, Japan; bigrock1964@hotmail.com*).

Many studies have reported that forests can promote human health. Forest amenities might have the effects of preventing illness, all while providing a relaxing place, a rehabilitative environment, a care & treatment place for disabilities, a peaceful counseling space, and so forth. By experiencing forest activities over a longer period of time, clients with mental, psychological, and physical disabilities may improve their conditions. On the other hand, a lack of appropriate forest management has resulted in what is called "abandoned forests", and has remarkably increased in Japan. This study introduces cases of forest activities, "Forest Therapy (*Shinrin Ryoho*)", utilizing a regional abandoned forest in Japan. The clients were people with mental retardation, developmental disabilities, mental illness, cognitive impairment (dementia), and others. After experiencing the forest therapy activities, not only did client's physical & mental conditions improve, but the forest's environmental conditions also improved. These findings suggest that "Forest Therapy" can benefit both humans and forests.

The perception of internet users regarding to human health benefits provided by urban green areas. Viezzer, J., Biondi Batista, D. (*Federal University of Paraná, Brazil; jeviezzer@yahoo.com.br*; *dbiondi@ufpr.br*).

Urban green areas provide ecological, aesthetic and social benefits, and, among them, benefits regarding human health. Urban green areas provide emotional and spiritual fulfillment, promote a faster recovery of hospital patients, and help reduce the stress levels of the population. The aim of this study was to evaluate the perception of internet users regarding human health benefits provided by urban green areas. Thereby, a survey was designed and published online on Google Docs and released through social networks. 180 responses were gathered. The internet users utilize urban green areas from once a month to once a week (70%), and practice rest and leisure (73%), physical activities (49%), socializing and meeting (46%), and contact with nature (44%). The majority replied that some kind of health benefit was provided by the use of urban green areas (51%). Of these, 58% mentioned benefits to physical health, since urban green areas provide physical activity exercising, fitness, weight loss and recovery of respiratory diseases, and 46% mentioned benefits to mental health, since urban green areas provide relaxation, well-being, leisure and emotional comfort. Even though the majority of internet users notice the benefits provided by urban green areas, many responded that they have not obtained any benefits. This suggests that internet users do not realize the influence of the mentioned activities on human health.

Sovereignty of Indonesian biodiversity conservation and health through development of "Kampung Konservasi". Zuhud, E. (*Bogor Agricultural University (IPB), Indonesia; ervizal_amzu@yahoo.com*), Hikmat, A. (*Department of Forest Resources Conservation and Ecotourism, Indonesia; ahikmat62@yahoo.com*), Damayanti, E., Metananda, A. (*Bogor Agricultural University (IPB), Indonesia; e11yn.d4mayanti@gmail.com; arya_arismaya@yahoo.co.id*).

Indonesian tropical natural forest is very important to support human health, especially as the sources of material and services for livelihood sovereignty and human health. The tropical forest consisting of various types of forest ecosystem from mountain to the shore is the source of more than 2 000 species of medicinal plants that make human and livestock healthy. Deforestation is still a threat for the loss of biodiversity in Indonesia. Indonesia has a big chance to actively participate in developing a healthy body and mind of world society, through development of "Sovereignty of Indonesian Biodiversity Conservation and Health". "PANCASILA" is the unification tool for our nation and the world's peace. There are three stimuli as prerequisites for conservation, namely "voluntary stimulus", "natural stimulus" and "benefit/use stimulus" and the implementation of values in the community such as fair, civilized, and sovereign values. This paper reveals the research results of several kampongs of local communities in Indonesia. The efforts to develop biodiversity conservation kampong in each ecosystem of kampong village throughout Indonesia today and in the future must be maintained as the prerequisite for the nation's sovereignty to face globalization.

A-03 The value and challenges of integrating food and medicinal forest products into forest management

Organizers: James Chamberlain (U.S. Forest Service), Carsten Smith-Hall (University of Copenhagen, Denmark) & Tytti Sarjala (Finnish Forest Research Institute, Finland)

Potentials of Raphia hookeri wine in livelihood sustenance among rural and urban populations in Nigera. Aiyeloja, A., Oladele, A. (*University of Port Harcourt, Nigeria; aiyeloja@yahoo.com*; *adekunle.oladele@uniport.edu.ng*).

Raphia wine is an important forest product with cultural significance besides its use as medicine and food in southern Nigeria. This work attempts to evaluate the profitability of Raphia wine production and marketing in Sapele Local Government Area. Four communities (Sapele, Ogiede, Okuoke and Elume) were randomly selected for data collection via questionnaires among producers and marketers. A total of 50 producers and 34 marketers were randomly selected for interview. Data were analyzed using descriptive statistics, profitability analysis, multiple regression and rate of returns on investment (RORI). Total weekly profit was highest in Okuoke (Producers – ₦90,000, Marketers – ₦70,000) and least in Sapele (Producers ₦50,000, Marketers – ₦45,000). Multiple regression showed that location was significant (0.000, $\rho \leq 0.05$) on profit margins. RORI were Elume (66.7%), Okuoke (50.0%), Ogiede (42.9%) and Sapele (25%). Both males (58.8%) and females (41.2%) invest in Raphia wine marketing, while males (100.0%) dominate production. Results show that Raphia wine has potential to generate household income, enhance food security and improve life quality of rural and semi-urban communities. Improved marketing channels, storage facilities and credit facilities via cooperative groups were recommended for producers and marketers by concerned agencies.

Quantitative approach of *Sterculia setigera* Del. (Sterculiaceae) ethnobatanical uses among rural communities in Togo (West Africa). Atakpama, W., Batawila, K. (*University of Lomé, Togo; wouyoatakpama@gmail.com*; *batawilakomlan@yahoo.com*), Gnamkoulamba, A. (*National Institute of Agricultural Education (INFA) of Tové, Togo; atamag@yahoo.fr*), Akpagana, K. (*University of Lomé, Togo; koffi2100@gmail.com*).

The relationship between human beings, their culture, and their environment has high importance in the frame of sustainable management of natural resources. This study aimed to assess the local uses of *Sterculia setigera* within rural communities in Togo. The methodology followed during this study was based on inquiries. Fifteen ethnic groups were involved. The interethnic convergence was assessed by using four use indices: reported use, plant part value, specific reported use, and intraspecific use value. The mean reported uses showed significant difference between geographic zones, ethnic groups, age, and occupations; but no significant difference between genders was found. Pharmacopeia (67.00%), followed by magico-mystic (15.23%), and food (10.43%) were the main quoted uses. The most used organ is the bark. Decoction was mentioned as the most used method of preparation. Considering the socio-economic and cultural importance of this species, it is important to promote its integration in agroforestry systems.

Management criteria for non-wood forest products of vegetable origin of importance in the sociocultural context. Barrizonte, A.N. (*Instituto de Investigaciones Agroforestales (INAF), Cuba; adolfo@forestales.co.cu*), Figueras, Y.B. (*Universidad de Pinar del Río, Cuba; betancourt@af.upr.edu.cu*).

Categories and uses of non-wood forest products (NWFP) of vegetable origin used in the "Regla Ocha" cult are defined. This definition is based on a diagnosis of the current situation and a characterization of the community of Unión de Reyes, Matanzas, Cuba, of African descent, with its cult and consumption practices regarding NWFPs obtained from semi-deciduous forests growing on chalky soil in the named territory. Interviews, direct observation and documentary research confirm the use of 14 categories of NWFPs in the cult, obtained from 453 plant species of the country, distributed over 114 botanical families and 361 genera. In the studied forest, species, categories and uses that are most widely distributed in numbers are identified, and the economic value of these NWFPs in the territory is evaluated. Anthropic disturbances caused by the free collection of these products and their incidence in degrading wooded areas are described. The results obtained allowed to evaluate the importance of NWFPs in the sociocultural context and the formulation of management criteria for NWFPs of vegetable origin used in the context of the "Regla Ocha" cult.

Recovery of boldo (Peumus boldus), specie of high value in the field of the NWFP through intensive management. Benedetti, S., González, M. Hormazabal, M., Salinas, A. (*Instituto Forestal de Chile, Chile; sbenedet@infor.cl*; *mgonzale@infor.cl*; *mhormazabal@infor.cl*; *asalinas@infor.cl*).

The value of boldo (*Peumus boldus* Mol.), an endemic species from Chile, is given by its leaves, which were tradtionally used from the pre-Columbian era for digestive and medicinal purposes. The leaves have many active components present in them, with the alkaloid "boldine" being the most known. Export of the leaves begun in the beginning of the twentieth century, with exponential growth in Latin American, American and European markets. However, its commercial utilization has impacted the structure, distribution and surface of boldo, with its consequent degradation. With the objective of ensuring their sustainability, the species was evaluated during five years three intensities of harvest: 35, 65 and 100% removal of basal area. The experimental design corresponds to a systematic design with three replications and plots of 1000 m^2. The analysis was carried out using a longitudinal analysis using statistical linear mixed models. This analysis allows for the identification of the average effect of the treatment (intervention), the effect of time, and the interaction time per treatment. The results show a high recovery of the individuals at a higher intensity of management, greater increases in height, neck diameter and diameter at breast height, biomass, the amount of regrowth and better recovery of the individuals.

Ethnobotany of palms (Arecacea) in communities of Bajo Calima, Colombia. Bocanegra-Gonzalez, K., Mendez, F.F. (*Universidad del Tolima, Colombia; kellynda7_7@hotmail.com*; *fmendez@ut.edu.co*).

Palms are the main source of non-wood forest products (NWFP), and in Colombia there is a great diversity and they are widely distributed. This study was carried out in three human settlements of Bajo Calima. Inhabitants were interviewed about the traditions and uses of the Arecaceae family, a photographic register was prepared showing the products and the processes of their preparation; a plot of 1ha was established in a secondary forest adjacent to the three communities. The palms were counted and measured; the simplified importance value index was calculated and compared to uses, demands and supply of the species. 312 individuals of 13 species were registered. 80% is used for food, the rest for construction, crafts and medicines. On average, each species is used for food to an extent of 35%. 70% of the NWFP are commercialized; the remaining 30% are for domestic use. The market is small and local. Finally, the study recommends establishing management activities that make it possible to guarantee the existence of the species which deliver an economic income and, thus, contribute to the livelihood of the community and fulfill an important ecological function in the ecosystem.

Co-managing Appalachian hardwood forests for timber and non-timber products. Chamberlain, J. (*U.S. Forest Service, USA; jchamberlain@fs.fed.us*).

The forestry profession is supported by over 100 years of science-based knowledge on managing and growing trees, but it has very little information on managing herbaceous species. This presentation focuses on the ecological impact and implications of harvesting non-timber forest products on the forest ecology. It concentrates on three native herbaceous species: *Panax quinequifolius* (American ginseng), *Actaea racemosa* (black cohosh) and *Allium tricoccum* (ramps). The presentation examines the relationship of ginseng harvest to forest stand conditions to provide a means to focus conservation efforts for this medicinal forest product. Results of long-term studies of black cohosh are presented that illustrate the level of harvest that is unsustainable, as well as the relationship between forest canopy cover and plant growth. Changes in ramp populations, documented through long-term studies of sites that experience significant harvesting events are presented. The relationship between tree canopy development and the development of ramps is analyzed to illustrate the timing of harvest to ensure optimal biomass production. These examples set the stage for a discussion on the need to expand forest management to include the herbaceous plants in the understory.

Traditional knowledge of mushroom production in a changing world — case of Noto-Temari and dried shiitake-mushroom in Oku-noto Area, Japan. Kohsaka, R., Kohsaka, R. (*Kanazawa University, Japan; kohsaka@hotmail.com*; *tomiyoshi@staff.kanazawa-u.ac.jp*), Hashimoto, S. (*Kyoto University, Japan; hash@kais.kyoto-u.ac.jp*), Saito, O. (*United Nations University-Institute for Sustainability and Peace, Japan; saito@unu.edu*).

This paper reviews the existing literature on mushroom production and outlines the challenges that local communities and farmers face at the micro-level. We further propose possible measures for these challenges. First, this article reviews official statistic documents related to mushroom production in Japan. It elucidates the differences in production systems between the raw shiitake-mushroom and the dried shiitake-mushrooms. Secondly, we analyze the cause of increasing numbers of newcomers in mushroom production by focusing on an example of Noto-Temari, a newly-established raw shiitake-mushroom, in Ishikawa Prefecture, Oku-Noto area based on the field survey conducted. Lastly, we widen the scope to the nationwide crisis of the shortage of shiitake-mushroom logs due to the Fukushima nuclear plant incident. Based on these reviews and analysis, we

explore the possibility of regenerating Satoyama forests by utilizing or "selling" experiences of mushroom production for tourists or urban residents.

Biological properties of a non wood forest product (*Pistacia lentiscus* fixed oil) growing in Tunisia. Mezni, F. (*National Research Institute of Rural Engineering, Water and Forests (INRGREF), Tunisia; faten-mez@hotmail.com*), Miled, K. (*Pasteur Institute of Tunisia, Tunisia; miledkhaled@yahoo.fr*), Khouja, M. (*INRGREF, Tunisia; khouja.medlarbi@iresa.agrinet.tn*), Berdeaux, O. (*National Institute for Agricultural Research (INRA), France; olivier.berdeaux@dijon.inra.fr*), Maaroufi, A. (*Pasteur Institute of Tunisia, Tunisia; abderrazak.maaroufi@pasteur.rns.tn*), Khaldi, A. (*INRGREF, Tunisia; khalditn@yahoo.fr*).

Pistacia lentiscus L. is a species known, in some Tunisian forest areas, by its fruit oil extracted by rural women. This oil is locally used for culinary purposes and in traditional medicine for stomach and pulmonary diseases and for wound healing. This natural product has an important role in generating household income in the poor forest zones. As the case with a lot of neglected non-wood forest products (NWFP), *Pistacia lentiscus* fixed oil is poorly studied and it needs more valorization. Hence, we conducted investigations to valorize this oil through the study of its biochemical and biological properties. The biochemical characterization of *Pistacia lentiscus* fixed oil showed that it contains an important amount of unsaturated fatty acids, tocopherols and carotenoids. It has also a high antioxidant activity that reflects it richness in antioxidants. The antimicrobial and wound healing activities and cytotoxicity of this oil were tested. The oil showed fungicidal and antimicrobial effects, especially against dermatophytes strains, a cytotoxicity against BHK21 cells, and an important wound healing effect. These findings are consistent with its traditional uses. Such a study highlights the nutritional and pharmaceutical value of this NWFP. This valorization enhances the possibility of the forest species conservation.

Impact of bark and foliage harvesting on fruit production of the multipurpose tree species, *Afzelia africana* in Burkina Faso. Nacoulma, B. (*University of Ouagadougou, Burkina Faso; nblandine@gmail.com*), Lykke, A. (*Aarhus University, Denmark; aml@dmu.dk*), Sinsin, B. (*University of Abomey-Calavi, Benin; bsinsin@gmail.com*), Thiombiano, A. (*University of Ouagadougou, Burkina Faso; adjima_thiombiano@yahoo.fr*).

In sub-Saharan Africa, the need to meet daily livelihood has resulted in uncontrolled exploitation of bark and leaves of tree species for medicinal uses and livestock feeding. However, overharvesting of bark and foliage of valuable trees species is compromising the fruit production of the species and threatening their reproduction. This study evaluates the impact of debarking and pruning on the fruit production performance of *Afzelia africana* in Burkina Faso. We compared fruits and seeds borne at different harvest intensities on the base of field investigation data. Data of fruit yields were randomly collected from 91 trees with a history of very severe, severe, weak and no-harvest intensities. Our results revealed that severe pruned trees as well as a weak debarked trees bore 50% to 70% lower and heavier fruits, and seeds than none-harvested trees. No significant difference was detected between non-pruned and weak-pruned trees. Trees in very severe pruning conditions do not produce fruits. The debarking effect is size-specific, whereas the pruning effect is not. Weak-debarked trees with small diameter bore seven times lower fruits yield than non-debarked trees. Overall, bark, severe and very-severe foliage pruning is negatively affecting *Afzelia africana* fruit production and should be completely prohibited. Only weak pruning should be allowed.

Non-wood forest products in a context of sustainable forest management: case studies in Ukraine, Russia and Sweden. Nataliya, S., Elbakidze, M., Angelstam, P. (*Swedish University of Agricultural Sciences, Sweden; Natalie.Stryamets@slu.se; marine.elbakidze@slu.se*; *per.angelstam@slu.se*).

The role of non-wood forest products (NWFPs) for local livelihoods in forested regions differs in time and space. During recent decades, NWFPs have attracted considerable interest as an important component of sustainable forest management. The aim of this study was to analyse the use and the governance of NWFPs in different governance context and economic conditions. Three case studies in three countries (Ukraine, Sweden and Russia) have been chosen. These case studies are characterized by a long history of forest resource use and free accesses to NWFPs collection, and represent different governance systems. 150 qualitative interviews with local stakeholders, forest managers and local governmental authorities were done. Data collected included: (1) management rules for NWFPs collection; (2) stakeholders' rights regarding use of NWFPs; (3) stakeholders' opportunities to influence the forest management; (3) traditional and current practices of NWFPs use. Results showed that NWFPs use was still active and important in three countries. We discussed different approaches to include stakeholders and their perspectives in natural resource planning and management towards sustainable forest management.

The economic consumptive value of forests: evidence from the wet and dry forest zones of Ghana. Obiri, B.D. (*Forestry Research Institute of Ghana, Ghana; bdobiri@yahoo.com*), Treue, T. (*University of Copenhagen, Denmark; ttr@ifro.ku.dk*), Obeng, E. (*University of Missouri, USA; amadanso@yahoo.co.uk*), Marfo, E., Cobbinah, J., Nutakor, E., Damnyag, L. (*Forestry Research Institute of Ghana, Ghana; emarfo@csir-forig.org.gh*; *jcobbinah@csir-forig.org.gh; enutakor@csir-forig.org.gh; ldamnyag@csir-forig.org.gh*).

The magnitude of forests' contribution to rural household food and health security is hardly quantified in Ghana. Consequently, forest based interventions are skewed towards commercial timber production even on small holdings. This paper estimates the economic significance of the food/nutritive (including medicinal) values of forests to households on the fringes of wet and dry forests in Ghana. Data gathered from quarterly questionnaire surveys of 600 rural households over one year was analyzed descriptively and quantitatively. Results indicate that households rely on forest resources mainly for subsistence and exploit these resources throughout the year. Households in the middle income class exploit forest resources more than those in the lower and upper classes. 49% and 52% of household forest collections in the Wet and Dry Forest Zones respectively comprise game, snails, mushroom, fruits, nuts, vegetables, root tubers and medicines with a value of $7,500 and $8,000 representing 47% and 24% of estimated household annual forest income in the Wet and Dry Forest Zones respectively. The paper concludes that the dietary and medicinal values of forests to rural household welfare cannot be undervalued. Pro-poor forest based interventions need to be targeted at multiple products that satisfy households' cash, nutrition and health needs.

Sago forest management and investment opportunities in special autonomy eria in West Papua, Indonesia. Salosa, S. (*Forest Research Institute of Manokwari, West Papua, Indonesia; susan_3sa@yahoo.com*), Tatik, R. (*Forest Research and Development Agency, Indonesia; rostiwati.silvi@yahoo.com*).

Over half of the world's sago potential lies in West Papua within an area of about one million ha. Unfortunately, sago has not been fully utilized yet either for food, for energy or for general needs of local communities. Mostly, local people depend on rice imported from outside Papua Island. Some Papuans, especially those living in low-lying and coastal areas prefer to consume sago from planted sago trees because of high density of its content and its taste, but the numbers of users have decreased recently. On the other hand, wild sago has less contribution on local people's lives because the yield is not significant enough for food. It might occur as a result of lack of maintenance and the remoteness of sago's hamlet. Sago forest management faces some problems such as difficult topographic conditions, customary rights and adequacy of labor. The local government requires investors to prioritize the local community's welfare as a condition of developing the sago industry in Papua. In the special autonomy era in Indonesia, it is a must to get local communities involved in the entire process of sago exploitation and management. The investors have to give the appropriate compensation for the customary owners.

Natural resources for human health: the reliance on medicinal plants for health care in rural Nepal. Thorsen, R., Pouliot, M. (*University of Copenhagen, Denmark; rith@ifro.ku.dk*; *mapo@ifro.ku.dk*).

Traditional medicine is argued to play an important role in health care in developing countries. Very little research has quantified the household level reliance on medicinal plants or determinants of a choice of health care. Understanding the reliance of medicinal plants at different levels is critical for the development of both efficient environmental and health policies. This study quantifies traditional medicine reliance and the determinants of choices of health care. Different forms of traditional medicine are defined, encompassing both formal (e.g. ayurvedic medicine) and informal (e.g. home treatment with medicinal plants). Structured household surveys (n=785) were conducted in four sites of rural/peri-urban Nepal in 2012 to collect data on household assets, treatment seeking behavior and knowledge and collection practices relating to medicinal plants. Results suggest that reliance on traditional medicine is limited in rural Nepal, and that the most common form of traditional treatment is self-treatment with medicinal plants which constituted 10% of the total number of treatments carried out. Household location, socio-economic characteristics and medicinal plant knowledge are shown to be important determinants of medicinal plant consumption in rural Nepal, and those are discussed in the light of environmental and health policy recommendations.

A-04 Resilience and Identity with urban forests: A landscape system approach

Organizers: Wybe Kuitert (Seoul National University, Republic of Korea), Cheng Wang (Chinese Academy of Forestry), Giovanni Sanesi (University of Bari, Italy) & Amila Brajic (FOPER-University of Sarajevo, Bosnia-Herzegovina)

Greenspace infrastructure and public perception of representative country parks in Beijing, China. Gong, L., Xu, C. (*Beijing Forestry University, China; lan.gong86@gmail.com; cyxu@bjfu.edu.cn*), Qi, Y. (*Southern University, USA; yadong.qi@gmail.com*).

Rising urbanization and the human population is taking its toll on the availability of urban greenspaces in cities. To provide places for people to enjoy outdoor recreation and experience nature, the city of Beijing started its massive "country park circle" project located between the fourth and fifth Ring Roads in 2007. To further understand the structure and functions of this new establishment, we selected thirty country parks resulting from the project and analyzed their green infrastructure characteristics including species composition, richness, diversity, uniformity, tree height, DBH, density, and canopy diameter from 2010 to 2011. During the same period, we conducted an on-site public acceptance survey in eight selected country parks. The assessment shows that these parks were generally low in species richness and diversity and high in tree density. Among the survey results, the public preferred trees with large canopies, more available understory spaces for recreation, and trees with different characters such as fruit and flower trees. The greenspace infrastructure, public perception, and associated management strategies are discussed. The results provide baseline information useful to better understanding and future management of these country parks in the city of Beijing.

Water management for urban forestry: a case study on urban parks in Seoul. Hu, X. (*Seoul National University, Republic of Korea; huxiaohuan1989@gmail.com*).

Restoring the forests and other green spaces in urban areas is a pragmatic and artistic way to redesign and transform our unnatural modern cities into ecological and sustainable ones. However, the cost of natural resource consumption for such transformations still lacks deserved attention, which definitely will raise queries on the sustainability of these transformations. This study, based on field research on 12 urban parks in Seoul in South Korea, is trying to offer a new practical method to move us out of the dilemma by shedding light on the new water management paradigm: combining water footprint analysis with rainwater harvesting. This research, using GIS and water footprint analysis, estimated the annual fresh water consumption of several Seoul urban parks respectively, and the related rainwater resource that could be potentially utilized, taking the urban park's surrounding landscape into consideration. This study determined that in order to maintain urban parks' eco-services (including urban forest) for the public, considerable fresh water resources (varied with park type and size) has to be squeezed from other purposes; the recent urban water management neglected bountiful rainwater resource, which could be used in a cost-effective way for urban greening.

Determination and estimation of temporal changes in land cover in northern forest of Istanbul, Turkey. İnan, M., Yurtseven, H. Eken, M. (*Istanbul University, Turkey; inan@istanbul.edu.tr*; *huseyiny@istanbul.edu.tr*; *melisaeken@gmail.com*).

As a bridge of Asia to Europe, Istanbul is a developing city which attracts migrants from surrounding cities. This migration and development have caused a real affective pressure on its forests. As a result, rapid changes in forest lands have occurred. In this

study, the changes occurring to forest cover and other land use forms in northern forest of İstanbul were determined by the post classification comparison change detection method. For this purpose, standard topographic maps and forest management maps with 1/25 000 scale, 1987 Landsat TM and 2006 Landsat ETM+ and 2013 Landsat OLI multispectral satellite images were evaluated as data for this study. The changes of forest cover and other land use forms in northern forest of Istanbul about 30 year period were investigated. After analysing the results of forest cover changes, the potantial situation of the northern forest cover by the year of 2025 were predicted. Consequently, planning interventions, incentives and constraints, such as reserve areas and infrastructural changes that may alter the course of development in the change prediction process, were suggested for the northern forest of Istanbul.

Long-term landform transformations in a suburban forest using aerial photographs and digital elevation models generated from historical topographic maps. Itaya, A.T. (*Mie University, Japan; itaya@bio.mie-u.ac.jp*).

We quantitatively examined the long-term landform transformation in a hilly area using aerial photographs and digital elevation models (DEMs) generated from historical topographic maps. Slopes and water features such as channels and drainage basins were identified using these DEMs. These features, coupled with elevation data, were compared over time. Forest decreased by approximately 50% in the 2000s compared with the 1960s. Although the elevation change has increased in recent years, there are equal negative and positive changes over the observation period. A recent development was a flattening of the terrain. Many water channels were lost, and they have been filled in later years whereas many of the boundaries of drainage basins, which would show as ridges, have been excavated. There were small landform transformations until the 1960s, after which there were huge landform transformations linked to housing developments. As a result, although aerial photographs and satellite images have been used in preference to historical topographic maps in the past, we found that the latter also are useful for sustainable land management within the traditional agricultural landscape and other conservation areas.

Perceived restorativeness of different urban green typologies of two cities in Italy. Lafortezza, R., Sanesi, G. (*University of Bari Aldo Moro, Italy; raffaele.lafortezza@uniba.it*; *giovanni.sanesi@uniba.it*), Carrus, G. (*University of Roma Tre, Italy; carrus@uniroma3.it*), Colangelo, G. (*University of Bari Aldo Moro, Italy; giuseppe.colangelo@uniba.it*), Scopelliti, M. (*Interuniversity Research Centre on Environmental Psychology (CIRPA), Italy; m.scopelliti@lumsa.it*), Semenzato, P. (*University of Padua, Italy; Paolo.Semenzato@unipd.it*).

Green spaces have positive effects on human well-being and quality of life in cities. So far, studies in this field mainly compared preferences for, and outcomes of contact with, natural vs. built environments. Less attention has been given to the study of the psychological effects of contact with green spaces differing in their degree of naturalness. This paper thus aims at understanding the relation between ecological (e.g., level of naturalness) and psychological factors (e.g., perceived restorativeness) in shaping evaluations of different urban and peri-urban green spaces. Five different typologies of green space have been identified in the city of Bari (southern Italy) and Padua (northern Italy), ranging from minimum (i.e., high level of man-made elements) to maximum levels of naturalness (i.e., low level of man-made elements). A set of pictures of the different urban green space typologies were shown to fifty undergraduate students of each city, and then measures of perceived restorativeness were taken. Results show that perceived restorativeness is the highest in peri-urban green spaces, and increases significantly as a function of the level of naturalness.

The effect of the mega-flood disaster on tree species diversity in Bangkok metropolis and suburban, Thailand. Leksungnoen, N., Eidthong, W. (*Kasetsart University, Thailand; ffornsl@ku.ac.th*; *ffforwce@ku.ac.th*).

According to the mega-flood disaster in Thailand in 2011, tree species in Bangkok metropolis and suburban areas were entirely inventoried after standing water had been present for 2 months. There were 386 species in 60 families of tree species before flooding. After mega-flood period, all trees were classified into 3 groups including (1) flood intolerant (70 species) indicated by more than a 50% fatality rate of all trees in each species (2) medium flood tolerant (288 species) indicated by less than 50% fatality rate of all trees in each species, and (3) flood tolerant (29 species) which did not show any sign of damage. Native habitat appears to correlate with flood tolerance. Most flood intolerant tree species were naturally distributed along the highland well-drained soil. Thus, planting those species in urban areas located in lowland-shallow and muddy soil caused the sensitivity for flooding or other stress environments. Flood tolerant tree species are mostly native to riparian habitats, resulting in less vulnerability to flood stress. Therefore, the selection of suitable tree species to plant in urban areas should be made wisely in order to prevent them from damage by environmental disaster.

Old growth urban forests: synthetic research methodology and historical continuity management. Loeb, R. (*Pennsylvania State University, USA; RXL5@PSU.EDU*).

Old growth urban forests developed in cities around the earth with human actions that have changed arboreal composition and forest dynamics. Reversing impending losses of species diversity and forest structure requires synthetic historical ecology research to determine past species composition and environmental conditions in order to restore the historical continuity of the forests. Synthetic historical ecology research has two methodologies: historical species diversity and forest remeasurement. Historical species diversity research utilizes paleopalynology, witness tree records, and early floras to determine the species present as the old growth urban forest developed. Forest remeasurement provides information on changes in the forest layers which is essential to an understanding of long-term forest dynamics. Plans for historical continuity restoration projects are based on the record of forest changes revealed by the synthetic historical ecology research. Beyond plantings to restore species diversity, efforts must address disturbances such as invasive species, deer browsing, and human trampling that threaten plantings and spontaneous regeneration which eventually leads to loss of the entire forest. Government agencies cannot do the restoration work alone. Instead partnerships of landowners, government, universities, and community neighbors must apply adaptive management to restore old growth urban forests.

Improving urban forest management using remote sensing technologies along major transport corridors in Sydney, Australia. Wang, M., Merrick, J., Chang, H. (*Macquarie University, Australia; mingzhu.wang@students.mq.edu.au*; *john.merrick@mq.edu.au*; *michael.chang@mq.edu.au*).

With global warming and extensive urbanization, it is essential to refine urban forest management models for larger areas, which retain the capacity for detailed monitoring of forest variability at very small, local levels. In Sydney, the effect of urban forest on surrounding areas is not clearly documented. This study aims to investigate trees along two long-established transport corridors in the Sydney Metropolitan Area, using light detection and ranging (LiDAR) and Hyperspectral Imaging sensors. Integrating the two remote sensing technologies permitted rapid assessment of tree features including diversity of tree species, overall distributions and canopy parameters, even in small, inaccessible areas. Incorporating the same data in seasonal solar radiation models allowed shading analysis, which demonstrated the local variation of received radiation in the presence of trees and the respective contributions of evergreen and deciduous species. The shading impacts were significantly related to adjacent forest features. These studies highlighted the importance of trees around buildings and larger, taller trees that provided extensive shading. Remote sensing technologies can be used to indicate ways of planning shading and improving management and connectivity of all urban forest sub-systems. The basic management framework also allows inclusion of diverse data from multiple resources to enhance government decision-making.

Posters

Spatial distribution of green spaces in the urban area of Ponta Grossa (Paraná-Brazil). Carvalho, S., Queiroz, D. (*Ponta Grossa State University, Brazil; silviameri@brturbo.com.br*; *dulcinah@gmail.com*).

Green urbanism enables people of urban areas to profit from nature benefits as well as mitigates the side effects resulting from the urbanization proccess. For effective planning is needed to identify the distribution of green spaces in urban areas. The city of Ponta Grossa, located in southern Brazil, has experienced an intense urbanization process in recent years and this study aimed to analyze the spatial distribution of green spaces, represented by vegetation cover, open spaces and green areas in the urban area. We used Ikonos satellite images (2004) and geographic information systems (GIS). In this period, the urban area corresponded to 172.59 km^2 and had 266 683 inhabitants. It was found that the vegetation cover occupies 49% of the total urban area, with an index of 319.3 m^2/inhabitant. The spaces occupied 2.5% spread over 230 spaces of with 132 sports fields, 63 squares, four parks, six cemeteries, and eight leisure clubs, with an index of 16.4 m^2/inhabitant. Green areas occupied 2% distributed in 102 spaces with index 13 m^2/inhabitant per capita. Although the numerical results for each category are positive indicators proposed before, the distribution compromises their effectiveness.

Urban Forestry Changes in the Western U.S. Kuhns, M. (*Utah State University, USA; mike.kuhns@usu.edu*).

Urban forestry programs have undergone considerable change in the last few years due to a number of factors. In the western United States urban forestry is changing due to funding shortages, demographic changes, and other factors. In this presentation we explore the effects of these changes by reviewing the results of surveys of urban forestry experts (mostly professionals) in the western United States on the state of urban/community forestry programs in their area. This survey was first conducted 15 years ago and then was repeated in early 2013. We found that budget issues have caused considerable change in recent years, but some programs weathered those cuts better than others. As we found 15 years ago, a number of the changes going on in the region, like population increases in certain areas, are considered by urban forestry experts to be both positive and negative.

Effects of Ghanaian urbanization on urban forests and peri-urban community livelihoods. Opuni-Frimpong, N., Frimpong, E.O. (*Forestry Research Institute of Ghana, Ghana; nana.opunif@gmail.com*; *eopunifr@mtu.edu*).

Typical of any developing economy, Ghana is faced with the challenges associated with urbanization, especially those affecting the environment and peri-urban community livelihoods. As the urban population expands, more peri-urban lands are needed for housing and office space at the expense of limited forest cover and sources of livelihood for the people. The peri-urban communities around the cities – who are usually poor and less educated – are left with very limited sources of livelihood. City planners usually earmark protected areas around wetlands/water bodies and nature reserves to protect important species for recreation and conservation. However, our land tenure system gives sole ownership of community lands to the traditional rulers who are selling almost all the lands available to the highest bidders with limited regard for conservation of the environment. These communities are usually made up of peasant farmers, very small scale sole proprietors and a large pool of unemployed youth who previously depended on the land for their livelihood. The high national deforestation rate compounded by the depletion of limited urban forests may be contributing significantly to climate change. This paper discusses the impact of urbanization and depleting urban forest on livelihood of peri-urban communities and sustainable development.

A-05 Challenges and opportunities in forest management and utilization in rapidly changing Asian economies

Organizers: Ajith Chandran, Lianzhen Xu, Weiye Wang & Monika Singh (University of British Columbia, Canada)

Communication challenges in joint forest management in India: perceptions of senior Indian forest officers. Chandran, A. (*University of British Columbia, Canada; ajith.chandran@alumni.ubc.ca*).

The Indian Forest Department has been implementing joint forest management for the past two decades with considerable success in improving the livelihood of rural communities by regenerating forests. With an estimated 70,000 village institutions co-managing forest with local forest department, communication between the department and the community has been an

important element. Analysis of a survey of 52 senior forest service officers conducted across India has reiterated the importance of communication in forest management in general and its crucial role in joint forest management in particular. The survey conducted in 2012 looked at the emerging issues specifically in the backdrop of social and technological changes in rural India and the probable challenges that need to be addressed to improve governance and citizen role. Despite the common belief about the forest department as a monolith organisation, the perceptions among the senior forest department are varied and progressive. The suggestions from these officers, heading senior positions in the state and central departments, give directions on how future forest management strategies in India may evolve.

Creating both conflicts and solution between customary and legislative regulation – case of China. Dong, J. (*Fujian Agriculture and Forestry University, China; dsz.djy@163.com*), Liu, J. (*Renmin University of China, China; liujinlong@ruc.edu.cn*).

With the implementation of collective forest tenure reform since 2003 in China, many conflicts around forest tenure have sprung up, severely hindering the reform and social stability. By constructing an analytical framework of the country, society, and mafia-like gangs, this paper analyzed a conflict around a transfer of collective forestland, and revealed the checks and balances present in the system. Collective farmers often have an impact on local governments through continual appeals and petitions to force them to take beneficial actions. Local governments, who were sympathetic to farmers' experiences and also knew legality of transfer, usually play the role of coordinator rather than arbitrator. Forestry investors have been found to use unofficial measures, such as employing mafia-like gangs to reach their end goal; and in some cases, local governments tolerated these behaviors as a way to end the conflict. As a result, all three parties compromised to realize equilibrium, and the conflict was resolved. The study showed that while China was transforming from the traditional rule of right to modern rule of laws, the development and solution of collective conflicts of forest tenure were accompanied with the integration and conflict between formal and informal institutions, legislation and custom.

ASEAN-Korea Environmental Cooperation Project as a successful model of regional cooperation for human resource development and local community improvement. Kang, H., Lee, P., Park, J. (*Seoul National University, Republic of Korea; silvi@chol.com; shsnu337@gmail.com*; *parkjeongho82@gmail.com*), Bang, M. (*University for Peace, Costa Rica; bangmiin@gmail.com*).

Upon the degraded forest ecosystems and thus declined livelihood of local people across Asian countries, it is essential to develop human resources to restore these situations in collaboration with local people. ASEAN-Korea Environmental Cooperation Project (AKECOP), launched in 2000 based on the ASEAN-Korea Summit, has focused on developing human resources to deal with environmental issues in Southeast Asia's tropical forest regions. AKECOP has organized and implemented a range of graduate courses, short-term training courses, training workshops and conferences for local researchers in the ASEAN Member States (AMS). The training programs have focused on sharing of technology and information among AMS as well as between AMS and Korea. The programs have enhanced the capacity of researchers and institutions in managing AMS's degraded terrestrial and mangrove forest ecosystems. Some programs such as agroforestry practice have focused on sustainable income and food security in collaboration between the trained local researchers and local community. Based upon the successful experience of AKECOP, further projects for improving livelihood of local people in Asian countries as well as AMS are expected to be developed. To do so, it is required for AKECOP to cooperate with various international organizations including Asian Forest Cooperation Organization (AFoCO).

Participatory approach to reduce deforestation and forest degradation: a case study from Houykhing Village Cluster, Laung Prabang Province of Lao PDR. Paudel, S. (*University of British Columbia, Canada; shyam.paudel@gmail.com*), Hiratsuka, M. (*Mitsubishi UFJ Research and Consulting, Japan; hiratsuka@murc.jp*), Masahiro, A. (*Waseda University, Japan; masahiro_amano@waseda.jp*).

Lao People's Democratic Republic (PDR) has the highest proportion of forest in Southeast Asia. Forests have been an essential part of the national economy and rural livelihoods in Lao PDR. However, the forest cover has declined rapidly since last few decades from 49% coverage in 1982 to 41% in 2002. A socio-economic study was carried out to assess the driver of deforestation and to develop strategies to reduce deforestation and forest degradation. Various participatory tools were used to gather information from the village. The study found that forest concession, shifting cultivation, forest encroachment for agricultural land expansion, uncontrolled livestock grazing in forests and fuel wood based energy for cooking and heating were the major drivers of deforestation. After assessing the current situation, it was concluded that the complete abolishment of the current slash and burn practice was not a feasible option. A phase-wise and gradual approach has been recommended with the focus to improve the livelihood condition of people by improving the current agricultural practices and developing an agricultural market system. In the long run, the study suggested encouraging villagers to adopt permanent agriculture system with intensive farming by applying scientific land use and management practices.

Increasing tree cover in degrading landscapes: integration and intensification of smallholder forest culture in the Alutilla Valley, Matiranga, Bangladesh. Rahman, S. (*University of Copenhagen, Denmark; sumonsociology@yahoo.com*), Rahman, M. (*University of Rajshahi, Bangladesh; mfrahman@yahoo.com*), Sunderland, T. (*Center for International Forestry Research (CIFOR), Indonesia; t.sunderland@cgiar.org*).

Research was conducted in Alutilla Valley in eastern Bangladesh to identify the nature of existing agroforestry systems and to identify potential agroforestry models that could ameliorate currently degrading forest resources Data were collected through farmer participatory research and a structured quarterly survey in two villages. Qualitative and supplementary quantitative analysis methods were used to assess the financial potential of agroforestry systems. Various patterns of agroforestry exist in the study site, but all have two common principles, namely integration with agriculture and multi-functionality. Two agroforestry models

suitable for adoption by farmers have been identified. Multi-strata agroforestry, based on a fruit and timber tree canopy with vegetables and tuber species in the understorey, can be practiced in the shifting cultivation fields near settlements. Fruit and timber tree-based conservation agroforestry is well suited to manage large-scale biologically depleted landscapes. Both systems yield early financial returns, facilitating the change from shifting cultivation to multi-strata agroforestry or fruit and tree-based conservation agroforestry.

Changing the forest landscape in China. Wang, G., Innes, J. (*University of British Columba, Canada; guangyu.wang@ubc.ca*; *john.innes@ubc.ca*), Zhuang, A., Miao, G. (*State Forestry Administration, China; zhuangism@hotmail.com*; *mikebj312@gmail.com*).

Chinese forests and forestry have been experiencing a dramatic change in the past fifteen years. Since 1998, after the devastating floods swept through China, the government introduced several forest development projects known as the six key forestry programs. These have now expanded to eight programs, with more than $500 billion invested in the forestry sector. Through the implementation of forest tenure reforms, taxation and investment systems, payments for ecosystem services, and China's WTO entry, China's forestry has not only played an important role in relation to domestic needs, but has also shaped the flow of global wood trade. We used forest inventory results, 15 years of national and regional statistical data, and a questionnaire survey to analyze the effectiveness of the major forest-related programs and policy changes. Commercial forests, particularly short-rotation forests, have increased as a result of the tenure reform, and the area of ecological forest has increased through five of the key forest programs and through ecological compensation. Interactions between forest policies and programs have not always been positive. A systematic design and approach are badly needed for the development of future policies and programs. The lessons learned from China may benefit other countries in transition.

Posters

Emerging role of jurisprudence in shaping forest management in India. Singh, M. (*University of British Columbia, Canada; monika.singh@alumni.ubc.ca*).

Increasingly the Indian judiciary is directing the bureaucracy for forest lands' management. This change can be partly attributed to different perspectives on people's rights and access to forest lands and resources. On one hand the State governments combine with the corporate bodies to exploit the rich resources located in forest areas. On the other, the tribal communities, dependent on forests, oppose the exploitation and demand their traditional rights over the forest resources. This paper examines five judgments pronounced in India dealing with access and rights of tribal communities over forest lands they have traditionally used. Using content analysis, I examine the situation from the jurisprudence point of view. I found the basis of the judgments were related to the environment or religion, and not based on ensuring people's rights. Despite the Forest Rights Act, made to undo this historical injustice, factors other than people's rights prevail. I conclude that jurisprudence does not necessarily lead to justice or undoing the injustice. It is rather a tool that can be used for making decisions; and it can be used for having an outcome of justice if used correctly. In forest management it is being used to fight for peoples' rights over their traditional and cultural use of resources.

Community involvement in forest management (CIFMs) to improve livelihoods in Indonesia. Widyati, E. (*Forestry Research & Development Agency (FORDA), Indonesia; enny_widyati@yahoo.com*).

In Indonesia forests are managed by government, hence local people have very limited access to utilize the resource as a livelihood. Consequently, the communities are generally categorized as indigent. These situations lead to forest insecurity such as incidences of timber stealing, species devastation, land grabbing and fire. Community involvement in forest management (CIFM) is required both to improve community welfare and forest security. This paper will discuss some implemented CIFMs in Indonesia. Data on community income are calculated based on field studies, interviews, statistical data from the local government, and related published studies and reports. Studies were carried out in (East and Central) Java, Central Kalimantan and Jambi Province. Results showed that CIFMs in Indonesia were very site specific. In Java CIFMs was conducted by Perhutani, a government-owned company engaged contiguous-forest community. This activity increased forest security due to existing-voluntary forest guard in the society. CIFM in Central Kalimantan was piloted by the Watershed Management Unit which involved nearby transmigrants. This action improved the rehabilitation success of peat land. Whereas in Jambi CIFM was directed by the Forestry Service, and succeeded in Dragon Blood rattan preservation. The communities equally increased their income as well as improved their food, energy and water supplies.

Discourse strategy and action option: the natural reserve and peasants under the fishing and grazing ban policy. Zhang, Y., Yuan, M., Liu, J. (*Renmin University of China, China; zhangyiwen@ruc.edu.cn*; *foreverjane2006@126.com*; *liujinlong_jl@hotmail.com*).

This paper examines the strategies and actions of peasants and natural reserve managers when they are in conflict under the fishing and grazing ban policy, trying to understand how both sides use different discourse resources to uphold their interests. This research uses the actor-oriented approach and is based on the survey data acquired by in-depth interviews and semi-structural questionnaires in M Village in Northwest China. The finding is that peasants make use of moral economics discourse in fighting for their basic livelihood and adopt two strategies: direct rebellions including grazing and fishing without permission, and exaggerating the influence of the fishing and grazing ban policy to better bargain with reserve managers. Meanwhile, the reserve managers rest on the environmental protection discourse supported by laws and state authority. They actively participate in the policy formulation, implementation and monitoring process and emphasize the importance of policies to guarantee their power and pursue their own interests. Due to the lack of institutional safeguards, the peasants have an inferior status and cannot participate in the policy-making process. Their self-organized ability of using natural resources sustainably is ignored.

A-06 Forest-dependent community development

Organizer: Tuija Sievanen (Finnish Forest Research Institute, Finland)

Contribution of gum and resin commercialization to rural livelihood in the drylands of Ethiopia and Sudan. Abtew, A., Pretzsch, J. (*Dresden University of Technology, Germany; asmamawalemu@yahoo.com*; *pretzsch@forst.tu-dresden.de*), Secco, L. (*Universty of Padova, Italy; laura.secco@unipd.it*), Elfaki, T.E.M. (*University of Kordofan, Sudan; tarigcom@gmail.com*).

The present study investigates the extent to which the economic gains derived from gums and resins commercialization impact rural livelihood improvement under different resource management regimes in the drylands of Ethiopia and Sudan. Primary data was collected through semi-structured interview from 240 randomly selected smallholder producers in four regions with different resource management regimes. The survey was complemented by secondary data, group discussions and key informant interview. In the four regions, gum and resin income contribute to 15–28% of the smallholder producers' household income. The absolute income was positively correlated with resource management regime and commercialization level. The absolute income was higher from the cultivated resources on private lands, followed by regulated access of wild resources. In open access resources the producers' income was the lowest although accessed by the poor and women. However, dependence on gum and resin income was higher in open access resource area. Households' socioeconomic characteristics, resource access, production and marketing variables determining income from gum and resin were identified and their variation across the cases discussed. Overall, gum and resin commercialization in the study areas bear potential poverty alleviation roles through their safety net role and helping producers to move out of poverty.

Indigenous associations in the Peruvian Amazon: the comuneros' perspectives. Fernandez, A.V., Innes, J., Kozak, R. (*University of British Columbia, Canada; ecomundo.andrea@gmail.com*; *john.innes@ubc.ca; rob.kozak@ubc.ca*).

Peruvian Amazonian indigenous peoples are experiencing unprecedented changes as a result of the type of development currently being imposed on Peru (based on the extraction of natural resources). Indigenous Community-Based Associations (ICBAs) have emerged as a strategy for indigenous peoples to make their voices heard and to be able to decide on their own future. The recently adopted Peruvian law (29785) concerning the indigenous peoples' right to prior consultation, gives these ICBAs an important role/responsibility to act as an intermediary between the state and the indigenous communities, explicitly stating that "the indigenous peoples will participate in the processes of consultation through their associations that represent them." Through in-depth interviews and innovative methods of collective construction of data from the perspective of community members, this study (1) analyzes the desirable characteristics of the ICBAs' representatives to effectively address challenges and achieve their communities' objectives, and (2) determines recommendations to improve this representation model. Major findings point to the necessity of collectively identifying objectives that are shared between the communities and their ICBAs. The importance of frequent visits to their associate communities, and listening skills on the part of ICBA representatives also emerged as a common theme.

Conservation by people for people: impacts of community-NGO partnership on forest conservation and livelihood of riparian people. Gbedomon, R., Floquet, A., Kakai, R.G., Roch, M. (*University of Abomey-Calavi, Benin; gbedomon@gmail.com*; *anneb.floquet@gmail.com*; *glele.romain@gmail.com*; *rochl_mongbo@yahoo.fr*).

During the last decades, numerous approaches of forest management involving local communities have emerged. Among them, the approach of community based forest management (CBFM) has been strongly recommended. However, the capabilities of local communities to sustainably manage forest resources and improve their livelihood remain debatable. Thus, advocators of CBFM have also recommended partnership between community and external institutions such as non-governmental organizations (NGOs). We investigated the functioning of this forest management approach and its impact on conservation and livelihood of riparian people. The study was conducted on the community forest of Tobé-Kpobidon in Benin using focus groups, forest inventory and income survey. Findings showed the significant involvement of community people through endogenous institutions and use of tradition as forest management tools. This scheme of forest management was found to be effective in forest conservation especially for endangered species. The model has also fostered strong linkage between forest resources and riparian people. Indeed, riparian people took up to 25% of their annual income from the forest. Unfortunately, the system's sustainability has some limitations that were mainly related to high financial dependency of endogenous institutions toward the NGO and the inequity in benefit sharing.

Community perceptions of environmental and socioeconomic benefits from forest: an exploration in four protected areas of Costa Rica. Murillo, S.M. (*National University of Costa Rica (UNA), Costa Rica; sergiomolina@una.cr*), Shreeve, K. (*Colorado State University, USA; kellys07@rams.colostate.edu*), Montopoli, L. (*Pennsylvania State University, USA; lam5630@psu.edu*), Fernández Otárola, M. (*University of Costa Rica (UCR), Costa Rica; maufero@gmail.com*).

In this study we explored the perceptions that inhabitants from nearby communities have on the environmental and socioeconomic benefits provided to them by forested protected areas (FPA). From November 2011 to April 2013 we interviewed members of 365 households in 12 communities around four FPA in central Costa Rica. With the aid of two ordinal logistic models, we assessed the likelihood for environmental or socioeconomic benefits being identified by local inhabitants. As expected, in both models the perception of environmental or socioeconomic benefits was significantly influenced in a positive manner by the relationship that inhabitants perceived they had with the FPA. An additional non-parametric analysis indicates that once the number of benefits evaluated within each category (i.e., environmental or socioeconomic) is controlled for, the percentage of perceived environmental benefits is significantly higher than perceived socioeconomic ones (76.8% vs. 54.2%; Wilcoxon Z=–10.17, df=1, p-value=0.001). These results offer evidence to argue that despite the increasing awareness that locals living around FPA might have about the benefits provided by these ecosystems, having and maintaining a proximate relationship between communities and the FPA is central to this perception and consequentially, to the long term existence and effectiveness of FPA.

Local stakeholder's assessment of community-based forest management and the potentials of REDD+. Peras, R., Pulhin, J. (*University of the Philippines Los Baños, Philippines; rjjperas@gmail.com*; *jpulhin@yahoo.com*), Inoue, M. (*University of Tokyo, Japan; mkinoue@fr.a.u-tokyo.ac.jp*).

The Philippines is one of the pioneers in adopting a participatory approach to forest management locally known as Community-Based Forest Management (CBFM). It became the national strategy for sustainable forest management and social justice in the uplands. For 18 years, it has gained prominence in terms of its impacts on the livelihood assets of the community. CBFM has likewise evolved to include global concerns of climate change and biodiversity conservation. REDD+, being the new mechanism that will address triple benefits, will have important implications on the process and potential outcomes of CBFM. Hence, this paper highlights local stakeholder's assessment of livelihood assets with CBFM and the potentials of REDD+ implementation in the future. Findings of the study revealed that CBFM implementation contributes largely to building capital assets of the people's organizations. Although improving financial capital remains a challenge; there is optimism both in the part of PO members and local institutions (DENR, LGU, NGO) that REDD+ can contribute in further enhancing the local communities' capital assets and the achievement of triple-benefit; and despite optimism, threats exist in terms of the likelihood that REDD+ can create enclosure that will limit livelihood opportunities; also threat of in-migration with improvement in economic activities.

Mining in the boreal forest – effects on reindeer populations and indigenous livelihoods and the use of community-based monitoring by Sámi reindeer herders in northern Sweden. Sandström, P. (*Swedish University of Agricultural Sciences, Sweden; per.sandstrom@slu.se*), Herrmann, T. (*Université de Montréal, Canada; thora.martina.herrmann@umontreal.ca*).

Mineral exploration and extraction are increasing in the northern boreal regions, and usually adversely affect habitat and populations of reindeer (*Rangifer tarandus*) which are an important means of subsistence economies for many indigenous people. This paper explores the effects of human disturbance with a special emphasis on mining development in forested landscapes and implications for reindeer husbandry and livelihoods of indigenous Sámi people in northern Sweden. Through our case study we illustrate how Sámi reindeer herders use GIS to gather and compile information about reindeer husbandry to better communicate impacts of mining on reindeer grazing areas. Our case presents novel methods for community-based environmental research and monitoring, applying landscape approaches to land use planning, which denotes the active engagement of community members in environmental assessment processes, generating community-oriented data for management decisions. Furthermore we illustrate indigenous peoples' engagement in collective actions towards the maintenance of traditional subsistence activities. Ultimately, our case study demonstrates how the incorporation of technology in form of a participatory GIS can lead to better communication and illustrate its role for empowerment of communities and strengthening of the democratic process.

How do you do access? Indigenes and forest resources in a conflict-affected Indian region. Sareen, S. (*University of Copenhagen, Denmark; sid@ifro.ku.dk*).

This paper examines who accesses forest resources in a conflict-affected Indian region and how. The analysis of how access to three forest resources is gained, maintained and controlled by different actors describes who has what powers and how these are exercised locally. This empirical study of forest-dependent indigenes makes two contributions. The first is to current forest governance debates. With reference to five study villages, it describes the functioning of indigenous forms of forest governance; the extent and nature of the state's presence in India's Jharkhand; the influence of regional elites; and how the pertinent national and state level policies appear in practice at the local level. Forest governance is highly heterogeneous locally, even as the larger political economic context is commonly disabling across villages and resources. The second is to Ribot and Peluso's (2003) theory of access. Their framework is applied to spatially limited points of access across multiple resources, sharpening the analytical value of its 'bundles of powers' conceptualisation. In a conflict-affected region where forest governance is characterised by variability rather than structure, the categories maintaining and controlling access sometimes overlap in ways that make their distinction analytically unrewarding, while gaining access can take on continuing significance.

Community based forest management, an experience that goes from the field work to the improvement of indigenous community's livelihood. Valera, A., Arroyo, M (*WWF, Peru; alipse.valera@wwfperu.org*; *me.arroyo@wwf.panda.org*).

Puerto Esperanza, an indigenous community located in Ucayali is the first one who directly manages its forests under Forest Stewardship Council (FSC) standards. The community hired a forest enterprise to log their timber, with which it has a partnership agreement as they has also identified a buyer who will pay a fair price for their timber. In order to ensure compliance with FSC standards, prevent and handle conflicts, negotiate contracts or agreements and to handle administrative procedures, the community elected and trained six indigenous supervisors. As a result of this process, what the community expects is to improve their livelihood through the sustainable management of their forests and sale of their timber. From previous experiences, their annual income related to timber logging was less than $20 000 per year, while this year they are about to receive around $150 000. The income from the sale of their timber will be wisely spent, as they have developed an investment plan for which they have prioritized their needs. These needs range from the sustainable management and maintenance of FSC certification to satisfied collective basic needs such as the establishment of a basic health care center and also to distribute it among the families.

A-07 The social outcomes of community forestry: What do we know and how do we know it?

Organizers: Susan Charnley (U.S. Forest Service) & Rebecca McLain (Portland State University, USA)

Social contracts and community forestry: how can we design forest policy and tenure arrangments to generate local benefits? Benner, J., Lertzman, K., Pinkerton, E. (*Simon Fraser University, Canada; jpb7@sfu.ca*; *lertzman@sfu.ca*; *epinkert@sfu.ca*).

We examine the forest tenure system in British Columbia, Canada and evaluate recent attempts to create local benefits through community-based forest tenures. We ask whether community forest agreements (CFA) provide more local benefits than various other tenure arrangements. Additionally, we look at how our indicators of local benefits have been affected by major changes in policy related to the historical social contract that positions public forests as a benefit for local communities. We evaluate these questions through qualitative research and by conducting a quantitative fibre flow analysis using a large time-series dataset. Our analysis shows that indicators of local benefits were not strongly affected by policy changes in 2003, suggesting that broader fibre flow trends mask perturbations felt at more local scales. Our analysis of forest tenures shows that CFAs do not necessarily meet all expectations in every community but, as a group, community forests perform equal to or better than all other types of tenures as measured by our indicators of local benefits. Despite this overall conclusion, however, large variation among individual CFAs is evident, highlighting the disparate strategies used by communities to promote local benefits, as well as the influence of heterogeneous forest products sectors and land bases.

The social outcomes of Mexican community forestry: community forest enterprises, territorial zoning, and social capital. Bray, D. (*Florida International University, USA; brayd@fiu.edu*), Duran, E. (*National Polytechnic Institute (CIIDIR-Oaxaca), Mexico; eduran3@hotmail.com*).

Mexican community forestry is characterized by the devolution of successively expanded property rights, especially timber rights, combined with community-level governance institutions that mobilize social capital and a supportive policy environment. One of the most successful of these regions is the Sierra Norte of Oaxaca (SNO) in southern Mexico. In this study, we examine three approaches to improving social outcomes of community forestry in the SNO region: (1) territorial zoning, (2) the organization of community forest enterprises (CFEs), and (3) collective action around the CFEs. Based on remote sensing and interviews in 36 communities, we show that (1) territorial zoning has enabled the establishment of clear community rules over land use, reducing conflict and providing incentives for conservation, (2) the CFEs have generated significant employment for rights holders, and (3) collective action around the CFEs is associated with high social capital indicators. The approach used in Mexican community forestry provides an institutional model for generating positive social outcomes from climate change adaptation and forest conservation efforts outside of forest carbon markets. Our study demonstrates that a combination of remote sensing, interviews, and the use of social indicators is a promising method for evaluating the social impacts of community forestry.

The social outcomes of community forestry in the STEWARD project area of West Africa: methods, results, challenges. Charnley, S. (*U.S. Forest Service, USA; charnleysusan@hotmail.com*), Polasky, S. (*Oregon State University, USA; Sophia.Polasky@oregonstate.edu*).

In this presentation we discuss methods, results, and challenges associated with monitoring the social effects of community forestry on the livelihoods of rural community residents in the Upper Guinean Tropical Forest of West Africa. Our monitoring work is being undertaken as part of an integrated forest conservation, climate change, and sustainable livelihoods project funded by the U.S. Agency for International Development. The project operates in two priority zones for biodiversity conservation located in the trans-boundary areas of three countries: Sierra Leone, Guinea, and Côte d'Ivoire. We use household surveys, key informant interviews, focus groups, and event diaries to monitor the social and economic impacts of community forests in eight communities, and compare our findings from the two zones. Methodological challenges include the difficulty in obtaining and using quantitative data to monitor key indicators, and a relatively short time horizon for evaluating impacts. Challenges to providing social and economic benefits include the ways in which community forests have been externally-imposed by project implementers, and the fact that they are preservation- rather than production-oriented. We discuss the implications of our findings for development organizations that seek to promote community forestry as a mechanism for sustainable forest management to improve people's livelihoods.

Changing scope of community-based forestry: analysis of 30 years of community forestry impacts in Nepal. Lamsal, R. (*Ministry of Forests and Soil Conservation, Nepal; ramplamsal@gmail.com*), Khanal, S. (*Kathmandu University, Nepal; sanjay@ku.edu.np*).

Nepal pioneered community forestry (CF) and has experience of over three decades of sustainable management of forests to address the needs and aspirations of the local community. Based on primary data, practical experience, and relevant literature, this study assesses what livelihood impacts have occurred, for whom, and how. It also highlights why livelihoods have changed over the last 30 years, the main lessons learned and some key changes required in CF. This study has shown several important areas of change and impressive achievements in improving forest conditions and biodiversity, increasing supply of forest products and environmental services, building the community capacity with inclusive community institutions, developing local ownership and leadership, incorporating gender, improving livelihood and promoting a multi-stakeholder approach. The implementation systems created are both robust and with some areas of emerging fragility, likely to undermine the achievements. Problems of elite dominancy, lack of accountability, political pressures and conflicts, marginalization of very poor forest dependent households and issues of equity still persist. Improvement in CF is considered necessary due to changes in priorities and perspectives, new opportunities, and lessons learned to fulfill the gaps and achieve the vision on forestry based prosperity.

The assessment of successful community forest management in Thailand. Sunthornhao, P., Hoamuangkaew, W. (*Kasetsart University, Thailand; fforpts@ku.ac.th*; *fforwph@ku.ac.th*).

The Successful Community Forest Management (SCFM) is a long-term participatory action research for 2011–2020, now ongoing for its third year. The objectives were to determine SCFM, and analyze change of socio-economic, non-timber forest products (NTFPs) utilization, community forest health and people's opinions. The stratified sampling method by forest types selected 20 community forests (CF) countrywide. The participatory create criteria and indicator was done before data collection. The study indicated most of people who participate in community forestry activities were males with an elementary education and an agricultural occupation. Their annual household income and expense were similar: US$ 1,515. The CF is their most important

NTFPs source; annually it provides an average of 72 species. The density, biomass, and species diversity changed between 2011–2013 of 2.96%, 2.44% and 2.35% respectively, moreover the average current carbon stock is 284.69 tCO2/ha. The result of SCFM indicated a good success level and change of –2.65 or –3.45%. However, an analysis of variance indicated SCFM for each forest type was not different.

The role of community based forest management on the livelihoods of traditional timber extractors in the Brazilian central Amazon. Waldhoff, P. (*Education, Science and Technology Institute of Amazonas (IFAM), Brazil; philippe.tim@gmail.com*), Vidal, E. (*University of São Paulo-ESALQ, Brazil; edson.vidal@usp.br*).

The possibilities of community based forest management are impressive. Of the total 290 million ha of the currently registered Brazilian public forests, half of it is held by communitarians. Community forestry has been considered as a strategy to reduce deforestation, to strengthen land tenure and to reduce poverty. Nevertheless, in some cases, projects achieve conservation of ecosystems more efficiently than livelihood improvement, or yet, eventually fail in respect to both expectations. In order to assess the outcomes of sustainable forest management on the local people livelihoods, we adapted the tool "Sustainable Livelihoods Framework". We selected two regions in Amazonas State, Brazil as case studies, where timber production has resulted in important income to local households. Data collecting was based on structured and semi structured interviews, applied directly to forest users, stakeholders and experts, as well as document analysis. Comparing traditional logging and legalized forest management has shown that the latter has not been an appropriate strategy for livelihood improvement. Despite achieving positive outcomes primarily related to the natural and human assets, the current model of community based forest management does not allow the empowerment of forest users across the whole process, causing their distance due to high bureaucracy and tax rates.

A-08 Small-scale and community forestry for people, biodiversity and ecosystem services

Organizers: John Herbohn (University of the Sunshine Coast, Australia), Gun Lidestav (Swedish University of Agricultural Sciences), Gary Kerr (UK Forestry Commission), Jessica Leahy (University of Maine, USA) & Christoph Hartebrodt (Forest Research Institute Baden-Württemberg, Germany)

Why bother to plant trees? The difficulties of legally harvesting small-scale community forests in the Philippines. Baynes, J. (*University of Queensland, Australia; j.baynes@uq.edu.au*), Herbohn, J. (*University of the Sunshine Coast, Australia; jherbohn@usc.edu.au*), Gregorio, N. (*University of Queensland, Australia; no.gregorio@gmail.com*).

Small-scale forestry in developing countries has been extensively researched from a viewpoint of conservation or reforestation. Sustainable harvesting and livelihood development have received less attention. Hence, this study of the difficulties associated with community-based timber harvesting and processing may provide guidance for other communities which have established forests and wish to use them for livelihood creation. We conducted a two year study into the legal, administrative and wood processing problems which Peoples Organisations (POs) in the Philippines must solve if they are to successfully harvest trees. We found that even with the cooperation of government agencies, the inventory, mapping and documentation requirements for legal harvesting are far beyond the capacity of typical POs to manage. This has led to perverse outcomes in which planted trees are illegally harvested or destroyed because they compete with agricultural land uses. In addition, we found that high log defect and consequent low lumber recovery rates may preclude further processing and value adding. However, community members considered that converting trees into lumber for domestic consumption was an acceptable outcome. The implication of this study for other situations is that well-meaning but complex harvesting legislaton may act as a disincentive to community-based forestry.

Attitude towards risk and production decision: an empirical analysis on French private forest owners. Brunette, M., Kéré, E. (*National Institute for Agricultural Research, (INRA), France; marielle.brunette@nancy.inra.fr*; *eric.kere@nancy.inra.fr*).

In this paper, we are interested in attitude towards risk of non-industrial private forest (NIPF) owners and the role of this attitude on harvesting decision. Indeed, risk aversion is known to be important when analysing forest management decisions (Marshall, 1987; Caulfield, 1988; Clarke and Reed, 1989; Gong, 1998; Uusivuori, 2002; Gong and Löfgren, 2003; Alvarez and Koskela, 2006) even if currently no study estimates such risk aversion. However, to our knowledge, no study deals with the role of this aversion on harvesting decisions. They prioritized the impact of risk averison on forest investments (Taylor and Forston, 1991; Kangas, 1994), on NIPF owners' consumption and production decisions (Koskela, 1989) and on the decision to replant or not after a clear cutting (Lien et al., 2007), among others. Consequently, using data from 350 French private forest owners, we estimate an average risk aversion coefficient for NIPF owner using a context-free measure borrowed from experimental economics. Then, we simultaneously estimate the determinant of risk aversion and harvesting decision. Variables like surface and forest revenue appear to be determinants in explaining risk aversion. In addition, risk aversion plays a positive and significant role on the forest owner's harvesting decision.

Family forest ownership research in the United States: past, present, and future. Butler, B. (*U.S. Forest Service, USA; bbutler01@fs.fed.us*), Butler, S., Hewes, J. (*University of Massachusetts Amherst, USA; sbutler@eco.umass.edu*; *jhewes@eco.umass.edu*).

Families and individuals own a plurality of forest land in the United States – 114 million ha (282 million acres). This group, collectively referred to as family forest owners, is as diverse as the land they own and continue to be the subject of much research on the threats they face, the benefits they provide, and their general characteristics. A systematic review of the peer-reviewed research literature related to family forest ownerships published since 2000 is being conducted. Coding of the 700+ articles includes: methods and analysis techniques employed; theoretical underpinning; geographic scope and resolution; and,

most importantly, the findings. Common threats investigated include: climate change; development; fire; markets; parcellation; and taxation. Solutions discussed in multiple sources include: ecosystem services; education; incentives; markets; policies; social marketing; and new/revised tax policies. The most frequent behaviors investigated are: afforestation/reforestation; fire hazard reduction; harvesting; other management activities; and recreation. Characteristics of family forest owners commonly discussed are owners': attitudes; awareness of options; demographics; motivations; and ownership objectives. While specific future directions are unknown, some intriguing ideas include: landowner dynamics; intra-familial dynamics; micro-targeting; social capital; panel studies; and evidence based practices.

Factors influencing choice of forest management strategy among small-scale private forest owners in Sweden. Eggers, J., Öhman, K., Lamas, T., Lind, T. (*Swedish University of Agricultural Sciences, Sweden; jeannette.eggers@slu.se*; *karin.ohman@slu.se*; *tomas.lamas@slu.se*; *Torgny.Lind@slu.se*).

Half of the productive forest area in Sweden is owned by small-scale, non-industrial private forest owners. Forestry legislation leaves management decisions largely to the forest owner. The forest management choices of private forest owners have a decisive impact on forest composition and structure, and thus on many ecosystem services that forests provide. However, little quantitative data exists on the forest management strategies of Swedish private forest owners. In this study, we analysed survey results in order to assess the share of different management strategies among private forest owners in Sweden. The results are further analysed by means of Chi-square tests in order to learn which factors are most relevant in determining what management strategies individual forest owners choose. It was found that soft factors such as importance of economic income from the forest, membership in a forest owner association, certification, as well as interest in and knowledge about forestry issues have a stronger impact on choice of strategy than most hard factors related to owner or property, such as gender and distance to the property. However, the most important factor was property size, which was in turn associated with importance of economic income from the forest and several other soft factors.

Understanding forest owners' propensity to the provision of ecosystem services: a survey in the Veneto Region of Italy. Gatto, P., Secco, L., Pettenella, D., Vidale, E., Abatangelo, C (*University of Padova, Italy; paola.gatto@unipd.it*; *laura.secco@unipd.it*; *davide.pettenella@unipd.it*; *enrico.vidale@unipd.it*; *chiara.abatangelo@unipd.it*).

Similar to other industrialised countries, Italian forests deliver, besides wood products, several ecosystem services (ES), mostly provided as public goods. The ES provision has been an important aspect in the Italian Legislative Framework since the early 1920s. However, up to now, the overall effect of the forest policies has been a slow and constant land abandonment, while a new demand of ES provision by forests has arisen. The paper presents the results of a survey undertaken in Veneto region (northeast Italy) to understand forest owners' (FO) propensity to participate in active forest management for ES supply. The survey covers 30% of the forestland; about 200 FOs were interviewed. The characteristics of the forest estates, the FOs' features and the forest management practices in place are examined together to the causal-effect relationships between forest management and ES provision. Few ES provision contracts were recorded and limited inclination towards ES supply was stated by FOs. Main reasons for this are the low awareness of ES potentials and the small size of forest estates. The paper also frames these results in the broader context of regional forest governance and suggests the implementation of 'network contracts' amongst FOs, as innovative tool for fostering ES provision.

Designing mixed species systems for community and smallholder forestry in the tropics to achieve multiple objectives. Herbohn, J. (*University of the Sunshine Coast, Australia; jherbohn@usc.edu.au*), Ngyuen, H., Lamb, D (*University of Queensland, Australia; h.nguyen22@uq.edu.au*; *d.lamb@uq.edu.au*), Firn, J. (*Queensland University of Technology, Australia; jennifer.firn@qut.edu.au*).

This paper discusses the key issues assocaited with the design of mixed species systems in the tropics. In the paper we draw on both the literature related to mixed-species forestry systems and the literature related to smallholders and community participation in forestry. Based on this analysis, we develop generic guidelines for the design of mixed-species systems that potentially have broad application in tropical regions. We then use these guidelines, combined with extensive datasets collected over the past 10 years, to propose specific systems suited to smallholder and community forestry in the Philippines. These systems provide a range of short term and longer term financial and livelihood benefits, along with other social and ecological benefits including biodiversity.

The association of forest owners after the restitution process in the Czech Republic. Jarský, V., *Šišák,* L., Kupcak, V. (*Czech University of Life Sciences Prague, Czech Republic; jarsky@fld.czu.cz*; *sisak@fld.czu.cz*; *kupcak@fld.czu.cz*).

The paper analyzes the changing structure of forest ownership in the Czech Republic in the past twenty years. We present the process of restitution of the former state property and the way it helped the new forest owners to unite in associations. Our methodology comprises literary research and personal interviews with members of selected associations. The analysis shows that at the very beginning, municipal forest owners were the first and most active to begin associating, while private forest owners joined later. The reason for hesitation was their deep-rooted mistrust and scepticism of collective ownership from the past, and also a lack of knowledge and experience with forest management. Two structurally different types of associations gradually emerged. The first type is represented by a patronage national association, based on a combination of top-down and bottom-up principles, aiming to promote municipal and private forest owners on the national level. The other type is represented by local associations of minor forest owners and is created on the bottom-up principle, its aim being cooperative management of their properties. The analysis also shows that the Czech Republic effectively supports the associating of forest owners, and the national support was the main reason why some of the associations were established.

Biodiversity and ecosystem carbon budget in the upland landscapes following shifting cultivation by small-holder kaingin farmers in the Philippines. Mukul, S. (*University of Queensland, Australia; sharif_a_mukul@yahoo.com*), Herbohn, J. (*University of the Sunshine Coast, Australia; jherbohn@usc.edu.au*).

Shifting cultivation, locally known as *kaingin*, is one of the common forest uses in upland Philippines. Despite efforts by the Philippines government to ban this practice, *kaingin* systems play an important role in the food security of small-holder farmers. We conducted an exploratory survey in Leyte province across fallow *kaingin* areas of four distinct categories (i.e. 0–5; 5–10; 10–20; and 20–30 years) and in secondary forests without any *kaingin* history. A transect method was followed, and 20 transects of 50 m × 5 m were established along each fallow category and in forests where we recorded tree diversity, standing biomass, biomass in dead/dying/burnt woods, biomass of leaf litter/woody debris/ undergrowths and in fine roots. Study reveals that fallow areas of older age embrace a considerable amount of tree diversity and carbon comparable to secondary forests. The contribution of small diameter trees and dead/dying/burnt woods were however prominent in carbon budget of young *kaingin* areas where large diameter trees have the largest share in secondary forests. Greater understanding of the pattern and processes of biodiversity and carbon pool in *kaingin* landscapes could be useful to restore the degraded upland areas more efficiently, and could help develop possible mechanisms to reward small-holder farmers to avoid this age-old practice.

Factors influencing the level of participation of community forest association members in participatory forest management: a case study of Kenya. Musyoki, J. (*Kenya Forestry Research Institute, Kenya; josephinemusyoki@yahoo.com*), Mugwe, J. (*Kenyatta University, Kenya; jaynemugwe@yahoo.com*), Muchiri, M. (*Kenya Forestry Research Institute, Kenya; mbaemuchiri2002@yahoo.com*), Mutundu, K. (*Mount Kenya University, Kenya; kkmutundu@yahoo.com*).

Forests contribute to the livelihoods of adjacent communities by providing various ecosystem goods and services. Using a case study of Ontukigo and Ngare Ndare community forest associations (CFAs) involved in participatory management of Ontulili and Ngare Ndare forests in North Central Kenya, the relationship between the level of CFA participation in participatory forest management (PFM) and their perceived benefits was assessed. Community perceptions on the contribution of CFA to improved forest cover and PFM contribution to improvement of CFA members' livelihoods were assessed through semi-structured questionnaires and participatory rural appraisal tools. The level of CFA members' participation was positively influenced by the level of perceived PFM benefits (χ^2 = 38.73, P=0.05); range of farm size (χ^2=12.72, P=0.05); and nature of household headship (χ^2 = 29.99, P=0.001). Increase in forest cover was associated with CFA participation in PFM. Improvement in CFA members' livelihood was associated with their participation in PFM. Enhancing income generating activities in and off the forest and streamlining modalities of benefit sharing between Kenya Forest Service and the CFA members were proposed for improved community livelihood and enhanced participation in PFM.

The present state and prospects of private forest owners' associations. Pezdevšek Malovrh, Š. (*University of Ljubljana, Slovenia; spela.pezdevsek.malovrh@bf.uni-lj.si*), Avdibegovic, M. (*University of Sarajevo, Bosnia and Herzegovina; mavdibegovic@gmail.com*), Zadnik (Stirn), L., Krč, J (*University of Ljubljana, Slovenia; lidija.zadnik@bf.uni-lj.si*; *janez.krc@bf.uni-lj.si*).

The study analyses the challenges and prospects of private forest owners' cooperation in association in Slovenia applying the SWOT (strengths, weaknesses, opportunities, and threats) method. The data from questionnaires with private forest owners and presidents of associations were used to develop and to analyse the strategies for forest owners' cooperation. Results reveal that the members of associations are only partly satisfied with the operation of the existing associations and that the activities of associations meet the members' interests related to forest management. Thus, associations are recognized as a suitable form of forest owners' cooperation. The presidents of associations perceive the group activities and investments of members, as well as educating of members as major strengths of private forest owners associations. Further, participation in tenders and change of legislation is recognized as an important opportunity. The individual interests of members and insufficient cooperation with other institutions are identified as weaknesses for associations, and the ignorance of some institutions is identified as a critical threat. However, the rank of importance of the SWOT groups leads to defensive approach in the strategic planning where associations have to minimize weaknesses in order to avoid threats. These results provide important insights in the future development of forest owners' cooperation in associations.

A culturally focused life cycle sustainability assessment: analysis of forestry value chain options with Māori land owners. Pizzirani, S. (*Scion, New Zealand; stefania.pizzirani@scionresearch.com*).

Forestry provides a range of benefits to indigenous communities, both tangible and intangible. In particular, the cultural benefits associated with forestry are distinctly important yet often go unrecognised. The indigenous Māori of New Zealand are one of the largest forest owners in the country, and have a keen interest in forestry. Currently the most common type of forestry is even-aged plantations of exotic species which provides a degree of long-term profit and economic stability. However, Māori also wish to pursue alternative forestry options (including the use of native species or uneven aged management). To explore forestry options a participatory case study was undertaken with the Ngāti Porou iwi (tribe) using the life cycle sustainability assessment (LCSA) technique to review the impacts of proposed alternative forestry value chains. LCSA assesses a product's environmental, social, and economic impacts from the 'cradle to the grave'. In this case study, indigenous cultural impacts were also included in the LCSA thus reporting impacts along a quadruple bottom line, the first of its kind. This research presentation reviews the process of integrating culture into the LCSA technique and the quadruple bottom line LCSA impacts of the current and proposed forestry value chains.

Small-scale forestry and policy challenges in East Asia. Sato, N. (*Kyushu University, Japan; sato.noriko.842@m.kyushu-u.ac.jp*), Choi, S. (*Department of Forest Resources, Sunchon National University, Republic of Korea; csi9626@yahoo.co.jp*), KANG, H. (*National University, Republic of Korea; kanghagmokang@yahoo.co.jp*), Tseng, Y. (*National Changhua University of Education, China-Taipei; yuliang318@yahoo.co.jp*).

Japan, Korea, and Taiwan face common rural problems. The first is rapidly aging populations. The second is the under-used resources of domestic forests, as symbolized in extremely low timber self-sufficiency rates (Japan, 26%; Korea, 15%; and Taiwan, 1% in 2011). The third is the fragmented small-scale ownership of private forests. An effective policy for sustainable forest

management requires the enhancement of cross-national research in the East Asian countries. Employing government statistics, secondary sources, and case studies, this study illuminates the similarities and differences of forest policies and their impacts on small-scale forest owners. In Japan, forest policies has been actively carried out to enhance timber production, as seen in the coordination and consolidation of forestry practices among groups of small forest owners and the subsidies to the actors who formulated their forestry management plans. In Korea, the upgrading of timber distribution structures has begun in order to enhance timber self-sufficiency. In Taiwan, policies have focused on forest conservation and the self-support of rural mountain communities, such as through eco-tourism. The authors explain the effects of these policies on the household economies of small-scale forest owners, inheritance practices and land transactions, and the social structures of communities.

Community forestry and fire management: combining social and ecological research to strengthen land management in communal forests in rural Mexico. Sheridan, R. (*Northern Arizona University, USA; rs253@nau.edu*).

This project uses social and ecological diagnostic tools to develop a fire management strategy for a communal forest containing an economically valuable piñón pine species, *Pinus cembroides* subs. *orizabensis*, in the state of Tlaxcala, Mexico. The ultimate goal was to not only to preserve this endemic species but also to benefit the local community. This project combines education, outreach, social science, and ecological research to examine how communities can better manage their common-pool resources, thereby creating more sustainable and resilient landscapes and livelihoods. The social assessment was conducted through household interviews, community workshops, and direct participant observation. The ecological diagnostic was carried out through a fuel inventory and forest structure survey. The ecological risk of fire was quantified and coupled with the social analysis to develop an integrated management strategy on how to reduce the risk of fires in these communal forests while simultaneously benefiting the community economically and organizationally. Results indicate that human activities directly influence forest fuel structure and composition; local social dynamics also determine feasible management options. Combining both social and ecological diagnostic tools provide a more comprehensive understanding of the risks to forests and identifies more realistic community-supported options for conservation.

Modeling private woodland owner timber harvesting behavior using social interactions, risk perception, and peer-to-peer networking. Silver, E., Leahy, J., Weiskittel, A. (*University of Maine, USA; emily.j.silver@maine.edu; jessica.leahy@maine.edu*; *aaron.weiskittel@maine.edu*), Kittredge, D. (*University of Massachusetts, USA; dbk@eco.umass.edu*), Hiebeler, D. (*University of Maine, USA; david.hiebeler@maine.edu*).

Privately-owned woodlands are an important source of timber in North America and worldwide. Available timber supply is difficult to estimate because complex behavioral theory informs the owner's decision to harvest. The decision-making environment consists of exogenous market factors, internal cognitive processes, and social interactions with fellow landowners, foresters, and other rural community members. This study seeks to understand how social interactions, risk perceptions, and peer-to-peer networks influence timber-harvesting behavior using an agent-based model. This theoretical model uses a 4 000 ha^2 world with forested polygons in various states of 'harvest readiness' and three types of agents: forest landowners, foresters, and cooperators (individuals trained in conservation who use peer-to-peer networking). Agent rules, interactions, and characteristics were parameterized with values from existing literature. Three experiments were run 500 times, with varying levels of risk perception: (1) A forester and cooperator on the landscape, no neighbor-neighbor interaction; (2) No foresters or cooperators, neighbor-to-neighbor interaction; and (3) A forester, cooperator, and neighbor-to-neighbor interaction. Results indicate that parcels are more likely to be harvested, and harvested sustainably (i.e. parcels "ready" to harvest are harvested) under scenarios 1 and 3. Model output and equations will inform forest policy and understanding of land-use change.

Forest land ownership changes in Europe: significance for management and policy. Weiss, G. (*University of Natural Resources and Life Sciences, Austria; gerhard.weiss@boku.ac.at*), Lidestav, G. (*Swedish University of Agricultural Sciences, Sweden; gun.lidestav@slu.se*), Nybakk, E. (*Norwegian Forest and Landscape Institute, Norway; nye@skogoglandskap.no*), Schraml, U. (*University of Freiburg, Germany; ulrich.schraml@ifp.uni-freiburg.de*), Sarvasova, Z. (*National Forest Centre, Slovakia; sarvasova@nlcsk.org*), Lawrence, A. (*Forest Research, United Kingdom; anna.lawrence@forestry.gsi.gov.uk*).

Forest ownership is changing across the world. In Europe, particularly notable changes include a move towards increasing numbers of 'absentee' forest owners in some regions and moves towards 'community-based' forest management and smallholder forestry in other areas. Both as a result of these ownership changes and because of the increasing complexity of forest management objectives (timber production, biodiversity conservation, climate change adaptation and mitigation, and provision of other ecosystem services), the practices of forest management are also changing. The interactions between ownership type, actual or appropriate forest management approaches, and policy are of fundamental importance in understanding and shaping forestry, but represent a neglected research area. This presentation builds on work from 28 countries, coordinated through the European COST Action FP1201 FOREST LAND OWNERSHIP CHANGES IN EUROPE: SIGNIFICANCE FOR MANAGEMENT AND POLICY (FACESMAP). Drawing on an evidence review across the 28 participating countries, the paper describes the manifold dimensions of changing ownership, both in their local contexts and spatially across Europe; and provides an analysis of the relationships between such ownership changes, forest management approaches, and effectiveness of policy support.

A-09 Communities, forests, forest industries and the Social Licence to Operate

Organizers: Peter Edwards (Swedish University of Agricultural Sciences), Justine Lacey & Kieren Moffat (CSIRO, Australia)

Gaining a social license to practice the assisted migration of species in forestry. Klenk, N. (*University of Toronto, Canada; nicole.klenk@utoronto.ca*).

The idea of evidence-based decision-making (EBDM) has been put into practice in numerous government agencies in Europe and North America as a response to demands for increased efficiency and transparency in public policy-making, for achieving high standards of policy performance and increasing the legitimacy of public policy choices. The idea of EBDM has received critical attention by academics concerned with the political dimensions of the social construction of evidence. In this paper we present results from a case study of the policy process that enables the range expansion of western larch in British Columbia, the first policy of its kind in Canada. The politics of EBDM in this case is directly related to obtaining a social license to engage in the assisted migration of species, a hotly debated climate change option in the scientific community. Our paper addresses the following research questions: (a) what data was selected as evidence in developing the western larch policy; (b) what were the social and political practices involved in the construction of evidence in the western larch policy process; and, (c) how was the social license to practice assisted migration obtained by government scientists and policy developers involved in developing the western larch policy?

Social licence as social contract: procedural justice, democracy and activism in the Australian forest industry. Lacey, J. (*Commonwealth Scientific and Industrial Research Organisation* (*CSIRO), Australia; Justine.Lacey@csiro.au*), Edwards, P. (*Swedish University of Agricultural Sciences, Sweden; peter.edwards@slu.se*), Lamont, J. (*University of Queensland, Australia; julian.lamont@gmail.com*).

The term, social licence to operate, originally emerged from the mining and extractive sector. However, it has been used in the forestry sector since the late 1990s to refer to the broad acceptance communities and other stakeholders provide to industry's development of forest resources. In this context, the social licence has also been described as a form of social contract. Increasingly, members of society are taking an active interest in how natural resources are used and developed. This reflects the expectations society has about the relative costs and benefits of these activities, and what they are willing to accept. In Australia, there have been a number of significant examples of citizen action against the forest industry which have lead to industry failure. In some cases, a lack of social licence has been cited as the reason for this. However, there have also been landmark agreements reached between the forest industry and communities in Australia that reflect a shared vision. Using examples of citizen participation in the Australian forest sector, this paper summarises recent research on the processes and failures of social agreement making that highlight the role of procedural justice as a critical factor for achieving a social licence.

Obtaining and maintaining social licence to operate – British Columbia's quality assurance model. Oman, D., Ryan, T. (*BC Forest Practices Board, Canada; Darlene.Oman@gov.bc.ca*; *Tim.Ryan@gov.bc.ca*).

British Columbia (BC) has a unique approach to quality assurance for forest practices that is an important part of the BC forest industry's social licence to operate. Consisting almost entirely of publicly owned forest land, British Columbia depends on maintaining public support and approval to engage in forest resource use and management. In the late 1980s and early 1990s, BC's forest industry essentially lost its social licence, culminating in massive protests and citizen arrests as the public expressed dissatisfaction. Since that time, a unique model of quality assurance has evolved, and today, BC's forest industry enjoys much stronger public support. The four components of BC's quality assurance model are: government regulation, professional reliance, industry certification and independent oversight. Few if any other jurisdictions have all four parts, at least formally. Government has put considerable focus on regulating forest practices for the past two decades. Forest professionals have mandatory registration, independent of government. Industry has invested heavily in certification. The Forest Practices Board provides the public with assurance and an avenue into the quality assurance system. Based on interviews, opinion polls and observations, this paper explores how this model fosters public confidence that practices are sound.

The socioeconomic impacts of smallholder industrial tree plantations in the Philippines. Peras, R., Pulhin, J. (*University of the Philippines Los Banos, Philippines; rjjperas@gmail.com; jpulhin@yahoo.com*).

Massive reforestation and spontaneous tree growing are the initiatives undertaken in the Philippines to address forest degradation. Unfortunately, only about 10% of the targeted degraded areas have been rehabilitated so far by the government and the private sector. Much of the additional cover is contributed by the industrial tree plantations (ITP) promoted by corporations either through outgrowing schemes or by direct investment. ITP is seen as an important key player in the national and local socio-economic development. It is also an offshoot of the decreasing supply of commercial timber from natural forests. The interestingly high incidence of smallholder tree farming in Caraga Region, Mindanao for timber production purposes has spread like wildfire all over the region. Hence, the paper highlights the socio-economic impacts of tree farming at the household level using a combination of qualitative and quantitative data collection methods. The study revealed that tree farming contributed to the improvement the livelihood of the household, local economy, and the quality and quantity of forest areas. The major challenge facing the practice is the equity issues associated with costs and benefits favoring the middlemen more than the tree farmers.

New Generation Plantations: all forestry has to become social forestry. Silva, L.N. (*WWF, Portugal; lnsilva@wwfint.org*).

A seven billion person world requires forestry and farming practices that produce more with less land and water, while empowering communities to achieve their aspirations. In many rural areas, forestry companies are the best resourced and best connected institutions around. The challenge is how to channel investment through forestry into benefiting communities. Investing in locally controlled forestry is an idea whose time has come. New Generation Plantations (NGP) has the premise that skilled, motivated local people can run successful forestry businesses, helping forest industry secure a reliable supply of wood. NGP links forestry with communities and governments to unlock funding to scale-up smart forestry investment that shares the benefits and ownership with communities. The NGP concept describes an ideal form of plantation that maintains ecosystem integrity, protects high conservation values and is developed through effective stakeholder participation, contributing to an economic inclusive green growth. The New Generation Plantations is a learning and influencing platform of WWF, companies and governments, in dialogue to develop sustainable solutions for better plantations. The platform advocates for better plantations in key regions by learning from real-world experiences of participants, showing and sharing practical examples of how plantations can be done.

Collaboration opportunities in Corporate Social Responsibility (CSR) reporting for Finnish non-industrial private forestry (NIPF) and non-integrated sawmilling industry. Toivio, M., Toppinen, A., Lähtinen, K., Suur-Uski, O. (*University of Helsinki, Finland; matti.toivio@helsinki.fi; anne.toppinen@helsinki.fi*; *katja.lahtinen@helsinki.fi; olli.suur-uski@helsinki.fi*).

Importance of the information on the acceptability of forestry-sawmilling production chains is increasing as a factor of competitiveness in the forest products markets. In the future, capability of production chains to produce reliable Corporate Social Responsibility (CSR) information on the economic, environmental and social sustainability of their operations may create new business opportunities especially in the environmentally and socially conscious pioneer customer segments. In recent years, lots of sustainability measurement systems for assessing, e.g. regional and national sustainability of forest sector operations have been developed, but generally their applicability at firm-level decision-making has been weak. In this study, critical CSR measures for assessing the sustainability impacts of Finnish forestry-sawmilling production chains and collaboration opportunities for developing common CSR reporting between NIPF and non-integrated sawmills are presented. The data of the study were gathered by using the Global Reporting Initiative (GRI) framework as a reference both from the representatives of Finnish NIPF and non-integrated sawmills in August-October 2013. To receive information on the relative importance of different GRI measures in the CSR reporting of the production chains, the survey questionnaires were structured and analyzed by employing Multi-Criteria Decision Analysis (MCDA) methodology.

Corporate responsibility development paths in the forest sector. Toppinen, A. (*University of Helsinki, Finland; anne.toppinen@helsinki.fi*), Tuppura, A., Arminen, H. (*Lappeenranta University of Technology, Finland; anni.tuppura@lut.fi*; *heli.arminen@lut.fi*).

In the past two decades, the growing public interest in environmental and social issues has intensified pressures on forest industry companies in their efforts to gain license to operate by meeting often mutually conflicting stakeholder expectations at both global and local levels. Today, integrating social and environmental concerns responsibly into business operations (i.e. implementing corporate social responsibility, CSR) is essential. In the global forest industry, adoption and development of CSR practices in a company is likely to be path-dependent, requiring an adoption of specific sustainability practice before another can be successfully implemented. The path-dependency may influence on the companies' possibilities to gain competitive advantage in the future. In this explorative study, we use the leading measure capturing multi-dimensionality of CSR, namely the Kinder, Lydenberg and Domini (KLD) index to empirically study the development of the CSR performance among large U.S. forest companies. We applied trajectory analysis to identify sub-populations that follow similar CSR developmental trajectories over time, and to find out whether forest sector companies belong to the same sub-population. Further, trajectory analysis facilitated the shapes of the particular trajectories, and indicated the possible CSR leaders and laggards among forest industry companies.

First Nations and forestry companies in Canada: possibilities and pitfalls of an informal social licence in a contested environment. Wyatt, S. (*Université de Moncton, Canada; swyatt@umce.ca*).

Industrial forestry in Canada most commonly occurs on the traditional lands of indigenous First Nations, and forestry companies are increasingly recognizing the need to gain acceptance and approval of communities – often referred to as obtaining a social licence to operate (SLO). We conducted an inventory of forest sector collaborative arrangements in 474 Aboriginal communities, identifying a wide variety of techniques and practices. These range from protests or actions that deny social licence, through economic partnerships and consultation processes to new governance and soft law arrangements such as forest certification. This presentation will explore both advantages and disadvantages of SLO in the context of Canadian First Nations. In particular we note that direct engagement between industry and Aboriginal communities can help foster respect and relationships, while also favouring better distribution of benefits and innovation and improvement in practices. However, questions remain concerning the ways that SLOs are negotiated, implemented and monitored, especially given cross-cultural situations with differences in power, values and expectations. Furthermore, the informal nature of SLOs may be inappropriate in an environment of contested rights and judicial rulings. These remain subjects for further research.

A-10 Establishing social institutions for co-management of public forest lands

Organizers: Jamie Barbour (U.S. Forest Service), Cassandra Moseley (University of Oregon, USA) & Susan Charnley (U.S. Forest Service)

Stakeholders' participation in community based forest management (CBFM) in Cross River State, Nigeria. Abi, E. (*Forestry Research Institute of Nigeria (FRIN), Nigeria; eneabi2008@yahoo.com*).

Stakeholders' participation in Community-Based Forest Management (CBFM) in Cross River State (CRS) was assessed in order to gain insight into the workings of CBFM in CRS for efficiency and effectiveness. A three-stage sampling technique was used to administer four sets of questionnaire to forestry officials, community/rural dwellers; timber dealers/sawmillers and non-governmental organizations (NGOs) with interest in environmental issues. Eight communities from four local government areas (LGAs) were randomly sampled. Data collected were analysed using descriptive statistics. The study revealed that all the stakeholders had heard about CBFM and its practices. The most significant gain of the CBFM has been the meaningful partnership between the Cross River State Forestry Commission (CRSFC) and the people in protecting and managing the forest resources. The existing benefit sharing ratio of CBFM proceeds is 20:80 for government established plantations while communities have 70:30 from products derived from community forests. The current sharing ratio for the products obtained from the forest reserve is 50:50. Some of the identified challenges confronting the implementation of CBFM were inadequate encouragement and cooperation among some members of the communities; inadequate incentives and equipments. For effective CBFM, stakeholders should be trained on modern strategy of community forestry and sustainable forest management.

Implementing Collaborative Natural Resources Governance for the Sustainable Management of the Mt. Makiling Forest Reserve, Philippines. Bantayan, N. (*University of the Philippines Los Banos, Philippines; ncbantayan@gmail.com*), Castillo, M., Sargento, J., Breva, R., Barile, J., Balahadia, N., Castillo, L. (*Makiling Center for Mountain Ecosystems, Philippines; mannycastillo100@yahoo.com; josargento@yahoo.com; rvbreva@yahoo.com*; *jojobarile@yahoo.com; nbalahadia@yahoo.com; mcme_leilani@yahoo.com.ph*).

This study proved that collaboration of forest managers with stakeholders lead to sustainable management. We collaborated with stakeholders that included the villagers or local people, local leaders and the private sector in a program on collaborative natural resources governance that was implemented on the Mt. Makiling Forest Reserve (MFR), Philippines – a public forest. Several activities were put in place, namely; a volunteer forest conservation program, regular census of forest occupants, and a tree planting and nurturing program with the private sector. The volunteer forest conservation program trains and deputizes selected forest occupants to become the protectors of the forest while at the same time benefiting from the produce of their agroforestry farms. As a result, our latest surveys revealed that the problems of MFR have become less from the occupants inside the forest reserve but more from the people outside its boundaries. Concurrently, a 100% re-census of forest occupants is being completed to update the data from 2003. Thirdly, members of the private sector are apportioned parts of the public forest that need restoration through a program dubbed Tree Planting and Nurturing that lasts for at least three years or until such time that the area is fully restored.

The first four years of a collaborative forest landscape restoration project on Colorado's Front Range: successes and lessons learned. Dickinson, Y. (*Colorado State University, USA; yvette.dickinson@colostate.edu*), Beh, G. (*Beh Management Consulting, USA; gali@behconsulting.com*).

The lower montane forests of the Colorado Front Range have changed significantly over the last 150 years. In the absence of the historic mixed-severity fire regime, the density of small and medium-sized trees has increased greatly. This increased tree density has been associated with increased occurrence of large uncharacteristically severe fires, insect outbreaks, and the degradation of open-woodland habitat. Furthermore, the wildland urban interface (WUI) is continuing to expand as more people build their homes in these fire-adapted forests. As such, there is an increasing pressure to restore the structure and function of these forests, and reduce the likelihood of uncharacteristic wildfire. In 2010, the Front Range Roundtable (a community group comprising non-government organizations, researchers, private stakeholders, and federal, state and local agencies) and two national forests (Arapaho and Pike National Forests) embarked on the Front Range Collaborative Forest Landscape Restoration Project (CFLRP). Over the past four years this collaborative project has endeavored to set restoration goals, carry out restoration treatments, monitor the success of the treatments and use adaptive management principles. We will present the successes of this collaborative project, and describe the lessons learned about working collaboratively to restore these forested landscapes.

Participatory management model of the socio-ecological system for sustainable rural development and community forestry wellbeing in Mexico. Lujan, C., Olivas-Garcia, M (*Universidad Autónoma de Chihuahua, Mexico; clujan12@hotmail.com; jolivas@uach.mx*), González-Hernández, H. (*Programa de las Nacionales Unidas-Comision Nacional Forestal, Mexico; gzilda@yahoo.com.mx*), Vazquez-Alvarez, S. (*Forestry Consultant, Chihuahua, Mexico; p76977@yahoo.com.mx*), Hernandez-Salas, J. (*Universidad Autónoma de Chihuahua, Mexico; jhernans@uach.mx*).

In Mexico, challenges of globalization, climate change and biodiversity loss have created the need to concentrate efforts for strategically managing processes and building capacities in forest ejidos and communities, since they are who live with the effects of any action. For that, it is necessary to apply a participatory management model of the socio-ecological system in forest ejidos and communities for sustainable development. The model includes: (a) Multisearch Conference, which is a participatory and bottom up decision-making process, and (b) participatory strategic management model for the competitiveness of community forest enterprises. The integral model is based on three principles: strategic thinking, holistic vision, and participatory democracy. It includes strategies for designing, implementing, and monitoring strategic plans for managing sustainable forestry development. Examples of application of this model are: (a) participatory strategic master plan for sustainable forestry development in Chihuahua, Mexico, and (b) integral forestry development of the forest Ejido "El Largo and Anexas", Madera, Chihuahua, Mexico. In sum, the participatory model promotes an anticipatory, and self-managed sustainable community forestry development. The model represents a paradigm shift to get sustainable community forestry development.

Co-management of government-owned lands: lessons from across the globe. Moseley, C. (*University of Oregon, USA; cmoseley@uoregon.edu*), Barbour, R., Charnley, S. (*U.S. Forest Service, USA; jbarbour01@fs.fed.us; scharnley@fs.fed.us*).

For three decades, countries across the globe have been experimenting with co-management of forests that are owned by the state. Places as diverse as Canada and Nepal have developed co-management systems. These schemes can range from informal collaboration to more formal shifting of decision-making to nongovernmental actors. Regardless, the emergence of these sorts of systems can change the relationships between state and societal actors along with economic opportunities and power relationships at multiple scales. In this presentation, we identify key successes, limitations, and lessons from forest co-management for practitioners and policy makers. We also identify questions for future research, building on the other presentations in this panel along with a review of the broader literature.

Eco-agriculture, green rural economy and sustainable governance of the forests in the Congo Basin. Njomkap, J. (*African Model Forests Networks, Cameroon; jc.njomkap@africanmodelforests.org*).

The Model Forest is a multi-actors discussion platform for land stakeholders with a common vision and sustainable development priorities. This is also an integrated approach for participatory land management and a tool for the long-term implementation of projects managed by local actors. The unified economic program (ONE PROGRAMME) of the African Network of Model Forests is an economy promotion tool to strengthen the leadership of the communities regarding the enforcement of emerging opportunities, such as adaptation to climate change, REDD+ and payment for environmental services. The Travelling Model

Forest School trains local expert facilitators and producers in creating enterprises, developing value chains, micro-financing, appropriate technologies, participatory follow-up evaluation, with the aim to promote, under the label of MF, a green rural market economy and natural products. The areas of ONE PROGRAMME are eco-agriculture, non-wood forest products, timber, ecotourism, the valorization of heritage and traditional knowledge, rural hydrology and renewable energies. By facilitating partnership between universities, research centers, public administrations and local actors, Model Forest landscapes build up interfaces between science, politics and sustainable development.

Participatory forest management networks of Odisha – time for more recognition. Siripurapu, K. (*University of Maryland at College Park, USA; kanna@umd.edu*).

Community-based forest networks of India and Nepal have been suffering from serious neglect and left at disadvantage due to lack of legal recognition. A brief review of literature on community-based forest networks found that they lack certain attributes that are necessary to be considered as equal partners in the activities aimed at forest conservation and livelihood improvement. In this review a brief on the informal community-based forest networks of Odisha and their status of recognition through the Forest Rights Act (FRA) 2006 is presented. It was found that there are many studies conducted on joint forest management, community-based forest management, and recently on the impacts of FRA 2006, in Odisha. However, it was found that there has been very little or no research studies conducted on the impacts of FRA 2006 on community-based forest management networks of Odisha. It is thought that more research studies should be conducted on how FRA 2006 could strengthen community-based forest management networks of Odisha.

A-11 American Indian forestry

Organizer: Donald Motanic (Intertribal Timber Council, USA)

Anchor forests: A multi-ownership pilot project in eastern Washington to maintain working forests. Andringa, S. (*Yakama Nation, USA; steve@yakama.com*), O'Laughlin, J. (*University of Idaho, USA; jayo@uidaho.edu*).

The ability of our nation's forests to continue to provide a wide array of ecosystem services and economic benefits is being diminished by fragmentation and the loss of infrastructure for management, harvesting, transportation, and processing. A pilot project is being pursued in eastern Washington to explore the potential to sustain economic and ecological functions on the landscape through anchor forests. Anchor forests are large tracts of forest land that are expected to remain under long-term stewardship, including substantial commitments for commodity production. They could provide focal points for investments in ecosystem services and infrastructure needed to sustain working forests on the landscape. The anchor forest concept will be explained and progress on the pilot project reported, including resource assessment, collaborative cross-ownership strategies, and identification of barriers to meeting management objectives.

Sustainable forest management within the context of ecological change: community perspectives and challenges from the Menominee Tribe of Indians of Wisconsin. Dockry, M. (*U.S. Forest Service, USA; mdockry@fs.fed.us*), Langston, N. (*Michigan Technological University, USA; nelangs3@mtu.edu*).

The Menominee tribe has emerged as a global leader in sustainable forestry. Over the past 150 years the tribe has harvested timber from their reservation on a sustainable basis. In the 1990s, tribal foresters began to use even-aged silvicultural techniques to regenerate shade intolerant species like white pine (*Pinus strobus*). This paper outlines multiple tribal perceptions of even-aged silviculture, ecological change, and highlights differing community definitions of sustainable forestry. We use historical and qualitative social science research techniques to analyze land survey records, planning documents, and interviews with Menominee community members. The results of the study show forest composition has shifted in some areas due to fire suppression and uneven-aged harvesting. Community interviews indicate that some tribal members view even-aged silviculture as contrary to Menominee traditions while others believe it maintains forest diversity. Despite conflicting views, interview participants explained that forest management has allowed the tribe to control their territory, maintain their forest, and foster their culture. Sustainable forestry, according to interview participants, incorporates history, economics, ecology, and tribal values. This study suggests that an understanding of the historical, ecological, and social context of forest management is necessary to develop management goals in the context of ecological change.

Recruitment and retention of tribal youth as future management leaders. Hoagland, S. (*Northern Arizona University, USA; serrahoagland@gmail.com*), Motanic, D. (*Intertribal Timber Council, USA; donmo@itcnet.org*).

Tribal youth tie the past with the present and the promise of tomorrow. Like many organizations responsible for natural resource management, Indian tribes are struggling with ways to replace the knowledge, experience and leadership being lost through an aging workforce. This presentation will discuss efforts to encourage tribal youth to become future leaders in resource management by drawing upon the wisdom of elders and knowledge keepers within tribal communities and the methods and skills they learn as they pursue academic degrees.

Pacific Northwest Research Station Tribal Climate Change Research Program. Kruger, L. (*U.S. Forest Service, USA; lindalaska2003@gmail.com*), Lynn, K. (*University of Oregon, USA; kathy@uoregon.edu*).

The impacts of climate change will not be evenly distributed. Indigenous populations may be among the most heavily impacted because of their dependence on natural resources for economic and cultural identity. The objectives of the Pacific Northwest Tribes and Climate Change Project are to (1) increase understanding of the needs and opportunities for tribal climate change planning; (2) examine impacts of climate change on tribal cultures, sovereignty, and traditional ways of life; and (3) examine the role of traditional knowledge in climate change assessment and planning. Activities include providing information on government

programs, a funding guide of US climate change programs, tribal climate change profiles that showcase innovative efforts by tribes to address climate change through adaptation and mitigation strategies. A Pacific Northwest Tribal Climate Change Network was established, monthly conference calls and an annual conference provide opportunities to disseminate information and share resources. The Network has grown to over 185 participants from tribal councils and staff, public agencies, non-governmental organizations, universities, and others. A study of the role of gender and indigenous people in a climate change context has been initiated in an effort to frame the role that gender may play in defining climate change impacts and solutions.

Overview of Indian forests and forestry. Motanic, D., Rigdon, P. (*Intertribal Timber Council, USA; donmo@itcnet.org*; *prigdon@yakama.com*).

The health and productivity of forests are crucial for many Tribal communities across the United States. The capacity of Tribes to sustain the broad array of benefits the forests have provided for countless generations is coming under serious threat from fragmentation, wildfire, insects, disease, and climate change. The presentation will focus on ways that tribal involvement can help restore the health and productivity of our nation's forests.

A-12 Participatory protected area management at the human needs and sustainable wildlife conservation interface

Organizers: C.A.M. Sylvestre Djagoun (Université d'Abomey-Calavi, Benin), Hugues Akpona (National Forest Office, Benin), Edward D. Wiafe (Presbyterian University College, Ghana) & Achille Assogbadjo (Université d'Abomey-Calavi, Benin)

Spotted necked otters vs. fishermen in Hlan River, Benin: key ecological and socio-economic factors of a conflict. Akpona, A. (*Direction Générale des Forêts et des Ressources Naturelles, Benin; akpona@gmail.com*), Djagoun, C., Sinsin, B. (*University of Abomey-Calavi, Benin; dchabi@gmail.com*; *bsinsin@gmail.com*), Mensah, G. (*National Institute of Agricultural Research of Benin (INRAB), Benin; mensahga@gmail.com*).

This study highlights the motivations and identifies factors that explain conflicts between fishermen and otters in Hlan River. We conducted a questionnaire survey among fishermen (n=163) to investigate perceptions of otter predation and damage estimation. Among them, 30 fishermen were daily monitored to establish the key ecological and socio-economic context of the conflict through several predictions. We performed the hierarchical classification analysis using ward distance to categorize fish species according to otter damage intensity and used generalized linear models to identify predictors that better explain otter damage. From the 16 fish species inventoried as the mostly caught by fishermen at Hlan River, otters were reported to favor the most expensive and, the total loss of income attributable to spotted-necked otters' damage is estimated at 9%. Our model shows that otter damage increase significantly with the total adult fish captured while the cost of the species' damage increases with the equipment setup time duration. The equipment set up duration in otter damage intensity, fixing the threshold at 1 000 minutes and recommend an increase of the fishing equipment checking to minimize damage. Sustainable management of these conflicts requires an integrated approach that will contribute to build more effective solutions.

Rodents as food sources in Lama Forest Reserve in Benin. Assogbadjo, A. (*University of Abomey-Calavi, Benin; assogbadjo@gmail.com*).

This study was designed to look at the consumption of rodents as a food source combined with a survey of rodents sold in markets in Benin. Data was collected on rodents species consumed, frequencies of consumption and food preferences in the Lama Forest Reserve in Benin. Some animals were captured in order to confirm the species. Rodents were a major part of diet included ten species: grasscutter (*Thryonomys swinderianus*), giant rats (*Cricetomys gambianus*), Gambian Sun-squirrel (*Heliosciurus gambianus*), crested porcupine (*Hystrix cristata*), ground squirrel (*Xerus erythropus*), grass rat (*Arvicanthis niloticus*), slender gerbil (*Taterillus gracilis*), Kempi's gerbil (*Tatera kempii*), multimammate rats (*Mastomys spp.*) and grass mouse (*Lemniscomys striatus venustus*). On average, young people and children consumed rodents 6 times per person per month. The preferences of local populations were grasscutter and giant rats which were sold in local markets at relatively high prices: US$8–10 and US$2–4 respectively. Wildlife constitutes an important food resource, which cannot easily be replaced or removed without causing negative socio-economic disturbances. Finally, the impact of hunting on the rodent populations and dynamics was discussed and sustainable harvesting techniques have been proposed.

Integrating local communities to safeguard livelihoods and resolve conflicts in the Kakum Conservation Area, Ghana. Danquah, E., Oppong, S. (*Kwame Nkrumah University of Science and Technology, Ghana; emmanueldanquah@yahoo.com*; *kobbyoppong@yahoo.com*).

Severe elephant crop raiding at Kakum Conservation Area (Kakum) in Ghana has resulted in several confrontations between management and farmers. The study aims to integrate local communities in conflict resolution with the specific objective to build the capacity of farmers in crop protection methods. The study initially covered 750 farmers in 30 fringe communities. The farmers adopted basic community based problem elephant control mechanisms into their farming practices and this resulted in about 50% reduction in raids around Kakum. Following these successes, 40 additional farmers in 10 other fringe communities were included in the study. This resulted in 30% more reduction in raids. The combined effect of these interventions was an 80% reduction in crop raids around Kakum leading to tremendous improvements in farmers' livelihoods as crop losses to elephants were significantly reduced. The net effect was a general reduction in the number of confrontations between management and farmers and increased integration of local communities in the management of Kakum. The results highlight experiences and best practices in participatory wildlife management involving local communities at Kakum, with a particular focus on conflict resolution, safe-guarding livelihoods and promoting wildlife conservation, which was hitherto non- existent.

Bovid responses to anthropogenic effects, habitat and environmental parameters in the Pendjari Biosphere Reserve (Northern Benin) during the dry season. Djagoun, C. (*University of Abomey-Calavi, Benin; sylvestrechabi@gmail.com*), Mensah, G. (*National Institute of Agricultural Research of Benin (INRAB), Benin; mensahga@gmail.com*), Sinsin, B. (*University of Abomey-Calavi, Benin; bsinsin@gmail.com*).

Multiple land uses around protected areas can be a serious complication for wildlife management. We calculated habitat selection indices for ten bovid species to assess if habitat use differed in each bovid species between hunting and non-hunting zones. Presence/absence data was used in resource-selection functions based on a generalized linear mixed effect model to examine factors that explained bovid species distribution. We observed stronger avoidance of open habitat types in the hunting zone than in the non-hunting zone for the hartebeest, oribi, roan, kob, waterbuck and reedbuck. In contrast, in grey duiker, red-flanked duiker, bushbuck and buffalo we found no differences in habitat use between hunted and non-hunted areas. This may indicate that the latter species show more pronounced ecological and behavioural plasticity. Further, resource selection of bovid species on a small scale was influenced by other factors such as habitat structure, landscape characteristics, and human disturbance. This preliminary assessment of bovid habitat relationships in West Africa suggests that human hunting activities may cause species to alter their habitat selection. We therefore suggest habitat models may need to incorporate this source of variation if they are to accurately predict habitat use or distribution of a species.

Wildlife laws monitoring as an adaptive management tool in protected area management in Ghana: a case of Kakum Conservation Area. Wiafe, E. (*Presbyterian University College, Ghana; edward.wiafe@presbyuniversity.edu.gh*).

The wildlife laws of Ghana alienated the rural communities from forest materials they depended on for their wellbeing. As a result many local hunters operate secretly for both commercial and personal consumption. The discrepancies in the laws manifest themselves in the continuous battle of the park management staff and poachers from the fringes of the protected areas. The main aim of this study was to determine key factors that influence poaching rates in rainforest protected areas and the specific objectives were to determine firstly, the optimal patrol efforts necessary to reduce illegal wildlife use to minimal; secondly, the influence of the rainfall and seasonal activities on illegal wildlife use and thirdly, the effect of prosecution on incidence of illegal activities. The study took place in Kakum Conservation Area from January 2005 to December 2009. The relationships between the relative levels of illegal activities and patrol efforts (distance and mandays), rainfall, farming seasons and prosecution were examined. The results indicated that as the patrol efforts increased the encounter with illegal wildlife use also increased until a certain point that the encounter rates started decreasing. Neither the rainfall, seasonal activities nor prosecution were able to influence the illegal activities but the patrol efforts.

Posters

Exploring opportunities for participatory wildlife management at the Bia Biosphere Reserve in western Ghana. Danquah, E., Oppong, S. (*Kwame Nkrumah University of Science and Technology, Ghana; emmanueldanquah@yahoo.com*; *kobbyoppong@yahoo.com*).

Biodiversity loss from over-exploitation is likely to worsen around the Bia Biosphere Reserve (Bia) if measures are not adopted to secure the cooperation of local communities. To ensure integration of local communities, the Ghana Wildlife Division is implementing the Community Resources Management Area (CREMA) concept, which attempts to link the conservation of biological diversity within community forestry systems to the social and economic development of fringe communities. A major challenge however, is to design core areas within the CREMAs where little or no human activity takes place that not only will ensure the long-term viability of species and ecosystems but also will be politically and economically acceptable to local communities and government. In this paper we highlight ongoing experiences and best practices in participatory wildlife management involving local communities at Bia. We also discuss the attitudes and expectations of fringe communities on the CREMA concept and the long-term viability of CREMAs to address the complex and multidimensional nature of linking biodiversity and community forestry systems, with a focus on economic, livelihood, cultural, institutional and policy issues. A number of possible conservation and silvicultural measures allowing for the survival of wildlife as well as improvement of rural livelihoods are recommended.

Stable carbon isotope analysis of the diets of West African bovids in Pendjari Biosphere Reserve (Northern Benin). Djagoun, C. (*University of Abomey-Calavi, Benin; sylvestrechabi@gmail.com*), Codron, D. (*University of Zürich, Switzerland; darylcodron@gmail.com*), Sealy, J. (*University of Cape Town, South Africa; Judith.Sealy@uct.ac.za*), Mensah, G. (*National Institute of Agricultural Research of Benin (INRAB), Benin; mensahga@gmail.com*), Sinsin, B. (*University of Abomey-Calavi, Benin, Benin; bsinsin@gmail.com*).

Bovid diets have been studied for decades, but debate still exists about the diets of many species, in part because of geographical or habitat-related dietary variations. We used stable carbon isotope analyses of faeces to explore the seasonal dietary preferences of 11 bovid species from a West African savanna, the Pendjari Biosphere Reserve (PBR), along the browser/grazer (or C3/C4) continuum. We compare our carbon isotope values with those for eastern and southern African bovids, as well as with dietary predictions based on continent-wide averages derived from field studies. Oribi and reedbuck, expected to be grazers, were found to be predominantly C3-feeders (browsers) in the PBR. Bushbuck, common duiker and red-flanked duiker consumed more C4 grass than reported in previous studies. When comparing wet and dry season diets, kob, roan and oribi showed the least variation in C3 and C4 plant consumed proportions, while red-flanked duiker, bushbuck, reedbuck and waterbuck showed the most marked shifts. This study shows that animals in the better-studied eastern and southern African savannas do not exhibit the full range of possible dietary adaptations. Inclusion of data from a wider geographic area to include less well-studied regions will inform our overall picture of bovid dietary ecology.

Co-management approach to protect the protected areas: realistic or naive? Islam, M. (*University of Queensland, Australia; wasiulislam7@yahoo.com*), Sadath, M. (*Khulna University, Bangladesh & Georg August University, Göttingen, Germany; mnsadath@yahoo.com*).

The scarce forest resources, particularly the forest-based Protected Areas (PAs) of Bangladesh, are under extreme pressure of deforestation and degradation due to various anthropogenic pressures. To address this dilemma, the PAs of Bangladesh are passing a transition management regime from traditional management approach to collaborative management or co-management approach (CMA). The goal of CMA is to manage and conserve the natural resources (i.e. biodiversity) of the PAs as well as the well-being of surrounding locals. The objective of this study is to perceive the perceptions of different stakeholders on CMA and its associated problems in managing and protecting the PAs. Appreciative inquiry method was used in this case. Lawachara National Park (LNP) and Satchari National Park (SNP) were selected as the study areas. The results showed that most of the stakeholders of these two PAs were very positive. They were impressed to take part in the co-management process of the PAs. There were co-management plans for these two PAs for its effective management and protection. Alternative income generation activities have been prioritized in these management plans to uplift the socio-economic, environmental and institutional conditions of the local communities living in and around these PAs to reduce their traditional pressure.

Manning the front lines of biodiversity conservation: developing competency standards for protected areas management in the Philippines. Paras, F., Pulhin, J., Rebugio, L., Dolom, P. Cereno, R., Del Rosario, P. (*University of the Philippines Los Banos, Philippines; fdparas@gmail.com*; *jpulhin@yahoo.com*; *lucrebugio@gmail.com*; *predolom@yahoo.com; r.cereno@gmail.com*; *peterdelrosario@gmail.com*).

Considered both as a biological hotspot and a megadiversity country, the Philippines are placed as a top priority for global conservation. Currently there are 240 terrestrial, marine and coastal protected areas listed under Republic Act 7586: National Integrated Protected Areas System (NIPAS), all of which are teeming with rich and unique tropical wildlife. Protected areas are managed by the state, however with each site having its own externalities and peculiarities, management strategies need to be up-to-date, extensive and harmonized without being generic and restrictive. This paper will demonstrate how the country will hand-pick the select front liners of biodiversity conservation. This study is an unfolding of how competency standards for protected areas management was developed, resulting from a consultative, participatory and collaborative process taking into account the stakeholders' perspectives – a distinct practice in the country. The results presented will include: the core competencies for protected areas management staff, performance criteria, areas of execution, and behavioral evidence/needs. The way forward, issues, and implications to policy, education and execution for these standards will also be discussed.

Evaluation of the efficacy of pepper-grease fence to prevent elephant crop raiding on farms around Kakum National Park, Ghana. Wiafe, E. (*Presbyterian University College, Ghana; edward.wiafe@presbyuniversity.edu.gh*).

A pepper-grease-fence to prevent elephants of from destroying farms around Kakum Conservation Area was evaluated on its efficacy. Sixty fenced and sixty unfenced farms located at the peripheries of the protected area were selected and inspected regularly for a period of 12 months. 120 farmers were also interviewed about the use of the pepper-grease fences and its efficacy. In 75% of the fenced farms, the elephants came close but never crossed it and never visited 20% while in 5% of the fenced farms the elephants made an attempt to break through or enter the farms through different routes. Of the farms that were not fenced at all, 75% were completely raided by the elephants. The majority (76.7%) of the respondents had a good knowledge about the pepper fence with the major source of the information being the Wildlife Division staff and Agricultural extension agents. 54.5% heard it from other farmers (31.1%) while only 14.4% obtained their knowledge from observation of other farmers. In practice, 26.7% said they practiced it effectively, 22.2% practiced it partially, and 51.1% did not practice the method at all.The cost and difficulty of acquisition of materials were the main issues affecting the adoption rate.

A-13 Innovative planning and managing approaches for sustainable tourism in forests and natural areas

Organizers: Taylor Stein (University of Florida, USA), Peter Fredman (Mid Sweden University, Sweden), Nobuhiko Tanaka, Tokai University, Japan) & Liisa Tyrväinen (Finnish Forest Research Institute, Finland)

Do forests matter to the nature-based tourism industry? Fredman, P., Margaryan, L. (*Mid-Sweden University, Sweden; peter.fredman@miun.se*; *lusine.margaryan@miun.se*).

This paper aims to contribute to better understanding of the role of forest environments in the nature-based tourism (NBT) supply in Sweden by presenting results of a comprehensive NBT supply survey. Sweden, having a strong tradition of outdoor recreation, has experienced a relatively recent expansion of NBT as a commercial activity. Understanding the attributes of the NBT supply poses a number of challenges related to the lack of a universally agreed definition of NBT and consequential absence of a systematic data collection. Based on pre-test results, a dataset for the survey was gathered (N=2060) with the aid of Swedish regional tourism bureaus and a follow-up web-based survey was conducted in two waves during May-June and October-November 2013. The survey contained 49 major questions covering company characteristics, products offered, management specifics, and topics related to land use, access to nature, sustainable development and networking. The aim of this presentation is to provide an overview of the NBT supply in Sweden followed by an in-depth analysis on the role of forests and forest environments, including e.g. interactions between NBT and forest operations and the significance of forest environments and forest organizations for NBT success.

Tourism best management practices applications in southeast Alaska. Kruger, L. (*U.S. Forest Service, USA; lindalaska2003@gmail.com*), Needham, M. (*Oregon State University, USA; mark.needham@orgeonstate.edu*).

The United States manages 240 million acres (971 246 km^2) in Alaska, including southeast Alaska's Tongass National Forest, the largest national forest in the United States at 17 million acres (69 000 km^2). Tourism and outdoor recreation make up the fastest and most consistently growing industry in Alaska. In recent years around one million cruise ship passengers visited southeast Alaska each summer. This research focuses on the application of tourism best management practices (TBMP), a collaborative approach for addressing impacts of tourism, in the greater Juneau Alaska area and wilderness best management practices (WBMP) applied in nearby Tracy Arm-Fords Terror Wilderness on the Tongass National Forest. The approaches incorporate voluntary codes of conduct, an increasingly popular method for addressing impacts of recreation and tourism in protected areas. The research identified use-related indicators for inclusion in TBMP and WBMP programs. Findings, based on interviews with agency personnel, cruise industry representatives, and local residents, showed that vessel use levels, noise, pollution, and impacts on wildlife were important social and environmental indicators. Motivations for compliance included self-interest reasons (e.g., company image, public relations), peer pressure, awareness, and a sense of stewardship. The effort resulted in enhanced collaborative stakeholder relationships.

Definition of priority areas for public use using geoprocessing techniques in a conservation area in Brazil. Oliveira, C., Oliveira, F.B., Lima, J., Filho, R.B.R., Miranda, M.R. (*Espírito Santo State University, Brazil; carlos.oliveira@ifes.edu.br*; *fabriciabenda@gmail.com*; *juliao.lima@ufes.br*; *reinaldobrfilho@gmail.com*; *maiararm123@gmail.com*), Ferraz, F. (*Faculdades Integradas de Aracruz, Brazil; fillipe.ferraz7@gmail.com*), Zogaib Neves, L. (*Espírito Santo State University, Brazil; lomantozogaib@gmail.com*).

This work aimed to select the most appropriate areas for public use, in a conservation Area in the Sudeste of Brazil, in order to develop a procedure to guide managers through maps generated using multiple criteria analysis and geoprocessing techniques. In order to produce suitable maps, seven factors were defined, where relevant factors for evaluation of aspects related to ecotourism followed an order of priority established by Analytic Hierarchy Process. A map of suitability for public use was generated after the combination of factors, and as a result, a suitability surface ranging from less to more able was created, representing zoning area for the proposed objective. With the zoning of the conservation unit, it was possible to select areas suitable for ecotourism, as well as guide managers to restrict use in environments not suitable and that are being used today. Using the map as a guide and observing the tourism potential, it is possible to include new recreational activities in areas that have great potential for public use, but are not yet used.

A method to detect spatiotemporal changes of tourism/recreational potential in nature-based areas – with several case studies in Japan. Tanaka, N. (*Tokai University, Japan; tanaka_nobuhiko@tokai-u.jp*), Sugimura, K., Suzuki, A., Matsuura, T. (*Forestry and Forest Products Research Institute (FFPRI), Japan; kensugi@ffpri.affrc.go.jp*; *asakom@ffpri.affrc.go.jp*; *matsuu50@affrc.go.jp*).

Due to the long history between human and nature, Japanese countrysides are generally composed of a minute mosaic of traditional/modern, wilderness/urbanized landscapes, which attract a variety of tourists. This study developed a method to evaluate spatial characteristics of tourism/recreational (T/R) potential and their changes in such mixed landscapes in Japan. For evaluating T/R potential, we used geospatial filtering techniques to compute the densities in the distribution of various T/R resources or facilities. As case studies, we tested the method in several municipalities in Japan using an existing tourism database created by the Japan Travel and Tourism Association in 1998 and 2013. We found high potential areas where T/R resources or facilities were concentrated in each test site. The spatial distribution and the number of high potential areas partly changes during the studied period. Since tourist destinations are continuously changing due to discovery of new tourism resources or establishment/abolition of facilities; our method is useful for evaluating T/R potentials in such nature-based areas with changing mosaic land uses such as satoyama in Japan. This study was supported by the Global Environment Research Fund (E-0801) of the Ministry of the Environment, Japan and KAKENHI of the JSPS (Grant-in-Aid for Scientific Research (C) 24580226).

Towards sustainable growth in nature-based tourism destinations: clients' views of land use options in Finnish Lapland. Tyrväinen, L. (*Finnish Forest Research Institute, Finland; liisa.tyrvainen@metla.fi*), Uusitalo, M. (*MTT Agrifood Research Finland, Finland; marja.uusitalo@mtt.fi*), Silvennoinen, H. (*Finnish Forest Research Institute, Finland; silvennoinen@metla.fi*), Hasu, E. (*Aalto University, Finland; eija.hasu@aalto.fi*).

The recent rapid tourism development plans for nature-based tourism destinations have raised concerns about how sustainable land use targets can be achieved. This research aimed at studying tourists' environmental and accommodation preferences in northern Lapland tourism destinations. Altogether, 1 054 foreign and domestic tourists participated in the on-site survey carried out during 2009–2010 at two main tourism destinations in Finnish Lapland. The respondents were asked about their willingness to engage in sustainable tourism practices, as well as their evaluation of different land use development options in the tourism destinations. The results suggest that building density and patterns are important in defining the quality of the environment in tourism destinations, as they affect the nature experiences associated with accommodation. The tourists valued small-scale accommodation units, habitat protection, green infrastructure, and easy access to authentic nature in the environs of their accommodation site. The study results stress the need for careful planning and design in tourism destinations while aiming for eco-efficient land use. The efforts include conservation of natural forest vegetation and landscaping practices, in addition to ensuring views of nature from the accommodation.

Assessing sustainability of nature tourism along the Florida National Scenic Trail. Wan, B., Stein, T. (*University of Florida, USA; binwan@ufl.edu*; *tstein@ufl.edu*).

The sustainability of nature tourism was assessed from a socio-ecological approach at recreation areas. Key indicators were quantified in order to describe recreation areas in three dimensions: attractiveness, ecological sensitivity, and nature tourism-based

system risk factors. For measuring nature tourism attractiveness, qualitative and quantitative analyses were used to inventory and measure the existing attractions and their perceived importance. For measuring ecological sensitivity to nature tourism, a GIS model was developed based on vegetation, slope, soil and water variables. Integrating the previous two measurements and recreation pressure, a risk factor score was generated by using a fragility model. The findings demonstrated that areas have significantly different attractiveness related to perceptions about resource availability and desirability. A continuum map of ecological sensitivity to nature tourism was created based on their geographical properties. The fragility model operationalized risk assessment for each area. The analytical tool used here shows that a specific area can be better understood in its overall risk factor, which provides an indication to managers and planners on where their area falls on the evolution of nature tourism-based systems. With this information, decision-makers can then make appropriate management decisions with respect to the qualities they possess and the risks they face.

A-14 Integrating landscape protection, nature-based recreation and tourism, and rural development

Organizers: Tuija Sievanen (Finnish Forest Research Institute, Finland), Ellyn K. Damayanti (Bogor Agricultural University, Indonesia & Taiichi Ito (University of Tsukuba, Japan)

Using future scenario analysis to support participatory forest landscape planning in Vilhelmina, northern Sweden. Carlsson, J., Nordström, I., Öhman, K., Eriksson, L. (*Swedish University of Agricultural Sciences, Sweden; julia.carlsson@slu.se*; *eva-maria.nordstrom@slu.se*; *karin.ohman@slu.se*; *Ljusk.Ola.Eriksson@slu.se*).

Northern Swedish forests provide multiple ecosystem services, e.g. wood, biodiversity, reindeer husbandry, cultural and social values, water quality and carbon sequestration. Integrating these values into the forest planning process frequently requires that not only the forest owner but also other stakeholders be involved. The objective of this study is to assess the potential of future scenario analysis as a tool in participatory forest landscape planning. In a case study, Vilhelmina municipality in northern Sweden, forest owners and stakeholders were interviewed, and a workshop was held to discuss important factors for the future development of the local landscape regarding ecological, socioeconomic and political issues. Combined with researcher conducted process, this resulted in three alternative scenarios. We conclude that the scenario analysis process has produced information that can be used in forest planning. Primarily, the scenario method enables stakeholders to give input to the forest planning process, but enhances communication, learning and knowledge exchange among stakeholders to a lesser extent. The participatory element of the scenario analysis process can be extended further to enhance the participatory qualities and the participants' contribution to the scenario construction, i.e., by improving the discussion techniques and atmosphere, securing representation and increasing participation motivation in different ways.

Conservation of *Rafflesia zollingeriana*: Integrating conservation policy with local livelihood. Damayanti, E., Zuhud, E., Hikmat, A. (*Bogor Agricultural University (IPB), Indonesia; e11yn.d4mayanti@gmail.com*; *ervizal_amzu@yahoo.com*; *ahikmat62@yahoo.com*), Lestari, D. (*Indonesian Institute of Sciences, Indonesia; deeadewie@yahoo.com*), Syarief, N. (*Meru Betiri National Park, Indonesia; nur_rohmahtnmb@yahoo.com*).

Since its discovery in 1902 by Koorders at Puger (Jember, East Java), there are only a few studies on *Rafflesia zollingeriana*, e.g. Hikmat (1988), Zuhud (1988), Zuhud (1989), Hikmat (2008) and Dhistira (2011), and all focusing on bioecological aspects. *R. zollingeriana* is the only *Rafflesia* species found in eastern part of Java and distributed only in Meru Betiri National Park (Zuhud, 1998; Nais, 2001). Together with 17 other *Rafflesia* species, its existence has been threatened by (1) forest degradation; (2) double habitat specialization: Rafflesia species only grow in certain host (*Tetrastigma* spp.) and the host occurs only in certain habitats; (3) until now no one succeeded in *Rafflesia* propagation; and (4) collection of the *Rafflesia* buds by local communities for medicinal purposes. Though it is threatened, conservation policy of Rafflesia spp. has not become a top government concern. While biologists are making efforts in Rafflesia propagation, the first and fourth threats are also in progress. Various efforts to counter the threats are necessary. This study will clarify the perspectives of local communities and the park management on the future of *R. zollingeriana*, their ideas in conserving *Rafflesia*, and recommendations for conservation policy of *Rafflesia zollingeriana* will be formulated to improve local people's livelihood as well as incentive for *Rafflesia* conservation.

Effects of anthropogenic activities on forest landscape in the Khumbu valley, Nepal. Garbarino, M. (*Marche Polytechnic University, Italy; m.garbarino@univpm.it*), Lingua, E. (*University of Padova, Italy; emanuele.lingua@unipd.it*), Marzano, R. (*University of Torino, Italy; raffaella.marzano@unito.it*), Urbinati, C. (*Marche Polytechnic University, Italy; c.urbinati@univpm.it*), Carrer, M. (*University of Padova, Italy; marco.carrer@unipd.it*).

High altitude Himalayan regions are geo-dynamically active and sensitive to natural disturbances and, even in this remote region, human pressure greatly affects forest and landscape structure. The influence of human activities on the distribution of tree species and forest structure was assessed both at stand and landscape scale in the Sagarmatha National Park, Nepal. In the last decades, the fuelwood demand has increased due to the increased number of tourists and mountaineers. Stand structure and environmental variables were sampled in 173 plots, and anthropogenic variables were derived from thematic maps and satellite images. Through multivariate statistical analyses, we detected relationships between forest structure, anthropogenic influences, and topography. Due to lack of alternative energy sources, intensive logging is becoming a major threat in the area. Low density stands having sparse trees and rare big trees were located in close proximity to tracks and lodges. The excessive green branch removal has adverse effects on tree growth, forest resistance and resilience and the regeneration capacity of the forest. Natural resources have the potential to supply the local population needs, but current practices are not sustainable. A new management approach is necessary to enhance natural regeneration, maintain forest cover and increase protective functions.

Linking empowerment outcomes, social capital and gender in forest-based community ecotourism in Ghana. A multi-method approach. Hidalgo, A.R. (*University of British Columbia (UBC), Canada; anaelia@interchange.ubc.ca*).

Empowerment is seen as an expected outcome of community-based natural resource management (CBNRM) projects. This study assesses: (1) five dimensions of empowerment (i.e., political, social, economic, psychological and environmental); and (2) their links to gender and social capital (i.e., social networks, trust and norms), in the context of two forest-dependent community ecotourism projects in the Volta Region of Ghana. A mixed-method approach, including ongoing qualitative and quantitative analyses at the individual and community level, is used to unfold how social capital and gender may contribute to explaining outcomes within these five dimensions of empowerment. The presentation will focus on how this multi-scale and mixed methodology helps unfold the different ways in which empowerment outcomes differ by gender, and how social capital measures may partly explain these differences. Also discussed will be the likely motives and consequences of those gender differences in achieving sustainable forest management of community-driven projects.

An analysis of long-distance trail development in Japan based on protected area management and rural development. Ito, T. (*University of Tsukuba, Japan; ito.taiichi.ft@u.tsukuba.ac.jp*), Tanaka, N. (*Tokai University, Japan; tanaka_nobuhiko@tokai-u.jp*).

This paper reviews the development of long-distance trails in Japan from the view point of protected area management, and then reveals the value as tourism destination for trekkers as well as rural development for local people. Japan's recreational long-trail development started in 1969 inspired by the Appalachian Trail designation as one of the national trails in the United States as well as by the British countryside trails. Unlike these nations, Japan's Ministry of Environment developed a trail system stretching 21 000 km in 45 years without any trail laws or supporting non-profit organizations (NPOs). The results are mixture of mountain-ridge and countryside trails and paved sidewalks in urban areas while crossing many protected areas. The trail planners stressed easy access to trailheads, but trekkers preferred rerouting to mountain ridges while reducing paved routes. On the other hand, after the designation of pilgrimage trails in the Kii mountain range as a world heritage site in 2004, local NPOs started trail development independently from the national trail system. It is time to connect such popular local trails with national ones by communicating with each other. Such an experiment is being carried out in a new national park in tsunami-damaged areas expecting rural development by foot tourism.

Integrating community development with the management of grasslands and wetlands at Ke'erqin Nature Reserve, Inner Mongolia, China. Liu, J., Tu, C., Zhang, Y (*Renmin University of China, China; liujinlong@ruc.edu.cn*; *tuchengyue@qq.com*; *zhangyiwen@ruc.edu.cn*).

Since 2007, with the support of the UNEP/GEF funded Siberian Crane Wetland Project, various community development activities in the Beizifu community have been carried out at Ke'erqin National Nature Reserve in the Inner Mongolia Autonomous Region. These community activities covered a wide range of elements for an environmentally-oriented integrated development approach: restoration of traditional cultures, empowerment of local communities, self-organization, rural bio-energy, establishment of community revolving funds, promotion of micro-enterprises, participatory pasture management planning and monitoring, environmental education, and establishment of the community-initiated Beizifu Ke'erqin Pasture Protection and Management Association. Based on this intervention, this paper documents the reflections on key points for identifying interventions and projects in the Beizifu community supporting community-based natural resource management. These points are: translating the conceptual strategy for intervention into an operational strategy, targeting model and orientation, identifying actions supporting community-based resource management, developing trust between outsiders and the community, changing the behaviour and attitudes of local officials, and monitoring and evaluation of community actions. Finally, this paper reviews some critical issues for development interventions at the community level supporting sustainable natural resource management and biodiversity conservation, including development intervention, unification of community, culture – in particular traditional culture, and centralization and decentralization.

Is the sustainable forest management for ecotourism a food security plan? Rodriguez, S. (*Universidad Autónoma de Chihuahua (UACH), Mexico; sandra_osu@yahoo.com*), *Mayett-Moreno, Y.* (*Universidad Popular Autónoma del Estado de Puebla (UPAEP), Mexico; yesica.mayett@upaep.mx*).

In spite of several forest areas have been destroyed to increase land for agriculture, food insecurity is still an issue because people lack available cash to purchase food. Forest management for ecotourism becomes instrumental to community development, contributing to preserve resources and securing income to access food. The benefits associated with ecotourism are attractive to the new generation of farmers who want to stay on their farms. This study explores the perceptions of young adult farmers toward ecotourism as a substitute for farming and retention of work force in the community. It also identifies underlying motives to conserve the forest. Q methodology was used to assess perspectives, 36 statements were sorted by 16 young adults of a small rural community in Puebla, Mexico. Two factors that explained 47% of the variance were extracted. Young adult farmers are committed to conserving the forest and to following a management plan for ecotourism; however they do not perceive ecotourism as a substitute for farming but as a source of additional income and correlate it with their desire to stay in Mexico. The interest for forest conservation relies on cultural traditions and as an opportunity for women's involvement in forest management.

A-15 The future of recreation in forests and other nature areas

Organizers: Peter Fredman (Mid-Sweden University), Frank S. Jensen (University of Copenhagen, Denmark), Tuija Sievänen (Finnish Forest Research Institute, Finland) & David Edwards (Forest Research UK)

Willingness to travel to avoid conflict for forest recreation planning. Bakhtiari, F., Jacobsen, J.B., Jensen, F. (*University of Copenhagen, Denmark; fba@ifro.ku.dk; jbj@ifro.ku.dk; fsj@life.ku.dk*).

Expanding knowledge of the conflict characteristics and the causes might assist recreation planners in conflict reduction (Jacob and Schreyer, 1980). Based on a questionnaire we categorised forest visitors according to their activities and for each group we looked at causes of conflict. Furthermore we constructed a choice experiment to estimate the distance visitors are willing to travel to encounter fewer visitors and thereby potentially fewer conflicts. Comparing marginal willingness to travel of different user groups suggests that some groups do have a willingness to travel further than the average to reach a forest with few visitors. In general average willingness to travel to reach a forest area with few visitors is 6 km per visit. But mountain bikers, peace lovers and horse riders are willing to travel 4 km more per visit to reach a less crowded forest. In the other end we find exercisers who are willing to travel 2 km less smaller than the average to reach a less crowded forest.The discussion provides managers with comprehensive information of the preferences of different forest user groups which can assist in a development of policies aimed at managing conflict among forest user groups.

Understanding perceptions of nature-based tourism's adaptive capacity to climate change in Maine. De Urioste-Stone, S., Scaccia, M. (*University of Maine, USA; sandra.de@maine.edu*; *matthew.scaccia@maine.edu*).

The purpose of this research is to gain an in-depth understanding of diverse perceptions of adaptive capacity of tourism destinations in Maine to climate change. Tourism is a key component of Maine's economy, and is increasingly important to the economic development of many rural communities. The majority of visitors to Maine participate in nature-based tourism activities. Climatic conditions are key attributes in attracting visitors to the region, making the industry highly sensitive to weather and climate variations. Climate change scenarios for Maine suggest increases in average annual temperature and precipitation and reduction in snow. A case study methodology is being used to understand stakeholder perceptions of climate resilience of rural tourism destinations. Data is being collected using semi-structured interviews with a diversity of tourism stakeholders to understand their perceptions of destination resilience, emissions reduction, and adaptive capacity. Initial analyses of the first round of interviews suggest different levels of concern exist about climate change impacts to the industry among the diversity of stakeholder types (private, non-governmental, NGOs). Few stakeholders have embraced emission mitigation strategies as part of their business practices. Limited adaptation strategies are currently in place (e.g. snowmaking, product diversification, etc.).

Forest recreation monitoring in Great Britain: lessons learned and future directions. Edwards, D., Marzano, M., O'Brien, L. (*Forest Research, United Kingdom; david.edwards@forestry.gsi.gov.uk*; *mariella.marzano@forestry.gsi.gov.uk; liz.obrien@forestry.gsi.gov.uk*).

Great Britain (GB) has a long-established programme of outdoor recreation monitoring, most notably as part of regular national surveys conducted separately in England, Scotland and Wales. A considerable body of data has been generated over the last 20 years revealing patterns and trends in forest-based engagement. This paper begins with a brief overview of the methods and key insights revealed by recent monitoring in GB. Our main aim, however, is to step back from the data and reflect upon the direction and purpose of outdoor recreation monitoring. Firstly, we examine how, and to what extent, the data is being used to support forestry decision-making. Secondly, we explore the shift away from visit numbers to include a greater range of measures of the benefits of engagement. Thirdly, we consider the evolution in conceptual frameworks away from indicators of sustainable forest management towards natural capital accounting and an ecosystems approach. There is a risk that monitoring becomes a tick-box exercise that generates data for its own sake. In contrast we highlight its important role in policy advocacy, and the need to generate tailored evidence-based claims of the positive impacts of engagement with nature on individuals, local communities, and regional and national economies.

A Web-based panel approach to outdoor recreation inventories – experiences from Sweden. Fredman, P. (*Mid-Sweden University, Sweden; peter.fredman@miun.se*).

This presentation deals with a novel approach to monitor outdoor recreation participation at the national level and presents preliminary results from an ongoing inventory in Sweden. The Nordic region is globally well known for excellent outdoor recreation opportunities, including the "friluftsliv" tradition and the Right of Common Access to nature areas. In Sweden, eight of the 16 national environmental objectives include goals related to outdoor recreation and in 2010 the Swedish parliament voted for a national policy on outdoor recreation which was followed by a government writ on measurable objectives for each of the ten policy areas in 2012. As indicators and methods to monitor these policies recently were developed, a "last-visit" web-based panel approach was implemented to monitor outdoor recreation participation and future trends. This approach includes twelve waves of 700 responses each during one year with questions concerning aspects such as participation, accessibility, motivation and constraints. The aim of this presentation is to provide a discussion on methodological considerations related to outdoor recreation population surveys as well as preliminary participation data and trends based on the ongoing national inventory in Sweden.

Using existing data in national biodiversity monitoring program (NILS) to create new approaches for monitoring recreational indicators. Hedblom, J., Christensen, P., Svensson, J. (*Swedish University of Agricultural Sciences, Sweden; marcus.hedblom@slu.se*; *pernilla.christensen@slu.se*; *johan.svensson@slu.se*).

The monitoring program National Inventory of the Landscape in Sweden (NILS) combines field inventory with aerial photo interpretation. The aim is to monitor prerequisites for biodiversity and impact of land use on a landscape scale. However, the sampling approach provides data that can be used for indicators, e.g. for recreational assessments. Line intersect field data can be used to generate information on the amount (m/ha) and length of paths in different areas and habitats. Detailed interpreted aerial photos can be used to detect changes in woodlands and forests that fulfill high recreational criteria, such as old, large-crowned deciduous trees and forests that are easy to access. The interpretation of these analyses has required a transdisciplinary approach. Natural sciences that collect biophysical data for biodiversity need to have a close dialogue with social sciences that know what data to combine to find landscapes with high recreational values. An innovative approach is to use existing photos, originally for documenting permanent plots, to rate amenity values in the landscape. In total about 28 000 photos, systematically collected, are available per national-scale inventory rotation. The data provided by NILS have been suggested to be used in the Swedish national environmental objectives as indicators for recreation.

Assessment of tourism impacts towards sustainable co-management approach- a case study at Satchari National Park, Bangladesh. Islam, M. (*University of Queensland, Australia; wasiulislam7@yahoo.com*), Rupa, M. (*Khulna University, Bangladesh; mehzabin.ku@gmail.com*), Sadath, M. (*Khulna University, Bangladesh & Georg August University, Göttingen, Germany; mnsadath@yahoo.com*).

Tourism expansion creates both positive and negative impacts on the destinations like Satchari National Park (SNP). The purpose of this study was to assess the socio-cultural, economic, environmental and institutional impacts of tourism development considering the local context of SNP and co-management approach (CMA). This study was based on field survey following a purposive sampling method for face-to-face interviewing of the local residents and project officials. SNP has potential for (eco)tourism because of its wilderness, landscape, biodiversity and easy communication. People from home and abroad visit this destination in large numbers during the peak season (November to March). The results showed that respondents strongly agreed with the idea that tourism provided many economic and socio-cultural benefits but the residents were ambivalent about its costs. They opined that tourism at SNP had the potential to generate alternative incomes to protect the park, build environmental awareness, increase literacy, etc. On the other hand, tourism caused social instability, a breakdown in traditional conservativeness, seasonality of jobs, etc. The findings of this research might be helpful to develop a strategic management plan for SNP tourism where the local residents are crucial tourism development partners on the way to sustainable application of CMA at the SNP.

Inclusion of recreational indicators in the National Forest Inventory – experiences and results from Denmark. Jensen, F., Nord-Larsen, T., Johannsen, V., Skov-Petersen, H. (*University of Copenhagen, Denmark; fsj@life.ku.dk*; *tnl@life.ku.dk*; *vkj@life.ku.dk*; *hsp@life.ku.dk*).

Several international processes aim to monitor forest status, and the focus on the recreational/social function is increasing – as well as the demand for cost-effective monitoring efforts. The Danish National Forest Inventory (NFI) is based on a 2 km × 2 km grid, with four sample plots placed in a 200 m × 200 m square in each grid cell. Based on a 2006 trial inventory, 11 recreational indicators were identified including trails, hunting facilities and litter. The paper presents results founded on a total of 4 138 forested clusters (constituting the primary sampling units) inventoried in 2008–2012. It was found that hunting facilities were present on 27% of the clusters; forest roads/trails on 35%, while tracks were found on 17% – indicating access facilities are present on more than half of the Danish forest area. The results can be related to ownership status and geographical/administrative regions. It is revealed that national forest inventories, which are relatively simple and cost efficient, can be expanded to include a number of recreational/social indicators which generally is not available otherwise. The continuity of the measurements will be a valuable addition to sustainable knowledge-based management and policy decisions.

Outdoor Recreation Future in Finland. Sievänen, T., Neuvonen, M. (*Finnish Forest Research Institute, Finland; tuija.sievanen@metla.fi*; *marjo.neuvonen@metla.fi*).

In Finland, the government and the ministries demand continuously updated foresight information. The systematic monitoring for outdoor recreation trends started in the end of 1990s. The national outdoor recreation demand survey has been conducted two times. The methodologies used both in data collection and with statistical calculation are designed to produce comparable recreation demand information across time. The trend information covers participation rates and frequencies of 86 recreation activities, characteristics of close-to-home recreation occasions and nature trips, use of different types of recreation areas, etc. One remarkable change over the last ten years is that people 65–74 years old are participating more actively now than the same age group ten years ago. Growing activities in popularity are, to mention some, spending time at recreation home, gathering small wood, forest work in leisure time, camping in back country and bird watching. Qualitative scenarios are used for better overall understanding how societal changes may reflect changes in outdoor recreation. The relevant components of change are identified as an aging population, expected increase in living multiple homes and climate change, which will have consequences related to where people recreate, what kind of recreation activities people participate in and how recreation opportunities are available for different population groups.

Managing forest aesthetics in the boreal fringe. Sténs, A., Marald, E. (*Umeå University, Sweden; anna.stens@historia.umu.se*; *erland.marald@idehist.umu.se*).

The value and management of forest aesthetics have been heavily studied since the early 1970s. However, studies moving outside of urban areas are less frequent. This also holds for Sweden. Previous research has focused on the southern, urban parts of the country rather than the sparsely populated, forest dependent, northern interior. However, to increase the quality of livelihood in these areas, an aesthetically attractive environment is an important component. This paper discusses the attitudes to aesthetical considerations among forest owners and consultants in the northern parts of Sweden. It raises questions such as: Which considerations have been taken to aesthetical values in boreal forests? What policies lay behind and what was gained from these considerations? What are the attitudes to forest aesthetics today and who will be responsible for the preservation and creation of aesthetical values in the future? The study has been conducted through a qualitative literary review of previous research and interviews with present stakeholders. Preliminary results show that the societal interest in forest aesthetics is high, but policies regulating these values have become more vague. There also seem to be a discrepancy between forest owner's and consultant's attitudes when discussing aesthetical considerations in boreal productive forests.

A-16 Ethics and values in relation to forest, wildlife and recreation management

Organizers: Christian Gamborg & Frank S. Jensen (University of Copenhagen, Denmark)

Fires, forests and conflict in times of rapid environmental change in Sweden and Australia. Eckerberg, K. (*Umeå University, Sweden; Katarina.eckerberg@pol.umu.se*), Buizer, M. (*Murdoch University, Australia; marleen.Buizer@gmail.com*).

Environmental problems seem to be increasingly complex, hard to solve by instrumental rationality, and laden with conflict when they demand human interventions in nature. The use of fire is one such contested intervention. This paper examines the role of conflict and deliberation in forest fire management practices in Sweden and Australia whose landscapes have historically been shaped by fire. In Sweden, burning is gradually emerging on foresters' and nature conservationists' agendas for nature conservation purposes. In Australia, prescribed burning has been practiced on a relatively broad scale, chiefly to prevent larger fires and also for nature conservation purposes. Touching on a wide range of values, including biological diversity, human safety, traditional heritage and professional identity, fire management is often the topic of fierce debate. Contemporary politics places high expectations on collaborative governance, drawing attention to the twin concepts of conflict management and deliberation. How does collaborative governance manifest itself relating to fire management? And what are its chances considering the Swedish and Australian contexts with their strong reliance on technical scientific expertise? We conclude that forms of local, collaborative governance in which conflicts and difference have a place, rather than generalized knowledge, are promising but rare processes to move forward.

A bottom-up approach to criteria and indicators: values and cues in public evaluations of forest management in Australia. Ford, R., Anderson, N., Williams, K., Bennett, L., Nitschke, C. (*University of Melbourne, Australia; fordr@unimelb.edu.au*; *neridama@unimelb.edu.au*; *kjhw@unimelb.edu.au; ltb@unimelb.edu.au*; *cnitschke@unimelb.edu.au*).

Criteria and indicator frameworks are an important tool for implementing and evaluating Sustainable Forest Management (SFM). While indicators are generally designed with some participation from interest groups, the values or criteria that members of the public use to evaluate forest management have received less attention. In this study, the aim was to explore values and cues in public evaluations of forest management and to consider implications for criteria and indicator frameworks. Data were collected through 35 laddering interviews with members of the public and forest interest groups in the state of Victoria. These were analysed for links among psychological concepts: held values, valued attributes (related to SFM criteria) and cues used to evaluate forest management (analogous to SFM indicators). Cues were compared to indicators in existing SFM frameworks. This process led to the development of a bottom up framework consisting of seven valued attributes and associated indicators. There were many similarities to existing SFM frameworks for attributes relating to productive, natural and socio-economic outcomes, but an important component of public evaluations, experiential valued attributes, is largely absent from current frameworks. We argue that experiential criteria and indicators should be considered for inclusion in future criteria and indicator frameworks for SFM.

Recreational hunting – a comparative study of attitudes to rear and release among Danish hunters, land owners and the general public. Gamborg, C., Jensen, F. (*University of Copenhagen, Denmark; chg@ifro.ku.dk*; *fsj@life.ku.dk*).

Forest- and open land-based recreation takes many forms. Hunting is a popular pastime in many western countries. Taking the example of Europe, in particular Denmark, hunting does not give rise to many serious area based conflicts – but is nonetheless controversial. In several countries, the population of wild birds is not abundant enough to meet demand, and hence the vast majority of birds shot every year are pheasant and mallard purpose-bred in cages, sheds and pens for the sport (thus a practice of shooting). Although perfectly legal, this practice give rise to value based conflicts and challenges more traditional hunting/anti-hunting arguments, such as hunting being based on sustained yield harvest principles. The paper presents results from a unique dataset consisting of nationally representative samples of approximately 1 100 answers from each of the three key actors: the general public, land owners and hunters on attitudes to rear and release. The data was collected as web-based surveys (2012/2013). The aim is to give a more nuanced view of the support/opposition to rear and release and to get a better understanding of this by means of underlying value issues. The paper analyses attitudes in relation to wildlife value orientations also obtained through this survey.

Effectiveness of integrated conservation and development projects around central Indian tiger reserves. Macura, B., Secco, L., Pisani, E. (*University of Padova, Italy; biljana.macura@studenti.unipd.it*; *laura.secco@unipd.it; elena.pisani@unipd.it*).

In tropical human-dominated forest landscapes, top-down exclusive approaches to forest and biodiversity conservation frequently creates local conflicts due to unequal distribution of power, rights and benefits. In India, the failure of restrictive policies has led governments to think of more inclusive approaches and to involve local people in conservation. While policies became more participatory, that is not proven true for local level practices. Integrated conservation and development projects aim to improve conservation outcomes with inclusive and incentive-based approaches. However, past attempts to implement these projects had mixed success. This study aims to (1) evaluate effectiveness of integrated conservation and development projects around central Indian tiger reserves with respect to changes in attitudes and behaviour of targeted local communities and (2) reveal the functional role of local governance, power relations and negotiation power in the project. The study will combine qualitative and quantitative methods including in-depth interviews with tiger reserves authorities; local NGOs; village self-government and eco-development committee members; and questionnaires administered at the village level with quasi-experimental design. Study results are expected to reveal the reasons for the misfit between policies and practice and to highlight the importance of local level social dynamics, actors and institutions.

Negotiating indigenous collaboration in forestry in Quebec, Canada: finding pathways through multiple processes and actors. Wyatt, S. (*Université de Moncton, Canada; swyatt@umce.ca*), Blanchet, É., Gonzalez, N., Fortier, J. (*Université Laval, Canada; edouard.julien.blanchet@gmail.com*; *noemie.gonzalez@gmail.com*; *jean-francois.fortier.1@ulaval.ca*), Fournier, A. (*Université du Québec à Rimouski, Canada; u_f_odrey@hotmail.com*), Hebert, M. (*Université Laval, Canada; Martin.Hebert@ant.ulaval.ca*), Lewis, N. (*Université du Québec à Rimouski, Canada; Nathalie_Lewis@uqar.ca*).

Indigenous peoples' roles in Canadian forestry have expanded enormously during recent decades, encouraged by a variety of policies and programs from governments, industry and indigenous organisations. While researchers have examined many models of collaboration, along with the interests and roles of participants, less attention has been paid to possible interactions between different processes or the effects of these. We undertook case studies with three indigenous communities in Quebec, Canada, identifying the range of different forest-related processes in which each community had engaged over the last twenty years. Focusing on critical processes, we examined the links between various processes, the outcomes of these and the relations between parties, both indigenous and non-indigenous. Our results highlight the complexity of each case, both in relation to the actors and the processes. Characteristics of actors include not only values, objectives and knowledge, but also perceptions of other actors, of context and institutions and of available options. Processes each have their own rules and resources, affecting actors' behaviour within the process and leading to changes in situations, in processes and in actors themselves. Mapping this complexity helps explain why the results of a single policy or program can be so different depending upon the situation.

The importance of the social and cultural dimensions of wildmeat in periurban indigenous communities in Leticia (Colombia). Yagüe, B. (*Universidad Nacional de Colombia Sede Amazonia, Colombia; blancayaguepascual@gmail.com*), Van Vliet, N. (*Office National des Forêts-Andina (ONF), Colombia; nvanvliet@onfandina.com*), Quiceno, M. (*Fundacion SI, Colombia; dhuryi@gmail.com*), Morsello, C. (*Universidade de São Paulo, Brazil; alicebrites@gmail.com*), Cruz, D. (*Fundación Omacha, Colombia; danielcruzantia@gmail.com)*, Avirama, M. (*College of the Atlantic, USA; anamaytik@hotmail.com)*, Nasi, R. (*Center for International Forestry Research (CIFOR), Indonesia; r.nasi@cgiar.org*).

In the Amazonian city of Leticia, Colombia, and in neighboring indigenous communities, the strong influence of market, migration, state policies and cultural changes, are pushing a nutrition transition also characterized by the substitution of wild animal proteins by industrialized meats. Despite the fact that commercialization is forbidden in the three countries that share this trifrontier region (Brazil, Peru and Colombia), bushmeat is still frequently consumed among rural and urban families. Through an ethnographic-based investigation with a participant-observation field work, our study explores the cultural values of bushmeat beyond market rules, the importance of animal hunting and wild meat consumption in indigenous communities near to urban areas, and its role in food security. Our study evidences the high value of subsistence hunting for nutritional purposes, and the dynamic networks of bushmeat that consolidates indigenous identity and solidarity. In addition, the results show native's deep knowledge of the territory, its inhabitants and interactions and how this is reflected in quotidian matters and forest management. This evidences that the cultural dimension of bushmeat contributes to social cohesion and cultural reproduction. Understanding this role of bushmeat in modern indigenous livelihoods provides tools for rethinking wildlife conservation and ecosystem services in a holistic way in complex contexts.

Conflictive interactions between traditional forestry knowledge of Dong minority and modern policy interventions in S village: an actor-oriented perspective. Zhang, M., Liu, J., Long, H. (*Renmin University of China, China; cathy_minghuizhang@163.com; liujinlong_jl@hotmail.com*; *longhx1986@163.com*), Yuan, J., Zhao, B. (*Guizhou University of Finance and Economics, China; yuanjuanwen@yahoo.com*; *121423074@qq.com*).

Enormous changes have occurred over the last 60 years in the interrelations of people, communities and forests, for many socio-economic and political reforms have been launched in rural regions since 1949. This paper demonstrates two stories of S village in south mountainous China, through actor-oriented perspective, to reveal the interface of differences between modern policy interventions and traditional knowledge for managing and using forest resources and to show the conflicts and compromises among various actors in the processes of interactions between the two kinds of knowledge systems. This paper summarizes that, traditions have been diminished in the era of rapid social change, including marketization and globalization. Meanings of trees and mountains for villagers have changed. As such the knowledge system for managing forests has also changed. The changes to the customary laws and traditional organizations for forest governance were the result of conflicts and compromises among various stakeholders whose knowledge and goals were impacted by the changing meanings of trees and mountains. Modern policy interventions may have conflicts with and displace traditional knowledge in community practices. With the increased influence of industrialization and marketization, the forests and mountains may be faced with more powerful interventions that displace tradition.

Triad stimulus NUR (Nature, Use, Religion) pro-conservation for sustainable forest management in Indonesia. Zuhud, E., Hikmat, A., Damayanti, E., Metananda, A. (*Bogor Agricultural University (IPB), Indonesia; ervizal_amzu@yahoo.com; ahikmat62@yahoo.com*; *e11yn.d4mayanti@gmail.com; arya_arismaya@yahoo.co.id*).

Forest management done by the Indonesian government has alienated local communities for over 50 years and has failed to achieve sustainable forests. Natural forest management by customary communities has been proven to realize forest biodiversity conservation in Indonesia more effectively. This experience deserved to become inspiration and a lesson learned to develop policy for sustainable management for forests now and for the future. Traditional communities who have been living in Indonesian forest ecosystems have been maintaining the triad stimulus pro-conservation to manage their forest sustainably. Triad stimulus pro-conservation are three stimuli that unite and develop attitudes (cognitive, affective, and overt actions) that are pro-conservation, namely: (1) Natural stimulus; truth values from nature that are derived from knowledge on the characteristics of biodiversity's biological ecology; (2) Use/benefit stimulus; use values for human, such as economic benefit, social benefit, ecological benefit; and (3) Religion (or interpreted as "voluntary") stimulus; intrinsic and noble values derived from the Creator, spiritual values, inner satisfaction, equitable, civilized, and sovereign values. Attitudes and actions of pro-conservation communities in managing forest sustainably are integrated in the triad stimulus pro-conservation.

A-17 Linking landscape, forests and people: The historical roots of biocultural diversity

Organizers: Mauro Agnoletti (University of Florence, Italy), Jinlong Liu (Renmin University of China) & Steven Anderson (Forest History Society, USA)

The Italian national register of historical rural landscapes. Agnoletti, M. (*University of Florence, Italy; mauro.agnoletti@unifi.it*).

Sustainable development, as well as environmental policies in the last decades, has developed strategies and actions considering farming and forestry mostly as a factor of disturbing or degrading the ecosystem. Taking into account the present economic, social and environmental problems of the earth, is probably necessary to develop a different approach, looking for examples of a positive integration between human society and nature, studying them and applying the lesson learned. The research for the national register of historical rural landscapes presents more than a hundred areas where the historical relationships between man and nature have generated cultural, environmental, social and economic values. It has involved 14 universities and more than 80 researchers for three years. The results show that is not only the economic face of globalization negatively affecting landscapes, but also inappropriate environmental policies denying the importance of cultural values. The recent CBD-UNESCO joint program on biocultural diversity finally recognizes these values, as well as UNESCO World Heritage List and the FAO Globally Important Agricultural Heritage Systems, which now also includes forest landscapes. This research has produced new laws establishing the National Register of Historical Rural Landscapes and Traditional Practices, which includes forests, pastures and farmed land and the National Observatory for Rural Landscapes.

Impact of ancient Maya land use on present-day forests. Brokaw, N. (*University of Puerto Rico-Rio Piedras, USA; nvbrokaw@ites.upr.edu*), Ward, S. (*Mahogany for the Future, Inc., USA; seward@hpcf.upr.edu*), Beach, T. (*Georgetown University, USA; beacht@georgetown.edu*), Cortes-Rincon, M. (*Humboldt State University, USA; marisol.cortes-rincon@humboldt.edu*), Luzzader-Beach, S. (*George Mason University, USA; sluzzadderbeach@gmail.com*), Walling, S. (*Community College of Philadelphia, USA; swalling@ccp.edu*).

We study how ancient Maya land use has affected present-day forests in Belize. The population of the ancient Maya peaked in about 900 AD, coinciding with widespread deforestation and soil erosion. The Maya then declined abruptly, permitting forest recovery that has been uninterrupted in our study area, where there are also abundant ancient remains. Our interdisciplinary research includes archaeology, geo-archaeology, and ecology. We study spatial patterns of ancient remains and land use, evidence of crops on ancient pot shards, soil history and present quality, ancient and present hydrological patterns, and present-day tree species composition, abundance, and diversity across the landscape. Contrary to expectation, our studies to date indicate that forests in our study area do not contain a disproportionate abundance of tree species reportedly used and promoted by the ancient Maya. However, these forests do vary according to topographic and soil conditions that were created or strongly influenced by the ancient Maya. We discuss the implications of our work for understanding the consequences of modern deforestation and for improved land use and forest management.

Disturbance history of the Medicine Bow Range, Wyoming, using historical documents, contemporary forest inventory, and lake sediment cores. Carter, V., Brunelle, A. (*University of Utah, USA; vachel.carter@gmail.com*; *andrea.brunelle@geog.utah.edu*), Shaw, J. (*U.S. Forest Service, USA; jdshaw@fs.fed.us*).

In the late 1860s, Euro-American settlement and related activities, including logging, began affecting the composition and structure of forests of the western United States. These impacts were likely to be most substantial along the corridor of the trans-continental railroad. Construction and maintenance of the railroad created a high dependence for wood, especially the cutting of lodgepole pine forests for railroad ties (known as tie hacking). Although some of the impact has been documented, the amount of ecosystem change in lodgepole pine forests is not well known. In this study we attempt to reconcile and interpret three different accounts of forest history data; (1) a moderately detailed written historical record, (2) a contemporary plot-based forest inventory, and (3) a sedimentary record of pollen and charcoal. The goal of this study is to characterize recent changes to lodgepole pine forest in the Medicine Bow Range of southeastern Wyoming, in the context of the pre-settlement forests. In addition to landscape-level patterns of stand age and distribution, we found distinct patterns in charcoal and pollen deposition corresponding to three distinct periods of forest history: the pre-settlement period, the railroad tie-hacking period, and the modern forest management period.

Influence of culture on greening the environment in Ido local government area of Ibadan, Nigeria. Julius, A., Akinyemi, O., Onilude, Q., Oniroko, N., Eyinfunjowu, L., Solanke, I. (*Forestry Research Institute of Nigeria, Nigeria; talktobayo247@yahoo.com*; *akinyemi77@yahoo.com*; *omoonilu@yahoo.com*; *chopperflows@yahoo.com*; *tessyplace101@yahoo.com; solancy1983@hotmail.com*), Ajisebiolola, B. (*National Institute for Cultural Orientation (NICO), Nigeria; omobolanle83@yahoo.com*).

This study examined the beliefs, customs, practices, and social behavior of Ido local government area (LGA) populace in relation to tree planting, tree conservation and forest management within their locality. 250 households were randomly selected among the houses with trees around, while structured questionnaires were administered among the selected household heads. The majority of the households (71.1%) indicated the reasons for conserving trees within their domain which are inculcated in their cultures, while others plants trees to landscape their environments. The tree species planted in the area included *Azadiracta indica, Threoboma cacao, Pinus radiata, Mangifera indica, Terminalia catappa* and various medicinal plants. Study further revealed that the households use these trees to protect their environment from degradation and loss of soil biodiversity; also the households always converge under the shade of these trees to solve their problems in their cultural ways. Sacred groves used for spiritual, rituals and initiation purposes were also sighted in the area. It is suggested that people should not undermine their culture and that culture should be transmitted from generation-to-generation for it may help in achieving a greener future at local and national levels.

Contributions to human well-being from sharing ecosystem services through non-market social networks in Satoyama landscapes. Kamiyama, C., Nakazawa, N., Saito, O. (*United Nations University, Japan; chihokamiyama@gmail.com; nakazawan@unu.edu*; *saito@unu.edu*), Hashimoto, S. (*Kyoto University, Japan; hash@kais.kyoto-u.ac.jp*), Kohsaka, R. (*Kanazawa University, Japan; kohsaka@hotmail.com*).

Satoyama is a term applied to dynamic mosaics of socio-ecological production landscapes maintained through long-term human activity, where people support each other to enhance their use of natural resources and play an important role in sustaining biodiversity. Such landscapes are often characterized by bartering or sharing diverse forest and agricultural products within and beyond their communities. However, urbanization and globalization in recent decades have weakened landscape-based personal connections and sharing mechanisms, which may undermine resilience of local societies against external shocks. The objective of this research is to quantitatively investigate how such sharing mechanisms work and how they contribute to human well-being in Noto Peninsula, Japan. In-depth surveys were conducted in four focal communities (Natauchi, Nagasaki, Kanakura and Shunran communities) to track trends and changes in communal sharing networks. We found that sharing of forest and agriculture products significantly contributed to human well-being, but due to demographic changes in community population and occupations in recent decades, some people are less dependent on locally available ecosystem services. The research also discusses the relationship between traditional knowledge and maintaining local networks, and explores future challenges of these networks to build localized models of societies living in harmony with nature.

Sustainable ecological history? A story of forest management practices out of the official silviculture along 1000 years of landscape dynamics. Salbitano, F. (*University of Florence, Italy; fabio.salbitano@unifi.it*).

In retracing the history of the relationship between man and the forest, it often falls into the temptation to translate the forest practices of the past into theoretical models of modern forestry. In doing so, the issue of sustainability has often been regarded as belonging to some models of forest management and not to others. But is this always true? In many places of the world the principles of forest management are almost unknown despite the fact that the woods are an integral part of the imaginary and of the everyday life of people. The forest is perceived as a resource but also as a cultural reference, a space that becomes a key part of the landscape. The case study of Mount Catria (central Italy) revealed precisely these characteristics: despite the long history of forest practices tied to a monastic property, the relationship between man and forest, society and landscape, found original pathways (practices and management systems) towards sustainability. The research evaluates the historical dimension of sustainability through the lens of landscape changes as induced by one millennium of human activities in and around the forest and now resulting in a vanishing cultural landscape.

Assessing the impact of changes in biodiversity on food security of local communities: the case of the Fatick province, Senegal. Sambou, A., Ræbild, A. (*University of Copenhagen, Denmark; ansa@life.ku.dk*; *are@life.ku.dk*).

The potential of biodiversity to increase and sustain food security is increasingly recognized by the international research community. In our days, dietary assessment studies that have assessed how biodiversity actually contributes to human food security are few. This study measured the proportion of cereals and their products; the cultivated vegetables and tubers; wild fruits and leaves; cube, salt and spices in the rural communities' diets. This study also measured the contribution of each food group in terms of nutrient values for rural communities. The origin of each food was assessed. We also assessed the status, the use and dynamics of vegetation. The food intake was estimated from four multiple-pass 24 hour food intake recalls in three villages (Samba Dia, Boly Serere and Poukham Tock) with 109 households. We used local knowledge (perception), ecological methods and satellite imagery analyses to assess the vegetation status, use and dynamics. The results showed that species diversity and density is higher in forest landscape that in cropland, fallow, tans and mangrove landscape. The most of appreciated species are rare in landscape classes (forest, cropland, Fallow, tans and mangrove). 98% of local people agreed that the vegetation changed. This is confirmed by satellite images analyses. Considering the proportion of food group, the cereal and their products constituted 80%.

A-18 Value of traditional knowledge for sustainable forest management

Organizers: Yeo-Chang Youn (Seoul National University, Republic of Korea), Jinlong Liu (Renmin University of China), William Armand Mala (University of Yaounde I, Cameroon) & Ronald Trosper (University of Arizona, USA)

Threats to indigenous beliefs and cultural practises used in forest protection: case study from southwest Nigeria. Babalola, F. (*University of Pretoria/University of Ilorin, South Africa; Fola.Babalola@up.ac.za*), Borokini, T. (*National Centre for Genetic Resources and Biotechnology (NACGRAB), Nigeria; tbisrael@gmail.com*).

Indigenous beliefs and cultural practises behind establishment of sacred forests play vital roles in forest protection and conservation in Africa. However, sacred forests have been reported to be disappearing with the inherent indigenous beliefs and cultural practises. This study investigated the socio-economic factors posing as threats to existence of selected sacred forests in Balogun and Ososun communities of Ogun State, southwest Nigeria. The selected sacred forests have historical background to establishment of the adjoining communities with strong linkages of indigenous beliefs and cultural practices to people's livelihoods and forest protection. The forests house Oso'ro River which is believed to possess special power to heal children from various sicknesses and diseases. Apart from developmental projects that pose great threats to existence of the sacred forests, the introduction of modern religion (Christianity and Islam) as well as modern cultures and lifestyles, especially among the youths and elites, are causing erosion of the local beliefs that are in support of sacred forests. There is need for re-orientation of the perception that removal of sacred forests will translate to removal of evil spirits. Local people also need to appreciate multiple roles of forests in addition to protection of their long standing cultures.

An unwelcome transition: declining traditional ecological knowledge and its implications on ecosystem services in northern Ghana. Boafo, Y., Saito, O. (*United Nations University, Japan; yaboafo@yahoo.co.uk*; *saito@unu.edu*), Takeuchi, K. (*University of Tokyo, Japan; atake@mail.ecc.u-tokyo.ac.jp*).

Northern Ghana's semi-arid ecological zone presents a prime example of exceptionally vulnerable ecosystems experiencing negative impacts of climate and ecosystem changes. Using an evidence-based approach, this study examines the linkages between traditional ecological knowledge (TEK) and ecosystem services in agro-based communities. We draw on multiple rapid rural appraisal approaches to document and evaluate socio-cultural norms, namely rituals, ceremonies and taboos regarding ecosystem services. Results point to the innate relationship between TEK and the collection, utilization and conservation of ecosystem services. Although TEK practices have acted as coping strategies against negative impacts of climate and ecosystem change, current socio-economic and political drivers; increased population, migration of youth, religious acculturation, changing land tenurial arrangements and central government structures hinder the effectiveness and practicability of TEK practices ecosystem service utilisation and management. While locals are increasingly aware of the dangers posed by degradation and loss of their ecosystem services, blamed largely on declining socio-cultural systems, the majority feel incapable of actively addressing them. The study concludes that TEK remains essential for enhancing resilience and adaptation to climate-variability and change. Suggestions on supporting TEK practices for ecosystem service sustainability advocating for high participation of local communities are proposed.

Value of traditional knowledge in sustainable forest management. Camacho, L., Gevana, D., Carandang, A., Camacho, S., Paras, F., Del Rosario, P. (*University of the Philippines Los Banos, Philippines; camachold@yahoo.com.ph*; *wuweidix@yahoo.com*; *papcarandang@yahoo.com*; *sonny_camacho@yahoo.com; fdparas@gmail.com*; *peterdelrosario@gmail.com*), Dulawan, L. (*Ifugao State University, Philippines; loinazdulawan@yahoo.com*), Rebugio, L. (*University of the Philippines Los Banos, Philippines; lucrebugio@gmail.com*).

One of the important considerations in pursuing sustainable forest management is the preservation of rich traditional forest management practices. The Ifugao Rice Terraces in the Cordillera Mountains of northern Philippines have been widely recognized as one of the most successful indigenous forestry cases in the world. Listed as a UNESCO World Heritage site, its agroforestry system known as *muyong* is lauded as a sustainable approach to forest conservation, watershed rehabilitation, biodiversity conservation and assisted natural regeneration. Given this background, we conducted a study to describe *muyong* in terms of its socio-economic and cultural impacts to local community. Key informant interviews were done to capture the facilitating factors that sustain such practice from centuries. Results showed that the protection of woodlots or watershed cover was regarded vital in sustaining agricultural production, water supply and wood. Protection of forest was also perceived essential in preserving the ancient practice of wood carving that gives the Ifugaos a distinctive mark from other ethnic groups in the Philippines. Some *muyong* practices were also identified as effective climate change adaptation strategies.

The status of restoration practices in degraded landscapes of Southern Africa. Chirwa, P. (*University of Pretoria, South Africa; paxie.chirwa@up.ac.za*), Mahamane, L. (*African Forest Forum, Kenya; M.Larwanou@CGIAR.ORG*), Syampungani, S. (*Copperbelt University, Zambia; syampungani@cbu.ac.zm*), Babalola, F. (*University of Pretoria/University of Ilorin, South Africa; Fola.Babalola@up.ac.za*).

Southern African woodlands support the livelihoods of millions of both the rural and urban dwellers through the provision of non-wood products including supply of energy and agricultural expansion thereby contributing to deforestation and woodland degradation. However, there are recognized traditional forest management practices and technologies that have the potential to promote rehabilitation and/or restoration of degraded woodlands provided proper policies and institutional frameworks are in place. This paper examines the causal factors of land and forest woodland degradation in southern Africa and highlights some of the successful practices for their restoration. Natural regeneration of different forms, including complete coppice; coppice with standards and selective cutting; pollarding, pruning and lopping, were found to be the predominant form of restoration in dry forests and woodlands of southern Africa. However, enabling policies for community based approach including clear cut land tenure and equitable benefit sharing are still not operational in most countries of the region. The conditions for up-scaling successful restoration practices identified include: (1) recognition of local knowledge; (2) institutional support for implementation of restoration activities; (3) income generating initiatives through marketing and value adding of natural resources; (4) taking on financial opportunities from CDM mechanism including REDD.

Can the traditional knowledge be prevented from being TRIPped? Kant, M. (*University of Delhi, India; medha.kant@gmail.com*).

Despite sustained efforts under the Convention on Biological Diversity (CBD) for the last two decades, forest communities holding valuable traditional knowledge have not yet been able to benefit significantly from their heritage. The legal framework of CBD seeks equitable sharing of benefits by streamlining the transfer and use of amorphous knowledge generated far in the past through unknown, and often unknowable, cumulative processes and shared for generations within and among communities. On the other hand the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) strives for protection and dissemination of the knowledge generated now by individuals and companies through clearly delineated processes that are open for legal scrutiny for the mutual advantage of both producers and users in order to promote innovations in future. The former seeks reward for possession of knowledge while the latter does so exclusively for new creations. Possibilities of conflict between the two arise when new innovations under TRIPS are based to some extent on the traditional knowledge recognized under the CBD. The paper reviews cases of such conflicts in the light of specific provisions of CBD and TRIPS and presents a possible framework for their satisfactory resolution.

What makes traditional knowledge communicable for sustainable forest management? Kim, I. (*University of British Columbia, Canada; inae.kim@alumni.ubc.ca*), Trosper, R. (*University of Arizona, USA; rltrosper@email.arizona.edu*), Bae, J. (*Korea Forest Research Institute, Republic of Korea; forestory@forest.go.kr*).

Traditional knowledge emphasizes democratizing knowledge and meaningful collaboration for sustainable forest management. The purpose of this research is to develop communication channels of traditional knowledge for sustainable forest management. We used a participatory and case study approach and conducted semi-structured interviews at Sts'ailes, an indigenous forest-dependent community in Western Canada, and Hoesan, a typical agricultural community near East Sea in South Korea. We compared and contrasted forest use types, forest functions, land tenure, forest management practices, user groups, forest governance institutions, and relevance of traditional knowledge of two communities. Both are similar because higher-level governments have exerted control over the land that is important for traditional culture. Traditional knowledge is highlighted in asserting traditional rights and titles at Sts'ailes. However, traditional knowledge has not been paid attention at Hoesan because of lack of interest and need. While Sts'ailes tries to revive the culture for their identity, Hoesan only maintains the religious ritual associated with the forest as a cultural heritage. The relevance of traditional knowledge is distinctively differentiated by continuity or absence of next generation of the community. The two communities require different types of channel to transmit and maintain forest-related traditional knowledge.

Can local wisdom be used in forest conservation around national park? The case in Seram Island, Central Mollucas, Indonesia. Liswanti, S. (*Center for International Forestry Research (CIFOR), Indonesia; n.liswanti@cgiar.org*), Tjoa, M., Silaya, T. (*University of Pattimura (UNPATTI), Indonesia; tine.tjoa@yahoo.com; t_silaya@yahoo.com).*

The forest in Seram Island, including Manusela National Park, is rich in biodiversity. The forests have used by the forest dweller for daily needs and livelihood for long time. This study exposes potential collaborations between indigenous people and those concerned about conservation. The data was collected using participant observation, in-depth key informant interviews and focus group discussions. We documented the forms and role of local wisdom by communities in forest conservation and focused on ten forest dweller communities around the park. The survey results revealed that all traditional communities use the customary rules to preserve and to manage their traditional forest, and are expected to provide economic benefits, ecological and socio-cultural. Local wisdom is still strong in this area including the prohibition of forest products collection for certain periods, supernatural use to prohibit any activity, and other traditional efforts to protect the forest. The local wisdom is important to protect the forests. This paper is a first step in providing a local perspective that might guide conservation planning and practices in the Seram. The results can be taken into consideration when decision makers, stakeholders and those working to conserve Seram's natural heritage can respond positively to local views.

Linking local traditional biodiversity conservation knowledge to combat rocky desertification in karst area in southwest China. Luo, Y. (*Northwest A&F University, China; lyfcl@163.com*), Liu, J. (*Renmin University of China, China; liujinlong_jl@hotmail.com*).

Rocky desertification seriously affects agriculture output in rural communities in southwest China. The Chinese government initiates many engineering projects, like large scale construction of terraced fields, which are aimed to convert rocky soil to cultivated land. However, without knowledge of the local social-ecological conditions, these interventions may negatively affect the resilience of local knowledge about working in rocky desertification. In this research, we try to collect and sort the traditional biodiversity conservation knowledge in the local production system in the Miao Minority area in Guanling County, Guizhou province, southwest China. Through field investigation, we found that much of the traditional biodiversity conservation knowledge of the Miao Ethnic people is valuable in combating rocky desertification and contributing to sustain farmers' livelihood. The Miao Ethnic people successfully plant vines in rocky fields, which can cover the bare rocky soils layer and prevent soil from water erosion. They seldom turn soils when plowing their fields, but instead leave the crop residues in place. The Miao diversify plants in their fields in the vertical farming style, with cash forest, food crops, and different vine and leguminous plants around farm lands. This research aims to strengthen understanding of the relationship between local biodiversity conservation knowledge and rocky desertification landscape in southwest China.

Governance of knowledge systems in developing adaptive forest-agriculture innovations. Mala, W.A. (*University of Yaoundé I, Cameroon; williammala@yahoo.fr*).

This study aimed to analyze under which conditions the structure, organization and integration of knowledge systems can provide an avenue for the development of forest-agricultural innovations under conditions of high biodiversity in the humid forest zone of southern Cameroon. The management of traditional agro-ecological sustainability is based on the local definition of well-being, social representation of space and on a multi-criteria approach combining the knowledge of interactions between crops, wild plant species, the tree species uses, the future use of a current land use, and the estimated land use for personal use and market access. The positive impact of slash-and-burn agriculture practices on the establishment of forest species with a potential for regeneration and forest recovery is confirmed, and this affects the composition and structure of forest landscape mosaics. Evidence emerges from this study regarding the determinants of sustainable traditional land use management to suggest that both the practices and land use systems have something to offer to the conventional thinking and agroforestry innovation processes in terms of high returns to labour input, biomass management, species enrichment, inter-dependence of agroforestry options and the issue of regulating community property rights and biodiversity conservation.

Indigenous people and their traditional knowledge on tropical plant utilization: a case study of Murut communities of Sabah, Borneo. Muthu, T., Muhammed, N., Kuppusammy, M. (*Sabah University of Malaysia, Malaysia; theresa.muthu@gmail.com*; *nur_md@ums.edu.my*; *mk.sekwi@gmail.com*).

The Murut community is the third largest indigenous community in Sabah, Borneo. The Nabaai and Gana tribes of the Murut community are the more modernized group of Murut. Their traditional practices are slowly vanishing. This study was carried out to document the utilization pattern of the identified plant species and explore the role of plants in the daily life of the Murut communities. Two villages were selected for this study. A total of 120 households were selected from three income groups: high, middle, and low income groups. The results show that the plant species found in the homestead of the Nabaai and Gana tribes are

utilized for three main reasons: food, medicine, and fuel wood. The Nabaai and Gana tribes practice traditional knowledge especially in medicinal plant utilization. 23 utilization patterns have been identified in this study, which is much lessthan what was found a decade ago (68 utilizations). The findings also show that most of the traditional knowledge on plant utilization lies with the respondents with low income group (59%) because of their high dependency on utilization of the surrounding resources in their daily life.

Valuing traditional knowledge for conserving biodiversity in Indonesia. Soedjito, H. (*Indonesian Institute of Sciences (LIPI), Indonesia; herwasonosoedjito@yahoo.com*).

Research on valuing indigenous and local knowledge for biodiversity conservation in Indonesia was started in the late 1970s when research interactions between the Dayak people with forest in East Kalimantan were conducted. A methodology of multi disciplinary approach was conducted by involving anthropology, biology and forest ecology. The Dayak traditional agricultural system was scientifically proven where Dayak people conserve genetic varieties of rice and by using radio isotope P^{32}, shifting cultivation system also proved as a way to optimally use tropical rainforest soils that generally have low nutrients. Tanah Ulen, a traditional conservation concept, also directly benefits sustainable forest products for food (fruits, vegetable, carbohydrates), meat (pigs, deer, fishes), as well as sufficient water (environment services) for their livelihood. Later studies were done to synergize science and the traditional knowledge of many indigenous people, namely the Baduy in West Jawa, Mentawaian in Siberut Island, Batak in Sumatra, Balinese in Bali, Ngata Toro and Kajang in Sulawesi, as well several Moluccas and Papuans in east Indonesia. Embedded in this traditional knowledge as a manifestation of collective community intellectual achievement are local innovations. These local innovations must be mapped, appreciated, strengthened and empowered for human livelihood.

Uses and management of fire by rural communities in coniferous forest in the Monarch Biosphere Reserve, Mexico. Torres, H.M., Salicrup, D.P. (*Universidad Nacional Autónoma de México, Mexico; lmartinez@cieco.unam.mx*; *diego@cieco.unam.mx*).

The coniferous forests of the Monarch Butterfly Biosphere Reserve (MBBR) in Mexico are the overwintering sites of the monarch butterfly (*Danaus plexippus*) that migrate from the U.S. and Canada. These forests are threatened by wildfires, caused mainly by anthropogenic activities (of rural communities living legally in MBBR). The purpose of this study was to document the use and management of fire in the MBBR. Based on literature information and semi-structured interviews with the authorities responsible for fighting fires and peasants that use the fire in different activities, we documented the use and management of fire. We find that traditional knowledge of use and control of fire for certain activities (mainly in agriculture) exists; other activities use fire without control and supervision (mainly cattle); and also, we find uses of fire in forestry activities that have not been reported for this natural protected area. However, the main use of fire is intentional to cause fires and/or promote land use change. So we can say that the rural people in MBBR maintain traditional knowledge on the use of fire, which is different for each activity, and that many of fires attributed to agricultural use are deliberate.

The role of traditional forest management on local livelihoods in northern Zagros oak forests of Iran. Valipour, A., Ghazanfari, H. (*University of Kurdistan, Iran; ahmadvalipour@gmail.com*; *Hedayat@uok.ac.ir*), Plieninger, T. (*University of Copenhagen, Denmark; tobias.plieninger@ign.ku.dk*).

Zagros oak forests, western Iran, are managed for soil conservation, water quality, non-wood forest products (NWFPs) and non-market ecosystem services. Large parts of these forests are subject to traditional land use practices supported by very old traditional ecological knowledge, called *Galazani*. Since the Galazani management system is little understood, this study aimed to recognize its components, objectives, silvicultural treatments and management interventions. We performed face to face interviews and participation in practices. Galazani performs to provide winter fodder for livestock, mainly Marxoz goat. Forest territories are pollarded in a unique way, known as crown-coppicing. The trees will cut for fuelwood once they do not provide high amounts of fodder. Forest dwellers manipulate trees to obtain the most fodder using a set of techniques. They are also structuring their territories to guarantee sustained yield via tree spacing and regulate annual allowable pollarding areas. The forest territories are also used as pasture for summer grazing. The traditional silvopastoralism is vital to meet daily needs. The Galazani creates a social institution which has encouraged people to protect forests, traditions and special species of goat: Marxoz. Traditional ecological knowledge mostly serves an economic function, more than the silvicultural aspects which need to be considered in forest management plans. Regeneration failure and inappropriate age structure are the main weaknesses that arise from the Galazani system.

Would traditional forest knowledge be useful for urban ecological restoration? Yeo-Chang, Y., Dyeok-Gyu, K., Youn, S., Koo, J., Eun-Hee, L. (*Seoul National University, Republic of Korea; youn@snu.ac.kr*; *sesimbul@snu.ac.kr; youn.susan.sojin@gmail.com; sele78@snu.ac.kr*; *skymorin@hanmail.net*).

Deforestation can be avoided by active participation of local people who acknowledge the value of forests. Village woodlands have been conserved thanks to the active participation of local people who hold ecological knowledge inherited from their ancestors. There is growing demand for more new urban green spaces from citizens. The traditional forest knowledge which has been supported the village woodlands to be conserved can be useful for restoring urban ecosystems. The perception of local residents on value and willingness to participate in conservation of village woodlands was surveyed in five municipalities around Mt. Jirisan using face-to-face interviews. The survey results reveal that the utility of woodlands can lead to positive attitudes toward active action for woodlands conservation. The utility of woodlands is closely related to the frequency of use for various purposes. The accessibility and use rights to woodlands, which safeguards local people's use regardless of land ownership, are important elements of sustainable woodlands management. The model of traditional knowledge-based management of village woodlands can provide valuable insights to city governments and civil societies which demand ecological restoration of urban areas.

Gender and traditional forest-related knowledge in China--a case from minority people in Guizhou province. Yuan, J. (*Guizhou University of Finance and Economics, China; yuanjuanwen@yahoo.com*), Liu, J. (*Renmin University of China, China; liujinlong@ruc.edu.cn*).

Women and men are different in viewing, accessing, and practicing traditional forest-related knowledge. This paper examines the differences in accessing and practicing the local knowledge of three minority groups in Guizhou province through interviews and participant observations. The main findings are as follows: It is traditionally women who are weeding in the sampling plot and men are cutting and transporting trees. Women are collecting fuelwood while men are making traditional charcoal. For the traditional way to make paper, the women are looking for the raw vine and make the paper. For traditional basket making, women gather the vine in the forest but men are more skillful in making the baskets. The inheritance and innovation for men and women in the above aspects are passing on by gender separation; for instance, textile dying technologies are tested by women and not men. The difference in traditional forest-related knowledge of women and men implies that the differences which may have key impact on the inheritance and innovation of traditional forest-related knowledge should be studied by the related researchers and policy-makers.

Posters

Traditional conservation practices and plant biodiversity potential of sacred groves in Ghana. Ameyaw, K. (*Forestry Commission, Ghana; kofiameyawkwakye@yahoo.com*), Enu-Kwesi, L. (*University of Ghana, Ghana; Botany@ug.edu.gh*), Yeboah, D. (*Ministry of Lands and Natural Resources, Ghana; dictyx55@yahoo.com*), Ameyaw, L. (*University of Washington, USA; lkameyaw@uw.edu*).

This study was conducted on Forest Biodiversity Conservation strategies within the traditional sacred grove concept across the three main ecological zones of Ghana. The main objective of the study was to ascertain the veracity, merits, and effectiveness of the traditional philosophy and governance systems underpinning the concept of sacred grove in order to incorporate their governance systems and mechanisms into formal conservation strategies. Methodologies employed included a secondary literature search, focus group discussions and questionnaire administration, and plant species inventory. Results indicated that the most sacred groves qualify as corridors for biodiversity conservation. Biodiversity potentials of sacred groves are not influenced by sizes and location but by the amount of stress they are exposed to. Sacred groves can be categorized based on their function into livelihood enhancers, reservoirs of threatened plant species, watershed protectors, places for religious rituals, royal mausolea, potential ecotourism sites, repositories of medicinal plants and sources of historical knowledge. Sacred groves were found to be threatened by several factors. The situation therefore calls for governmental commitment to coordinating a collaborative effort by all relevant stakeholders to help protect, manage, and develop sacred groves across the country in order to sustain their numerous benefits to ensure inter-generational equity.

Species diversity and management techniques of village common forests: a case study from Bandarban, Bangladesh. Hossain, M. (*University of Freiburg, Germany; mohitulh@yahoo.com*), Islam, M., Jashimuddin, M. (*University of Chittagong, Bangladesh; kamrul.forestry@gmail.com; mjashimuddin2001@yahoo.co.uk*).

Village common forests (VCFs), solely managed forest by the indigenous communities of Chittagong Hill Tracts (CHTs), have become ecologically, economically and culturally very important for the local community. This study was conducted in two VCFs of Bandarban district with the objectives to know floral composition and diversity, socio-economic importance as well as the institutions of indigenous knowledge systems in managing the VCFs. Data was collected by using direct field measurements, semi-structured questionnaire, and focus group discussion with VCFs stakeholders. A total of 45 tree species belonging to 31 families were found in VCFs, mainly dominating by timber species, with enormous natural regeneration (23 000 seedlings/ha). Diversity index showed that species diversity was much higher in VCFs than forests under other management systems because of the unique management system of VCFs. VCFs are collectively managed by customary and existing executive committee through unique sets of rules with the particular aim of biodiversity conservation. Respondents from the VCFs communities opined that they manage such forests to conserve their water sources, protection from natural calamities, provide food and medicinal ingredients as well as for income source ($260/year). The indigenous resource management techniques of VCFs communities showed excellent forest management model for rehabilitating degraded hilly watershed of CHTs.

Contribution of tribal women in biodiversity conservation and ecosystem restoration in the Bandarban Hill District of Bangladesh. Mohiuddin, M. (*Bangladesh Forest Research Institute, Bangladesh; uddinm59@gmail.com*).

Bandarban is the second largest hilly district of Bangladesh. It is the native home of thirteen tribal communities.The tribal women are involved from dawn to dusk completing all of their family activities. They are involved in all the activities of the shifting cultivation (jhum cultivation) and collect the dietary food returning from jhum field in sustainable conditions. 55 wild food plants are used for domestic purposes and also for marketing. The knowledge system varies among the men and women of the communities. Murang women have higher knowledge (77%) than the Marma women (64%) for agro-biodiversity. Murang females have 76% knowledge on seed storage, followed by Marma females (72%) and this knowledge varies from 68%- 60% in Murang and Marma males. The tribal people of remote areas are more knowledgeable than well connected areas from a conservation point of view. The tribal people also have their own sharing mechanism for conserving the agro-biodiversity crops. Women's resource knowledge, however, is disappearing because of urbanization and market oriented production system. Their knowledge is important for ecosystem restoration at local level. A three dimensional model proposed for strengthening the biodiversity conservation activities of the Bandarban Hill district.

The values of traditional knowledge and practices of nipa production to sustainable forest managment in Cortes, Bohol, Philippines. Paras, F., Camacho, L., Camacho, S., Carandang, A., Combalicer, E., Gevana, D. (*University of the Philippines Los Banos, Philippines; fdparas@gmail.com; camachold@yahoo.com.ph*; *sonny_camacho@yahoo.com*; *papcarandang@yahoo.com; eacombalicer@up.edu.ph*; *wuweidix@yahoo.com*).

Nipa (*Nypa fruticans*) is a true mangrove palm and a valuable resource found in coastal areas. It is primarily used as a sustainable thatching material in rural houses, sheds, cottages and small buildings; however, wine and vinegar can also be derived from its sap. In this study, however, aside from the economic values of nipa to the community, there are unique social values that it creates making it a possible socio-ecological keystone in the area. The paper employed a market study, survey, key informant interviews and a focus group discussion to derive the economic, social, and cultural values of nipa in Cortes, Bohol. The paper also illustrates traditional practices in nipa establishment, maintenance, protection, and production that were found to be unique to the site. Social and economic implications of this traditional knowledge and practices are discussed in order to evaluate the status of the nipa production in the site.

Traditional knowledge is trivial for managing mountain natural resources: a case study from the Eastern Himalaya. Saha, S., Chakraborty, T. (*University of Freiburg, Germany; somidh.saha@waldbau.uni-freiburg.de*; *tamalika.chakraborty@waldbau.uni-freiburg.de*).

Traditional ecological knowledge and wisdom of the Monpa tribe in managing resources like water, soil and forest in the high altitudes of the Eastern Himalayas had not gotten much attention. We aimed to describe traditional management of watersheds, forest and mountain farming in Tawang and West Kameng districts of Auranachal Pradesh, India, Eastern Himalaya. We selected 6 different villages located at 1500 m to 3500 m. We did participatory rural appraisal, socioeconomic survey and forest inventory. We found that traditional watershed management was highly diversified and had multipurpose use for agriculture to cattle ranching. Locals had developed unique irrigation system using gravitational force that checks surface runoffs, and maintains the water table in a permissible depth. We found unique alarm system for pre-detection of the flash flood using water force. Traditional intercropping systems with nitrogen fixating plants ameliorate soil fertility. Forests were managed as community property and customary rules were developed by the Monpa people for thinning oak (*Quercus lamellosa*) dominated forests, leaf litter and fire-wood collection. Sacred groves could be found throughout the landscape. We concluded that importance of traditional knowledge should not be overlooked for developing future natural resource management policies in the Eastern Himalaya.

Shifting cultivation: traditional ecological knowledge of the Dayak people in East Borneo, Indonesia. Siahaya, M. (*Samarinda State Polytechnic for Agriculture, Indonesia; marthasiahaya@yahoo.co.id*), Wanca, H. (*Mulawarman University, Indonesia; hefsinehemya@gmail.com*).

The lives of the Dayak people cannot be separated from the forest. The forest is an area that integrates them within the ecosystem. The forest utilization by the traditional societies comes from a very close interaction between the society and the surrounding forest. The interrelation between the Dayak people's culture and their dependence on forests has resulted in their ecological knowledge of the forest in East Borneo. This study aims to explain the interrelation of the indigenous societies in the form of shifting cultivation, which is one form of traditional ecological knowledge. The method used is a case study, where the data collection is done through in-depth interviews and participant observation. The results showed the various ethics and rules found on shifting cultivation practiced by the indigenous societies. The system is traditional ecological knowledge that has evolved from generation to generation. They practice the accurate selection of land, forest fire prevention and a fallow land period after harvesting. These practices raise the values of cooperation within the Dayak people.

Impact of falling culture and indigenous knowledge on forest conservation in southwest Cameroon. Suka, E. (*Ministry of Environment, Cameroon; emmanuelsuka@yahoo.com*).

Falling aboriginal cultures and indigenous knowledge has contributed about 75% to forest degradation in SW Cameroon. Forest communities conserved forests according to customary norms using local technologies, cultures and traditions from time-immemorial over whose lifestyles are intricately attached. Adulteration of traditional forest conservation methods by colonial legacy, introduction of sophisticated technologies and unorthodox forest exploitation and agricultural production methods have degraded forests. It is difficult to change these existing habits. Conservation projects have come and gone whereas indigenous people have lost their traditional knowledge, rights and supposed equitable shared benefits from access to forest resources. Integrated indigenous participatory method was used to rebuild the lost traditions and depleted forests. Interactive structured and semi-structured interviews, field surveys and inventories were conducted in 320 households in three villages with the aid of free listing using locally made cards. The analyzed data gave an idea about what people thought about plants, cultures and forest conservation. If the opportunity and a proactive role are given to indigenous forest communities to freely participate in reviewing forest conservation policies, benefits and rights to traditional knowledge can be useful in sustainable forest management. Traditional knowledge is a key to forest conservation science and essential to global development.

Mapping a full cycle of swidden cultivation in Laos. Takeda, S. (*Kyoto University, Japan; takeda@asafas.kyoto-u.ac.jp*).

In this study, we monitored swidden cultivation and forest fallow management in a Khmu village in Laos. Monitoring was conducted between 2005 and 2013 and covered a full swidden cycle. Through GPS mapping, interviews with swidden farmers, and on-site observation, we examined the present state of swidden cultivation in the village. Swidden farming is found throughout the mountains of mainland Southeast Asia; however, there is a current preference for the use of other land-use systems. The recent trend toward a market economy has forced the people and forests in the mountains of Laos to undergo various changes as they integrate into the world market. They have been impacted by the enclosure movement called the Land and Forest Allocation Program, the expansion of the cultivation of cash crops such as maize and Para rubber trees, the increase in logging concessions, and re-afforestation aimed at industrial wood resources. Here, we discuss the changes taking place in the relationship between the local people and their swidden cultivation system. We also examine the possibility of stabilizing swidden cultivation in the study areas to ensure a future in which the swidden farmers are able to live with a sense of security.

A-19 Wood and forest culture: merging the past with the present

Organizers: Howard Rosen (U.S. Forest Service) & Woo Chun Young (Kookmin University, Republic of Korea)

Vatican Coffins Project: the wood analysis of the third Intermediate Period coffins (Egypt). Amoros, M.A. (*Xylodata SARL, France; victoria.asensi@free.fr*).

In the context of the Vatican Coffins Project we analyze the wood of the Third Intermediate Period coffins conserved in the Vatican museum and those conserved in the Louvre museum according with the standard techniques of identification determined by the International Association of Wood Anatomist (IAWA). At the moment, we could analyze the wood of 14 out of 22 coffins held in the Vatican museum and 8 out of 42 of the Louvre museum. In total, we know about 150 coffins for the Third Intermediate Period in all Egypt with a wood identification and the aim of our work is now to compare the species used at that time in relation to the periods after and before in order to determine the continuity, the introduction or the abandon of some species in in the Egyptian landscape. The coffins of the Vatican museum present some homogeneity in the wood (*Ficus sycomorus*, *Tamarix* sp., *Acacia* sp., *Faidherbia albida*) but some elements present more exotic woods as *Quercus* sp. (oak) pegs, timber not much used in ancient Egypt.

Plantation grown tree species for wood carving in Ghana: concerns of traditional wood carvers. Appiah-Kubi, E., Tekpetey, S., Essien, C. (*Forestry Research Institute of Ghana (FORIG), Ghana; appiahkemma@yahoo.com*; *nii9lartey@gmail.com*; *caessien@ymail.com*).

In Ghana, traditional wood carving has been a major means of livelihood for a number of Ghanaians over the past years. In fact, wood carvings are diverse and each carver and association has its own specialization. Among the major wood carving products in Ghana are unity, stool, mask and talking-drums. The major material for carving is good wood. Limited tree species are available and preferred for use by carvers in Ghana. This paper assesses the type and characteristics of the wood species that local carvers prefer in different localities in Ghana for their works. It further projects the use of plantation grown tree species for wood carvings in the wake of concerns for dwindling traditional tree species for carving. Concerns on the use of plantation trees were solicited from local carvers in Kumasi through interviews. Carvers indicated their willingness to use any type of wood provided the tools and equipment for processing them engages well. Teak, a plantation grown tree species is already being used by some carvers. Training workshop should be organized for wood carvers in the country for improving their skills and also prepare carvers to use some other tree species and especially indigenous plantation grown tree species.

Protecting Amazon tropical forests for the future: Program São Paulo Friends of Amazonia. Filho, M.T., Santini Jr., L. (*University of São Paulo, Brazil; mtomazel@usp.br*; *luizsantini@biologo.bio.br*), Florsheim, S.M.B. (*Instituto Brasileiro de Florestas*, Brazil; sflorsheim@if.sp.gov.br).

The rainforests of the Amazon are a world heritage site renowned for their biodiversity and importance to the people of the forests in relation to the cultural, economic, historical and social aspects. On the other hand, these tropical forests supply the domestic and foreign markets with high quality wood, which exposes many tree species to overexploitation. Thus, efforts to control shipping and timber trade for higher consumption centers are strategic and important to safeguard and preserve this cultural heritage, keeping the ancient traditions. One of the most important initiatives of the last decades is the São Paulo Program Friends of Amazonia, implemented in 2007 in order to oversee and regulate the trade of tropical timber. Through the program, surveys are applied in the phases of transport and storage of tropical wood species and samples are collected for a botanical identification of species, and source documents are examined. The results of the implementation of the program indicate the effectiveness of the identification of tree species by wood anatomy as a tool for the monitoring and regulation of illegal trade in forest products, especially timber, in the state of São Paulo.

Traditional wooden architecture in the Alpine regions. Frattari, A. (*University of Trento, Italy; antonio.frattari@unitn.it*).

A particular traditional wooden architecture is widely diffused in the Alpine region between France, Italy, Switzerland, Austria and Slovenia. The barns are examples of this typical architecture and often they are damaged for different causes. The most diffused building systems are the log system and the frame system. The rehabilitation and the preservation is nowadays a problem. Currently there are two ways which are followed. The first one is the building up of open air museums or ethnographic paths where the most representative and meaningful buildings are conserved. The second one is the restoration and the rehabilitation for living purpose. This last way is very dangerous because often there is the possibility to change the inner meaning of the buildings especially for concerns over the constructive features. The University of Trento developed a methodology for conserving the traditional construction techniques through the improvement of the knowledge and through the reconstruction of meaningful examples in which to put in practice the theoretical knowledge.

Utilization of different Austrian wood species in past times – knowledge for the future. Grabner, M., Klein, A. (*University of Natural Resources and Life Sciences, Austria; michael.grabner@boku.ac.at*; *andrea.klein@boku.ac.at*).

The aim of the present study is to revitalize knowledge about historical wood utilization, which is buried in oblivion, but might bring a benefit in the future. Due to the shortage of resources, it will be important to foster the proper utilization of wood in general and to revitalize nowadays rarely used wood species. The inventory of three different museums has been analyzed to regain knowledge about wood species selection. In total 4 335 objects or 7 006 parts of those objects have been sampled. 50 different wood species could be distinguished, 17 thereof can be categorized as shrubs. Shrub species are hardly used today. They are often characterized by good mechanical wood properties, e.g. high wood density. Some fruit bearing species were of high value because of the high resistance against abrasion and good natural lubricity – properties which are hardly connected with wood nowadays. Last but not least, the color was decisive for selecting a wood species. Many of these rarely used species have a colorful appearance. Although those earlier valuated species might never be used in a standardized industrial way, they could be perfectly suitable for niche products and increase the sustainable utilization of forests.

Study on the forest culture construction of the Olympic Forest Park in China. Haixing, C., Kong, X., Xu, J. (*Renmin University of China, China; cuihaixing@sohu.com; k-xz@263.net*; *xu19910112@sina.com*).

The forest is the cradle of human civilization. Forest culture has a long history, is an important part of the excellent traditional culture of the Chinese. Building forest culture helps to coordinate the relationship between humans and nature, the relationship between humans and society, and people's physical and mental health. This paper expounds on the meaning and basic characteristics of forest culture: forest culture refers to people's forest awe, worship and understanding, it is establishing the simple feelings based in all kinds of forest benefits, and it reflects the cultural phenomenon of the relationship between humans and the forest. The basic characteristics of forest culture are mainly embodied in four aspects: ecology, nationality, regionality and humanity. The forest culture construction is an important part of socialist cultural construction, is the main content of the development of modern forestry, and is an important basis for building a harmonious socialist society. In the paper, five aspects were stated that the main content of forest culture construction from the forest landscape, forest culture facilities, forest culture products, forest culture communication, and forest culture team. With the example of Olympic Forest Park, the paper analyses the tourists' cognition of the forest culture construction by the combination of the questionnaire survey method and interview method. The results, from high to low in order were: forest culture landscape, forest culture team, forest culture communication, the forest culture facilities, forest culture products. The paper discusses the present situation and the existing problems of the Olympic Forest Park forest culture construction; and put forward countermeasures and suggestions for constructing the characteristic forest culture, to increase the propaganda, and to seek multi-directional cooperation.

Forests for Bamiléké people: founding principles of the identical values and source of the community's economic development. Inocent, N. (*Batoufam Fundom, Cameroon; nayangtoukam@yahoo.fr*).

For the Bamileke people, located in West Cameroon, the forest is one of the main community's founding principles through its diversified utility, its double sacred-popular dimension or preserved-exploited dimension. The main purpose of this paper is to develop the different forest's features for these people. Starting from the sacred dimension of the forest in which it shelters and passes on the wisdom to the future Sovereign then to his people, this presentation will show the various types of the forest's exploitation. These general ideas will be successively presented: The intangible exploitation of the forest through initiation rites of the future King and sacred forests; the transmission of the royal wisdom through the large symbols engraved on the doors frames and pillars; the wood's exploitation for the manufacturing of tools and artifacts which accompany the cultural and religious practices of the community; and the economic dimensions of the forest through handcraft, tourism, agriculture and hunting. This descriptive analysis will show the specificities of the traditional management techniques and preservation of the forest. These specificities will certainly allow understanding of innovative forms of sustainable development, management and renewal of forests.

Emerging patterns in the utilisation of wood and plastic products in building construction at Ibadan University Campus, Nigeria. Olorunnisola, A. (*University of Ibadan, Nigeria; abelolorunnisola@yahoo.com*).

Wood is one of the major construction materials at the 65 year old University of Ibadan, Nigeria, located on the borders of a tropical rainforest. A study was conducted to determine the traditional and contemporary forms of wood and plastic utilization in non-residential building construction on the university campus. The survey covered thirty non-residential buildings, comprising fifteen old and un-renovated/retrofitted ($\geq$ 10 years old) and fifteen new (newly constructed/renovated ($\leq$ 9 years old) buildings. Findings showed that sawnwood, plywood, particleboard and fibreboard were the predominant wood products used in the fabrication of roof rafters/trusses and allied roof members, wall partitions, doors and door frames, stair cases, and furniture items in the older buildings. While wood products remained the traditionally preferred materials for the fabrication of roof rafters/trusses/allied roof members and furniture items, the other itemized building components in newer/renovated buildings were plastic products. The growing preference for plastics was attributed to dwindling availability of matured, durable timber and wood-based panel products, rising cost of lesser-quality wood products; non-availability of modern engineered wood products that can replace the traditional wood products; and the growing acceptance of the aesthetically appealing plastic materials.

A-20 On farm trees: towards the promotion and development of a traditional or local silviculture in tropical and subtropical forest regions

Organizers: William Armand Mala (University of Yaoundé, Cameroon), Jinlong Liu (Renmin University of China). Steven Anderson (Forest History Society, USA) & Yeo-Chang Youn (Seoul National University, Republic of Korea)

Biodiversity and socioeconomic factors supporting farmers' choice of wild edible trees in the agroforestry systems in Benin (West Africa). Assogbadjo, A. (*University of Abomey-Calavi, Benin; assogbadjo@gmail.com*).

The present study assessed the farm diversity of wild food species and socio-economic factors that support farmers' choices for the tree species used on their farms. Data have been collected through a field exploration and a semi-structured survey among 435 selected households in each of the three climatic zones of Benin. The most culturally important species ranked by locals were determined for each climatic zone and the relations between the targeted species in traditional agroforestry systems and the reasons which support peasants' choices were described through a principal component analysis. A total of 43 wild edible trees (24 families) were present in the traditional agroforestry systems of Benin. There are three main reasons that support peasant ambition to conserve or to grow wild edible trees in their field. The first one is the contribution of species as food followed by its use in traditional medicine and ceremonies. Another important reason supporting the choice to conserve wild edible trees in traditional agroforestry is the farmer's perception of the availability of species in natural vegetation. This study reinforced the evidence of indigenous knowledge and agroforestry systems in the biodiversity conservation in Africa.

Profitability of on-farm adoption of short rotation forestry – a case study. Chauhan, S., Sharma, R. (*Punjab Agricultural University, India; chauhanpau@pau.edu*; *rajni@dr.com*).

On-farm intensive management of short rotation forest trees provides farmers with improved incomes as compared to venturing into other seasonal cropping rotations. However, these systems are need based and constrained by the resource base, thus variable at each scale. It is the perspective of the farmer who is confronted with the decision for adoption and usual proposed economics are not uniformly applicable. The proposed case study provides insight into the experience faced with the challenge to convince farmers to plant trees on their farm and to show them the potential benefit that may accrue to them from this system. The study will shed light onto the role of the financial profit for farmers in short rotation forestry (SRF). This aspect is important to the farmer, managers, industrialist, policymakers and also to potential third party who set out to develop an according project on SRF. In the paper, the farmer's perspective is considered rather than the technical economic aspects of SRF. The environmental services are difficult to seize economically and payment for environmental services have not yet been fully realized in India, and therefore are not included in the case study.

REDD+ versus practical silvicultural management for rural society benefits in Miombo woodlands, southern Africa. Geldenhuys, C. (*Stellenbosch University, South Africa; cgelden@mweb.co.za*), Syampungani, S. (*Copperbelt University, Zambia; syampungani@cbu.ac.zm*).

Millions of rural people depend on resources from the dry deciduous woodlands of Africa. Miombo woodland covers vast areas in southern Africa. Miombo woody plants developed unique underground rootstocks to survive fire and browsing in the seasonally dry areas. Cultivation of crops and harvesting poles and fuelwood by rural societies are the main causes of the perceived degradation and deforestation of these woodlands. However, deforestation is a misnomer in the context of fast recovery of the plant diversity and productivity through vegetative regrowth from the rootstocks, unless derooted for commercial agriculture. Degradation of stand structure is temporary. This paper presents an overview of the ecology of recovery processes in stand development stages in Miombo after the cyclic clearing for traditional slash-and-burn agriculture and charcoal production. An approach towards selective pruning of branches and thinning of stems in stand development stages is presented. This integrated multiple use approach will maintain the supply in fuelwood and poles, maintain plant diversity of the system, improve condition and productivity of the woodlands, increase carbon stocks and maintain a high rate of carbon sequestration, all to the direct benefit of rural small-scale farmers; in sharp contrast to the moribund old-growth stands in protected areas.

Indigenous agroforestry systems under pressure – the case of Gedeo agroforestry and its value to farmers' livelihoods, Ethiopia. Hillbrand, A. (*Bangor University, United Kingdom; Anique.Hillbrand@web.de*).

The importance of agroforestry in Gedeo is critical to farmers' livelihoods. However, the high population growth rate and consequent land shortage has caused a 'green famine' and high rate of agricultural intensification. This study investigates how indigenous multi-strata agroforestry practices in Gedeo provide multiple benefits for the livelihoods of farmers. It looks at changes over the past 50 decades and investigates how farmers' strategies might change in the future. For this study, 51 farmers, representing two economic-climatic zones, were randomly selected. There are some crops managed only by women and agroforestry in Gedeo provides women with unique opportunities to manage their own domain on a farm. The species diversity makes farmers less vulnerable to market price fluctuations and other shocks such as climate events. There are threats to the system such as an increase in *chat (Catha edulis)* plantations. However a previous government regime imposed mono cropping on some farmers, but when this was relaxed, farmers quickly switched back to their indigenous agroforestry practices. Altogether this research shows that Gedeo farmers are discerning adaptors of agroforestry farming practices to suit their circumstances.

Multipurpose trees based black pepper (Piper nigrum. L) production systems in Kerala, India: biomass production, carbon sequestration and nutrient fluxes. Kunhamu, T.K., Aneesh S. (*Kerala Agricultural University, India; kunhamutk@gmail.com*; *aneeshcof@gmail.com*), Kumar B.M. (*Indian Council of Agricultural Research, India; bmkumar.kau@gmail.com*), Jamaludheen V., Raj A.K. (*Kerala Agricultural University, India; vjamal2002@gmail.com; ashajayamohan@gmail.com*).

Fast growing multipurpose trees are traditionally grown for black pepper (*Piper nigrum*. L) cultivation in the farm lands of humid tropical regions of India. However, aboveground and soil productivity of these systems is highly variable with tree species. To further explore on this, a farm trial was conducted at Thiruvizhamkunnu, Kerala, India during 2009–12 to assess the total biomass production, carbon sequestration potential (tree + soil) and nutrient fluxes among six multipurpose trees used as support for black pepper viz. *Acacia auriculiformis, Artocarpus heterophyllus, Grevillea robusta, Macaranga peltata, Ailanthus triphysa* and *Casuarina equisetifolia*. Black pepper yield was highest for *Acacia auriculiformis* (2.56 Mg/ha/ yr), a nontraditional support tree species. *Grevillea robusta* recorded the highest total biomass production (366 Mg/ha) while *Ailanthus triphysa* showed the lowest value (155 Mg/ha). Total C stock were also highest for *Grevillea robusta* (169 Mg C/ha) followed by *Acacia auriculiformis* (155 Mg C/ha). The article further compares the tissue C concentration, biomass and carbon partitioning, soil carbon stocks, nutrient fluxes and tree-returns among the various trees species. The paper highlights the need for selection and management of tree species for optimizing productivity in tree based black pepper production systems.

Traditional forest management system from landscape perspective in Dong minority villages: a case from S village in China. Lee, J., Liu, J., Zhang, M., Fusheng, Z. (*Renmin University of China, China; allgreen0@gmail.com*; *liujinlong_jl@hotmail.com*; *cathy_minghuizhang@163.com; zhaifusheng@yeah.net*).

Forests, which are seen as an important environmental element, a livelihood source and a commons by Dong minority people who have lived on mountains since ancient times, form a landscape of a Dong village with farmlands, rivers, roads and wooden houses. This paper described and analyzed the traditional forest management system (TFMS) of S village in China by means of anthropological methods, such as participatory observations and in-depth interviews. It found that the TFMS in S village was effective to use and protect the forests and biodiversity. The TFMS was needed to understand a holistic perspective of the landscape, but existing theories of natural resource management couldn't be ignored. The TFMS was seen neither as a complete

paradigm of centralization or of decentralization as the theory of social cost, nor as a complete paradigm of a common pool as the public choice theory, but it should be seen as a management system that customary rules in different sites were various (e.g. the rules of forests where it was closer village houses were different from those where it was next to neighbor villages) in the whole landscape.

Attitudes and behaviour towards on-farm tree planting among smallholder farmers in Malawi. Meijer, S. (*University College Dubin, Ireland; seline_meijer@hotmail.com*), Sileshi, G. (*World Agroforestry Centre (ICRAF), Malawi; S.Weldesemayat@cgiar.org*), Catacutan, D. (*World Agroforestry Centre (ICRAF), Viet Nam; d.c.catacutan@cgiar.org)*, Nieuwenhuis, M. (*University College Dublin, Ireland; maarten.nieuwenhuis@ucd.ie*).

The role of trees on farms in poverty reduction, enhancing food security and avoiding deforestation is already widely known, albeit, the uptake of tree planting has been generally low. This paper examines farmer attitudes and behaviour towards tree planting in Malawi. Survey questionnaires containing an attitude scale that measures three attitude components namely, the attitude itself, subjective norms, and perceived behavioural control in relation to tree planting were administered to 200 farmers in Chiradzulu and Mzimba districts in Malawi. The study found that all three attitude components were generally positive, which meant that farmers are in favour of tree planting. Farmers who planted trees on their farms over the last five years had a more positive attitude, subjective norm and perceived behavioural control towards tree planting compared to those who had not planted trees. Nevertheless, many farmers considered household needs such as buying food and agricultural inputs, as well as children's education as more urgent than investing in tree planting. This suggests that despite perceived benefits from tree planting, wider adoption is hampered by farmers' capacity to address basic household needs, pointing to the need for various inducements that stimulate positive attitudes and behaviours towards tree planting in Malawi.

Underutilized and promising fruit tree species to enhance productivity of traditional agroforestry system through participatory domestication in West Java, Indonesia. Narendra, B.H. (*Research and Development Center for Conservation and Rehabilitation, Indonesia; budihadin@yahoo.co.id*), Roshetko, J., Tata, H., Mulyoutami, E. (*World Agroforestry Centre (ICRAF), Indonesia; j.roshetko@cgiar.org*; *h.tata@cgiar.org*; *e.mulyoutami@cgiar.org*).

This paper explores the potential for domesticating fruit species in traditional agroforestry system in West Java. *Parkia speciosa*, *Durio zibethinus*, and *Sandoricum koetjape* each hold promise to enhance farmer livelihoods and can be grown under the low management conditions common in smallholder systems. The three species represent different levels of tree domestication, but all three can be characterized as underutilized in smallholder agroforestry systems. Strong demand for *P. speciosa and D. zibethinus* across national, provincial and local markets is a significant opportunity for smallholder production. *P.speciosa* showed high potential for increased domestication with farmers' interest in the species, potential for expanding on-farm populations and existence of underexploited high-yielding genetic material. *D. zibethinus* has potential for domestication since the marketing is still underdeveloped and some local trees that have superior quality, good taste and thick flesh are available in the study area. Besides the fruit, *D.zibethinus* and *S.koetjape* are valued for their timber which is easy to work and polish. *S. koetjape* was selected as a fruit with cultural and niche market potential that would not attract broad competition. Domestication is potentially focused to enhance post-harvest handling and processing as well as develop a stable market price through consistent supply and quality.

Sustaining Ghana's forest cover: evidence in cocoa agroforestry system. Nunoo, I., Owusu, V. (*Kwame Nkrumah University of Science and Technology, Ghana; nunooisaac85@yahoo.com*; *victowusu@yahoo.com*).

In Ghana cocoa cultivation is a major source of livelihood to over 800 000 people in the forest communities. 80% of new cocoa planting in the Western Region has been established without shade trees, making it a major contributing factor to deforestation in Ghana. The intercropping of cocoa with several high value tree species in addition to other food crops provide economic, cultural and social benefits to farmers as well sustaining the forest. Efforts to promote any of these cocoa agroforestry systems requires empirical evidence. In this study we evaluated the viability of various cocoa agroforestry systems in Ghana. Input-output data were collected from 200 cocoa farmers in the Sefwi Wiawso district by means of multistage sampling technique through household structured interviews and focus group discussions. A discounted cash flow analysis were carried out to estimate the benefit-cost ratio (BCR), net present value (NPV), internal rate of return (IRR) at a 20% discount rate. The medium shade cocoa agroforestry system was the most viable among all other systems with BCR of 1.36, NPV of GH₵ 3 264 and IRR of 47.2%. The medium shade should therefore be promoted since it is the surest way of sustaining the country's forest cover and cocoa production.

Conservation and socio-economic importance of some agroforestry fruit tree species: farmers' participation, tree growth characteristics and market assessment. Onyekwelu, J. (*Federal Unversity of Technology, Nigeria; onyekwelujc@yahoo.co.uk*), Stimm, B. (*Technische Universität München, Germany; stimm@forst.wzw.tum.de*).

Deforestation and demographic pressures have greatly depleted populations of indigenous forest fruit trees that produce socio-economically important non-timber forest products (NTFPs). We assessed farm-level growth characteristics, market potentials and farmer's participation in conservation of *Chrysophyllum albidum, Irvingia gabonensis* and *Garcinia kola* in rainforest and derived savanna ecosystems of Nigeria. Growth measurements were made on 50 trees of each species from ten villages. Two sets of questionnaires were used to obtain information from 30 farmers and 60 marketers of the species fruits/seeds in 12 urban and rural markets. The trees were old (32.3–43.5 and 19.5–35.2 years for *C.albidum* and *I.gabonensis*) and large (DBH: 36.0–64.3 cm; 19.5–61.3 cm and 46.3 cm for *C.albidum, I.gabonensis* and *G.kola*, respectively). Farmers' participation in conservation (planting) was higher in derived savanna (40–80%) than rainforest (2–6%). Conservation is male dominated (76–92%) while marketing is female dominated (60–100%). Annual fruit production ranged from 500 to 1 000, depending on species. Averagely, farmers sold 60% of their fruits/seeds and earned between US$300 and US$1 300 annually, with income highest and lowest at farm-gate and urban market, respectively. This income contributed 21–52% to total household annual income. Thus, increased tree planting could substantially improve farmers' livelihood and economic sustainability.

On-farm trees management drivers of in smallholder landscapes of southern Cameroon. Robiglio, V. (*World Agroforestry Centre (ICRAF), Peru; v.robiglio@cgiar.org*), Mala, W.A. (*University of Yaoundé I, Cameroon; williammala@yahoo.fr*), Tiencheu, M.A. (*University of Dschang, Cameroon; avanatie@yahoo.fr*).

The present study analyzes the drivers and socio-ecological context of smallholder farmers decision to manage (preserve, protect, plant) on-farm tree resources in their landholdings at the tropical forest margin, and their outcome in terms of tree species abundance and distribution. Data on the management of trees resources in land use systems of smallholder landscapes (fallow, coca agro-forests and degraded remnant forest) were gathered in a household survey conducted between 2011 and 2012 in 14 villages along a gradient of deforestation, agricultural intensification and population density, and combined with tree inventories and vegetation surveys. Abundance and distribution of on-farm tree resources was analyzed in relation to household level socio-economic and cultural variables and of spatial variables at the village level, using logistic regression. Preliminary results are discussed to identify incentives to support the management of on-farm trees according to locally adapted management options.

Impact of traditional agroforestry systems practices on conservation effectiveness of useful trees: case study of Borassus aethiopum Mart. in Benin. Salako, V., Kénou, C., Thierry, H., Assogbadjo, A., Kakai, R.G. (*University of Abomey-Calavi, Benin; salakovalere@gmail.com*; *ckenou@gmail.com; houehanout@yahoo.fr*; *assogbadjo@gmail.com*; *glele.romain@gmail.com*).

Traditional agroforestry systems (TAS) are increasingly receiving attention as a means to conserve biodiversity and sustain farmers' livelihoods through preservation of numerous woody species. Whereas a number of studies have evidenced potential of TAS in hosting an enormous woody species, it is still questionable how effective their conservation would be in such systems. We provide a countrywide analysis of the effectiveness of traditional agroforestry systems for conserving the useful wild palm species, *Borassus aethiopum* Mart. in Benin. 240 1ha square plots were sampled through phytogeographical districts of Benin. Life stages were inventoried and sex, diameter and height of adult individuals were recorded and analyzed. Results showed that (1) *B. aethiopum* populations in agroforestry systems had a significantly female biased sex-ratio (SR = 0.69, Prob. = 0.001), indicating that farmers are saving female individuals at the expense of male ones, (2) practices in TAS did not promote seedlings-to-saplings and saplings-to-juveniles survival, (3) life stages distributions of the species displayed a strong spatial variation which was found to reflect the intensity of fruits harvest. To guarantee effective conservation of *B. aethiopum* it should be required that practices in TAS shift from only saving useful species to their effective plantations.

Posters

Impact of land use practices on traits and production of shea butter tree (Vitellaria paradoxa C.F. Gaertn.) in Benin. Akpona, T. (*University of Abomey-Calavi, Benin; ajeandidier@gmail.com*), Akpona, A. (*Direction Générale des Forêts et des Ressources Naturelles, Benin; akpona@gmail.com*).

The shea tree plays an important role in the livelihoods of local populations living around the Pendjari Biosphere Reserve and populations in the different land use systems. This study is to assess impacts of different land use systems on the production and morphological traits of shea trees. A total of 89 circular plots of 60 m in diameter were established using a stratified random sampling method. In each circular plot, all trees with a diameter at breast height (DBH) $\geq$10 cm were inventoried and measured for circumference, crown diameters, and total height. Additionally, shea butter production was estimated from 90 trees (30 trees in each site) selected randomly using the Jessen method. Our results revealed a significant difference in tree density in increasing order of 5.9±0.3; 6.3±0.9 and 16.9±1.1 respectively in the protected area, hunting zone and agriculture land. Highest value (3.71±1.1) for crow diameter was recorded in the agriculture land, while the DBH and total height parameters showed no significant difference in the different land systems. Production of the sampled shea trees was highest in the agricultural land. The findings of this study show that morphological traits and production of shea butter trees could be affected by land use systems.

Livelihood potential of *Moringa oleifera* tree and its role in food security and health care in Nigeria. Arabomen, O., Ayomide, A., Azeez, F., Odediran, F. (*Forestry Research Institute of Nigeria (FRIN), Nigeria; arabomenkevwe2009@yahoo.com*; *adedunmolalala@yahoo.com*; *abdfataiaranni2002@yahoo.com; festusbukola@yahoo.com*).

Several million people worldwide and particularly in Nigeria depend on the forest for their subsistence, food security, health care and cash income. Nigeria's tropical forests are both beautiful and useful as they house an abundance of non-wood forest products (NWFPs) including foods (edible nuts, mushrooms, fruits, herbs, fodder), fibres (bamboo, rattan), exudates (latex, gums and resins) and other plant and animal products such as medicines, honey and wax. NWFPs play an important role in food security and health care in Nigeria especially for women who rely heavily on them for food, medicinal plants and household utensils. *Moringa oleifera* is a multipurpose tree belonging to the family Moringaceae. It holds tremendous promise for benefiting humanity. Local management of this "Miracle Tree" has increased its diversity and distribution through domestication which can improve the quantity and quality thereby making it more attractive to farmers and more marketable, thus contributing to the alleviation of poverty. The great potential of the tree and its various products has not yet been fully recognized. This paper therefore seeks to review the livelihood potential of *Moringa oleifera* tree and its role in food security and health care in Nigeria.

The vital role of stallholder initiatives in forest restoration and reforestation: the case of Cameroon. Atyi, R.E. (*Center for International Forestry Research (CIFOR), Cameroon; r.atyi@cgiar.org*), Hiol Hiol, F. (*Observatoire des Forêts d'Afrique Centrale (OFAC), Cameroon; hiolhiol@yahoo.fr*).

A study was conducted with the aim of identifying key drivers behind forest restoration and reforestation in Cameroon. The methodology used consisted of: literature review, field surveys and interviews using a comprehensive questionnaire developed and adapted to each category of reforestation actors. The study showed that the main drivers of forest restoration/regeneration and reforestation from non-government actors are the opportunity for income generation given the high demand for fuelwood, poles, and timber; and decentralization and devolution of powers on forest management to local councils. Private eucalyptus plantations

that are generally small in size are the most successful as more than 95% of the supply of industrially treated poles for electricity distribution come from this source, although these villagers do not receive any support from the forestry administration. Domestication of forest species seems to be a hopeful niche. In fact, pressure from the use of forest products has significantly reduced the presence of several species which previously were part and parcel of the agrarian landscape and provided many services to the people.

***Boswellia serrata* gum oleo resin and its contribution to the rural economy of Sheopur district of central India.** Bhatnagar, P. (*State Forest Research Institute, India; pratibhasfri1@gmail.com*).

This paper estimates income to forest dwelling community from an important non-timber forest product (NTFP), *Boswellia serrata* gum oleo resin in Sheopur district of Madhya Pradesh. A household survey (n=104) was undertaken in 34 villages in 2011 to estimate average income, on the basis of seasonal collection by households, number of trees per household and average local market rate. The survey revealed that local tribes are dependent on NTFPs for subsistence income of which gum collection contributes substantially for eight months a year. These tribes have tenural rights over *Boswellia serrata* trees occuring in natural forests. However, the number of trees per household varies substantially. On one side, 5% of households, having tenural rights on trees ranging between 301 to 500 earned Rs. 47 232 per annum as compared to 45% of households possessing up to 100 trees earned Rs 6 197 per year indicating inequitable income distribution. However, 20.8% of households without tenural rights earned an average income of Rs. 11 718 by collection from trees owned by others. It is concluded that there is positive correlation between income and number of trees owned per household. Since this is a major source of livelihood income more reform and equitable distribution of trees is required.

Traditional silviculture through *Butea monosperma*: a multipurpose tree species in Balaghat, India. Bhatnagar, P. (*State Forest Research Institute, India; pratibhasfri1@gmail.com*).

Agroforestry can reduce the dependence on natural forests for meeting basic requirements of forest products by planting multipurpose trees with crop combination on farm lands. This paper discusses traditional silviculture through a multipurpose tree *Butea monosperma* planted on farm bunds. It provides lac, gum, medicines, leaves, fuel wood, dye, etc. A study of Balaghat district revealed that 34.5% of the rural population is engaged in agricultural activities, of which 22.70% are landholders and 11.82% work as agricultural labour. Small scale landholders have adopted agroforestry system on their farms, where they traditionally cultivate paddy crop, which is the major cultivated crop covering 26.42% of total agricultural land, in combination with Butea monosperma trees along farm boundaries. This multipurpose tree is also a host plant for the lac insect; lac cultivation is undertaken on farm trees on a huge scale. Approximately 947 tonnes of lac is produced, farmers earn about Rs. 800/- per tree. The leaves are used for making platters, cups, and bowls, and the flowers, stem, bark and roots are used for medicinal purposes and wood as fuel wood. The tree has proved to be a beneficial combination with paddy for generations.

Seed producer candidate selection of *Bertholletia excelsa* H. B. K. in degraded areas and forest fragments, Peru southeast Amazon. Correa, G., Aucahuasi, A., Escalante, A., Llanos, K., Quiñones, J. (*Universidad Nacional Amazónica de Madre de Dios, Peru; biologo.geo@yahoo.com*; *porelcambiodemadrededios@yahoo.com*; *cibdamdd@yahoo.com*; *slaveciser@yahoo.com*; *jjosealmiron@yahoo.com*).

Madre de Dios region, Perú southeast amazon is the only region where the Brazil nut (*Bertholletia excelsa* H.B.K.) is found in significant populations for their exploitation, being the economic livelihood of a large part of the rural population. However, the development of megaprojects in the last decade, and the increase of the alluvial gold mining, deforestation and land-use change have been accentuated. The aim of this study was to determine seed producer candidate trees (SPCT) in 1855 ha covering degraded areas and forest fragments in Chonta Microbasin, left margin, Tambopata district. Censused were 57 individuals, including 34 in degraded areas and 23 in forest fragments. Considering tree structural characteristics and phenotypic traits, four seed producer candidate trees were identified in degraded areas and three in forest fragments. These should be considered as suppliers of seed for regeneration natural and/or assisted regeneration of *B. excelsa*.

Agroforestry systems to rehabilitation forest vocation lands in Michoacán, Mexico. Espinoza, G.G., García, J. *(Universidad Michoacana de San Nicolás de Hidalgo (UMSNH), Mexico; lyera_1623@hotmail.com; garma@umich.mx*), Saenz, J., Muñoz, H., Ochoa, J.J., Ramos, J.H. (*Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), Mexico; trinisaenzreyes@hotmail.com)*, (*jesusmuflores@yahoo.com.mx; jimenez.jorge@inifap.gob.mx*; *hernandez.jonathan@inifap.gob.mx*).

In order to recover suitable lands for forestry, in Michoacán, México, several agroforestry design systems in alley mode with cropping and forest plantations were evaluated. Forest components were *Pinus pseudostrobus*, *P. michoacana*, *P. montezumae*, *P. ayacahuite* and *Cupressus lindleyi*, trees plantation densities tested were 625, 700, 1 250 and 1 400/ha, agricultural components were corn, wheat, triticale, oats, ebo or spring vetch, winter vetch, peach and the grasses rhodes, weeping and *Festuca* var. cajun. In evaluations of one to three years, the highest forage was obtained with oat var. Cuauhtémoc and ebo (16.0 t ha^{-1} yr^{-1} of dry matter) associated with 700 trees/ha in Zinziro Lake micro watershed; the highest grain yield was corn (4.2 t/ha/yr) and 625 trees ha in Pátzcuaro Lake basin. Annual forage production can feed 2–8 cattle animal units or 20–80 sheep for four months. Forest component survival was 35 to 90%, mortality was due to gophers, soil pests and cattle damages; plant heights were 22 to 180 cm for *P. michoacana* and *P. pseudostrobus* respectively. A benefit/cost ration of up to 1.87 was also calculated, which shows that agroforestry systems are economically viable and an attractive production option for forest owner lands.

Participatory inverstigation of the interaction between *Sclerocarya birrea* and intercrops in Kilosa district, Tanzania. Kagosi, P. (*Tanzania Forestry Research Institute (TAFORI), Tanzania; pjkagosi@yahoo.com*), Kessy, S. (*Sokoine University of Agriculture, Tanzania; seciliakessy@yahoo.com*).

The study was conducted in Kilosa district, Tanzania to examine interaction of *Sclerocarya birrea* tree species with intercrops (maize and beans). The species is a multipurpose indigenous and drought tolerant tree species. It is common and widespread

throughout sub-Sahara Africa and a keystone species in ecosystem and productivity. Agroforestry is less popular in most of Tanzania's dry land areas despite the fact that *S. birrea* can be used as agroforestry species. Nevertheless it is not exactly known if it successfully interacting with intercrops. The study aimed at assessing the influence of trees on growth performance and biomass of intercrops. The trees were selected from each collaborating farmer's fields. The area around each tree was subdivided into three concentric zones. The control plot for crop only treatment for each sampled tree was established at around 30 m away from the edge of the tree crown. Data were collected during harvesting period and grain of both maize and beans were oven dried and then measured in grams. MINITAB were used to analyse data and the result shows that *S. birrea* influences both mass and yield of intercrops, thus potential for agroforestry tree in dryland areas and suitable for reduction of climate change effects.

Recovering degraded forest area using agroforestry practice: case study on area of former Mount Batur eruption, Bali (Indonesia). Narendra, B.H. (*Research and Development Center for Conservation and Rehabilitation, Indonesia; budihadin@yahoo.co.id*).

This paper presents the result of reforestation trial using agroforstry practice in a former forest area degraded by the Mount Batur eruption. The area need to be recovered due to the important role as a buffer of Lake Batur and potentially supports the community life. The agroforestry practice was selected to attract community actively getting involved in the reforestation efforts and enhance their livelihood through productive land provision. The trial used alley cropping system that combined *Calliandra calothyrsus* trees as the hedgerow and red bean (*Phaseolus lunatus*) crops as the alley. Randomized completely block design was applied to assess the effect of 2 kg of chicken manure per planting hole, 2 kg of top soil per planting hole, and a combination of both as the treatments. Statistical analysis revealed that applied treatments were highly correlated to the calliandra growth and red bean yield. The analysis showed that manure can significantly increase soil N and P content 46 and 10 times higher, respectively, than the control. Manure treatment was able to produce the red beans up to 3.2 ton/ha or significantly increase by 22 times compared to the control. It will be a way for the forest to recover and enhance community welfare.

Crop diversity of upland farms in Apayao Province. Rodolfo, D. (*Apayao State College, Philippines; flynrodolfo@yahoo.com*).

This study was conducted to determine the socio-economic characteristics of the upland farmers, document their existing farming systems and practices and assess the crop diversity of their upland farms in Apayao Province in northern Philippines. A structured interview schedule was designed to generate data for the socio-economic profile of the farmer respondents and actual field observation, documentation and validation is undertaken for their farming systems, practices and crop diversity. The results showed that the respondents were mostly males in the working age group with an elementary graduate as their average level of education. The majority of the respondents are Isnegs, although just a percent higher than that of Ilocanos. The upland farming system can be considered as varied in terms of the variables in classifying agroforestry farming systems such as component combination, spatial arrangement, and time sequence. The agroforestry farming system of the area can be generalized as: improved fallow, multistorey cropping system, rice terracing with woodlot, Taungya, alley cropping and boundary planting. The species crop diversity index (H') of the upland farms using the Shannon-Weiner diversity index formula has a mean of 1.00 (range: 0.005–2.39).

Evaluation of tree species for agroforestry development in the Sudan Sahel region of Nigeria. Verinumbe, I. (*University of Agriculture Makurdi, Nigeria; iverinumbe@yahoo.com*).

Evaluation of *Acacia nilotica, Acacia senegal, Azadiracta indica, Eucalyptus camaldulensis, Khaya senegalensis, Leucaena leucocephala* and *Prosopis juliflora* for growth and interactions with soil and crops for agroforestry development was undertaken on entisols in the Sudan Sahel region of northeastern Nigeria. One hundred trees of each species were established at 2 m × 2 m spacing on a sandy loam entisol by intercropping with beans (*Vigna unguiculata*) for the initial two years. Tree growth was regularly recorded and changes in soil properties as well as yield of *Sorghum vulgare* on them also evaluated. The tree species recorded more than 60% survival and grew rapidly. The highest annual mean tree girth growth rate of 3.65 cm occurred in *Leucaena leucocephala*, while *Prosopis juliflora* recorded the lowest (2.23 cm). The trees also accumulated wind blown sand and improved nutrient status of the soil under them. *Sorghum vulgare* crop grown on the forest soils produced higher dry matter yield than the control. The highest crop yield of 3.22 g/plant occurred on *Leucaena leucocephala* soil, while *Khaya senegalensis* recorded the lowest (1.22 g/plant). The study ranked species according to their growth and agroforestry qualities. It also observed some inter-tree species interactions which, when fully developed, will be very useful for scientific management of mixed species; common in tropical agroforests.

A-21 Coppice forests – a tradition with future

Organizer: Gero Becker (Albert-Ludwigs-University Freiburg, Germany)

Sustainable coppice forest management in the Balkans. Kampen, P. (*Connecting Natural Value & People Foundation (CNVP), Macedonia; peter.kampen@cnvp-eu.org*), Kola, H. (*Connecting Natural Value & People Foundation (CNVP), Albania; haki.kola@cnvp-eu.org*).

Through participatory planning, sample plots established in private and public coppice forest and comparisons in increment and production, we demonstrate the wide social ecological impact of the inconsistency of silvicultural regime with socio economic conditions. The increase of non-renewable raw materials for heating in the last century lost the importance of coppicing in Europe, replacing it by converting objectives. This converting idea was imported as best practice from Balkan forest services, and soon turned on an objective for the most of Balkan coppice forest. The objective of converting, as part of forest policies, was followed by legal restrictions against coppicing regime, despite the fact that the heating source in most of the Balkan countries remains the firewood as of today. It leads to big gap between demands –offer for firewood, followed by illegal sporadic selective

cutting and high degradations in public forest. The coppicing regime survived in some private forest as for comparisons. Innovative forest management, decentralization clear ownership, use rights and supportive legislation to achieve increased contribution of coppice in Balkans rural livelihood through increased biomass production and improved diversity are the main recommendations of the study realized by CNVP supported by Sida and World Bank projects.

Valuable but threatened: how the abandonment of traditional forest management systems influences the occurrence of a rare tree species. Pyttel, P. (*University of Freiburg, Germany; patrick.pyttel@waldbau.uni-freiburg.de*), Weber, T. (*Lycée Technique Agricole, Luxembourg; tunweber@hotmail.com*), Kunz, J., Bauhus, J. (*University of Freiburg, Germany; joerg.kunz@waldbau.uni-freiburg.de*; *juergen.bauhus@waldbau.uni-freiburg.de*).

Sorbus domestica is one of the rarest tree species in Central Europe. Although its timber is of high value, there is little information on its growth. Many individuals are growing in aged oak coppice forests. Since coppicing is no longer practiced, it is unclear whether the *S. domestica* population can persist in a continuous cover forest system or if coppicing is needed for species preservation. The objectives of this study are to analyse stand development and growth related competition processes between *S. domestica* and other tree species (mainly *Quercus petraea*) in order to understand future forest succession processes within the extended aged coppice areas of western Germany. To reconstruct regeneration processes and growth, tree ring analysis was carried out at 42 *S. domestica* trees and their two nearest neighbours. Dendrochronological data support the hypothesis that coppicing promotes the establishment of *S. domestica*. Growth patterns suggest that *S. domestica* is an extremely light demanding species that is unable to survive long periods of intensive competition. We conclude that abandonment of coppicing in these forests does threaten the status of *S. domestica*. In order to preserve species occurrence, the resumption of coppicing should be taken into consideration wherever advisable.

Harvesting traditional coppice stands in the northwestern Italian mountains. Spinelli, R. (*National Research Council of Italy (IVALSA), Italy; spinelli@ivalsa.cnr.it*), Ebone, A., Gianella, M. (*Institute for Wood Plants and the Environment (IPLA), Italy; ebone@ipla.org*; *gianella@ipla.org*).

Traditional coppice stands cover millions of hectares throughout Europe and offer large amounts of biomass. The study analyzed 10 commercial coppice harvesting operations in northwestern Italy, where modern machines were deployed. Removals, prices, work, revenues and costs were carefully determined. Firewood was the main product, representing between 70% and 100% of the total product mass and value. Traditional coppice stands often yield over 200 m^3 of energy biomass per hectare, at the time of cut. Cable yarding operations were better organized than ground-based operations, which explained why they incurred the same harvesting cost, despite the more challenging site conditions under which they were deployed. Mean harvesting cost was 45€ m^{-3}, of which about 10% was needed for felling, 70% for extraction and processing, and the remaining 20% for loading and transportation. All operations accrued some profit, which varied between 13 and 43€ m^{-3} or between 1 600 and 8 600€ ha^{-1}, depending on operational efficiency, value recovery and stand yield.

Study the potential of Lebanon oak (*Quercus libani* Oliv.) for coppice regeneration in northern Zagros forests of Iran. Valipour, A. (*University of Kurdistan, Iran; ahmadvalipour@gmail.com*), Namiranian, M. (*University of Tehran, Iran; namiranianm@yahoo.ca*), Ghazanfari, H. (*University of Kurdistan, Iran; Hedayat@uok.ac.ir*), Lexer, M. (*University of Natural Resources and Life Sciences, Austria; mj.lexer@boku.ac.at*).

Regeneration failure due to livestock grazing is a major problem in the northern Zagros oak forests of Iran. Coppice regeneration provides a fast-growing alternative to seedling regeneration. Knowledge of sprouting ability is an essential prerequisite for the use of coppice regeneration in the context of adapted silvicultural strategies. We investigated the sprouting ability of Lebanon oak in Northern Zagros. In total 45 Lebanon oak trees from three diameter classes (25–35, 35–45 and 45–60 cm) were cut. To monitor the sprouting behavior during the first year after cutting the stumps were measured in June and September. The number of sprouts was largest for the intermediate DBH class with 101 and 81 sprouts per stump in June and September respectively. Whereas there was no significant difference in mean sprout height per stump between the dbh categories, the maximum sprout height per stump was significantly larger for the intermediate DBH category. A higher sprout density per stool in June leads to a stronger decrease in sprout density until September. In Zagros forests coppice regeneration may contribute to sustain fodder and fuelwood production for the upcoming decades. Studies like the present one can contribute to find management strategies for Zagros forests which are able to balance the protection goals and the needs of local stakeholders who depend heavily on the sustainable use of forest resources.

Posters

Ecological complexity, stand basal area and rooting intensity respond differently under edaphic drought in ecotones at abandoned coppice forests. Chakraborty, T., Saha, S., Reif, A. (*University of Freiburg, Germany; tamalika.chakraborty@waldbau.uni-freiburg.de*; *somidh.saha@waldbau.uni-freiburg.de*; *albert.reif@waldbau.uni-freiburg.de*).

We hypothesized that interactions between ecological complexity and stand basal area (SBA) would vary under drought stress in ecotones. We also hypothesized that above ground interactions between ecological complexity, canopy openness and edaphic drought would influence belowground rooting intensity (RI). Five abandoned coppice stands in southern Germany and northern Switzerland were selected in ecotones of European beech and Downy oak forests. We calculated tree size diversity index to measure structural complexity. Shannon diversity index was used to quantify compositional complexity of vascular plants. Edaphic drought was quantified as available soil water storage capacity (ASWSC). Inventory plots were installed from beech to oak dominated area for representing change in plant composition, slope and ASWSC. ASWSC significantly increased plant compositional and structural complexity, however, did not reduce SBA. Structural complexity significantly increased SBA, however, compositional complexity and canopy openness didn't. In belowground, ASWSC and compositional complexity significantly increases RI. We conclude that structural complexity plays crucial role to maintain above ground stand productivity,

however, compositional complexity benefits belowground root intensity under gradient of edaphic drought in oak-beech coppice forests. These results will contribute to better explain the resilience of forests under drought, and changes in forest types to their drought limit.

Potential production of short rotation coppice willow in Denmark. Larsen, S. (*University of Copenhagen, Denmark; slar@life.ku.dk*).

To meet climate and energy policy targets, there is a growing demand for biomass for energy in Denmark and Europe. Short rotation forestry with coppice willow can fulfill goals of high biomass production and at the same time provide ecosystem services such as soil carbon sequestration, biodiversity etc. It is, however, difficult to predict the yield of this production because of the lack of experimental data. This study examines the production potential of short rotation coppice (SRC) willow in Denmark by use of the mechanistic crop model BIOCRO. Based on an extensive input dataset on Danish climate, soil and land use, and validated against real production data modeled yield of SRC willow has been found for every field plot in Denmark. This is the first time it has been done for Denmark and in such high resolution. The study shows that it is possible to grow SRC willow in Denmark with a yield of 8 to 15 Mg DM/ha, but with large geographic differences due to differences in climate and soil. As a result of this study it is now easier to estimate the production in Denmark and take decisions regarding future placement of bioenergy plantations.

Eucalypt coppice management for rurally-based, small-scale timber growers in South Africa. Little, K. (*Nelson Mandela Metropolitan University, South Africa; keith.little@nmmu.ac.za*).

Eucalypt coppice management regimes that focus exclusively on maximising volume production are practiced within South Africa. To supplement timber requirements by these commercial companies, additional timber supplies have been obtained from rurally-based, small-scale timber growers. Although the average size of each of their planted areas is small (1.5 ha), collectively the large number of growers provides an important source of timber to the commercial companies. Besides supplying timber, the coppice stems are also used by these rural timber growers for fencing (droppers and poles), building (laths or poles), or as a source of firewood. Thus, the management of these stands is varied, with no consensus amongst the different growers as to the best management practices for any specific product. It is therefore critical to determine the most effective manner in which coppice regrowth can be managed for multiple-use (fuel wood, droppers, building material, wood for pulp, etc.) rather than focusing on maximizing volume production for the commercial companies alone. In 2005, a trial was initiated on a recently felled *Eucalyptus grandis* x *E. camaldulensis* stand. Twelve different multiple-use management scenarios were tested against a commercial control over the subsequent six years. The most appropriate coppice systems are highlighted that include product-specific, as well as multiple-product options.

Sycamore maple (*Acer pseudoplatanus* L.) potential for coppicing: a case study. Nicolescu, V., Sandi, M., Şimon, D., Sinca, I. (*Transylvania University of Brasov, Romania; nvnicolescu@unitbv.ro*; *sandymely@freemail.hu*; *simon.diana91@gmail.com*; *vnnicolescu@yahoo.com*).

The objectives of this paper were to evaluate the coppicing potential of sycamore maple (*Acer pseudoplatanus* L.) as well as the effects of reducing the stocking (number of shoots/stump) on diameter and height increment of individual shoots. For these purposes, a young coppice established in 2005 by low cutting sycamore maple trees planted as pure rows in 2003 has been measured repeatedly since 2011. The reduction of number of shoots/stump (stocking after respacing: one shoot/stump, two shoots/stump, and control) was performed in the same year. The analysis of field data was carried out from both quantitative and statistical perspectives. The study revealed the high coppicing potential and fast growth of the species at young ages, as well as the increase effect of reducing stocking on both diameter and height increment. However, the diameter increment was more responsive to stocking reduction than the height increment; consequently the stability index (*SI = (h/d) *100*) was positively influenced (reduced) by the heavier reduction of number of shoots/stump. Taking into account the high coppicing potential and early fast growth, the future use of sycamore maple in short rotation coppices is also outlined in the paper.

The effect of harvesting on stump mortality and re-sprouting in aged oak coppice forests. Pyttel, P., Fischer, U., Bauhus, J. (*University of Freiburg, Germany; patrick.pyttel@waldbau.uni-freiburg.de*; *u_fischer@yahoo.de*; *juergen.bauhus@waldbau.uni-freiburg.de*).

In Central Europe, traditional management of oak coppice forest was abandoned at the beginning of the last century, leaving large tracts of forest developing into aged coppice stands. Recently renewed interest in coppicing has developed in many European countries because of the increasing importance of fuel wood as a substitute for fossil fuels and the preservation of coppice forests as a historical landscape element and habitat with high nature conservation value. However, there are uncertainties about the re-sprouting ability of large and old oak stumps. In this study we determined the re-sprouting ability of sessile oak stumps 80 to 100 years after the last coppice cut. Stump mortality and re-sprouting intensity were analyzed in relation to three different harvesting methods, browsing intensity, vitality of parent trees and stump parameters. On average 16% of all sessile oak stools died within two vegetation periods after coppicing. However, numerous new stump sprouts were recorded. Growth of the new sprouts was mainly influenced by browsing. Our results indicate that the re-sprouting ability of 80–100 year old oak trees originating from former coppice management is still high and little influenced by harvesting methods. However, browsing must be controlled, as with any other form of forest regeneration, if coppicing is to be applied successfully.

Hybrid aspen coppice forest for energy in hemiboreal Estonia. Tullus, H., Lutter, R., Kraav, J., Tullus, T. (*Estonian University of Life Sciences, Estonia; hardi.tullus@emu.ee*; *reimo.lutter@emu.ee*; *jaan.kraav@emu.ee*; *tea.tullus@emu.ee*), Tullus, A. (*University of Tartu, Estonia; arvo.tullus@ut.ee*).

One effective method to produce woody biomass is to establish forest plantations with fast-growing and vegetatively regenerating tree species. Due to high initial density and the existing root system from previous generation, non-fertilised hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) sucker stand may show very high biomass productivity. In Estonia the establishment

of hybrid aspen plantations started just 15 years ago and this is the first study of the second generation here. As part of the study above-ground biomass production in three-year-old non-fertilised vegetative hybrid aspen stand growing on Mollic Planosol was estimated based on destructive sampling of model trees. Several foliar and soil characteristics were studied in order to explain the within-stand variability in number and growth rate of the shoots. On average 111 000±16 000 aspen shoots ha-1 had emerged after the first growing season. Average woody biomass of vegetative hybrid aspen stand after the third growing season was 16.6±2.4 t DM/ha reaching 30.6 t DM/ha in the best part of the stand. Biomass harvest in winter (without leaves) would mean one third smaller removal of nutrients. In favourable growing conditions hybrid aspen could be an alternative option to willows for producing energy wood.

A-22 Forests under pressure: prerequisite conditions for forest-related sustainable development

Organizer: Pia Katila (Finnish Forest Research Institute, Finland)

Forests Under Pressure: possible future pathways. de Jong, W. (*Kyoto University, Japan; dejongwil@gmail.com*).

We will present part IV of the volume: *Forests Under Pressure: Local Responses to Global Issues*. This Part IV reflects on "possible future pathways". Hence, we first introduce "forward looking" as an academic exercise: its use, purpose, how it is done and with some examples of studies where this has happened. We subsequently synthesize the four chapters of Part IV of the Forest Under Pressure book. This includes: (1) a reflection on how the concept of sustainable forest management has evolved during forest science's history; (2) a forest and forestry outlook exercise based on the latest conceptual and operational understanding of sustainable forest management; (3) a linkage of local and global forest and forestry scenarios, using as the basic tool multiscale participatory scenarios; and (4) shared socioeconomic pathways and the futures for sustainable forest management. We will make the links with the previous three parts of the book, especially on Part III that analyzes some 30 cases of sustainable forest management experiments worldwide. We will finally aim to derive important lessons, for policy makers or for other relevant constituencies.

Community-based forest management in Quintana Roo, Mexico. Ellis, E. (*Universidad Veracruzana, Mexico; ellis_eddie@yahoo.com*), Kainer, K., Huelsz, J.S. (*University of Florida, USA; kkainer@ufl.edu*; *jasierra@ufl.edu*), Negreros-Castillo, P. (*Universidad Veracruzana, Mexico; patri_nc@yahoo.com*).

The Mexican model of community forestry is often touted as an example whereby greater community control enhances both conservation and local livelihoods. We examine conditions that have enabled and challenged sustainable forest management within community forests in Quintana Roo, a tropical state strongly influenced by the Maya culture that currently boasts 91% forest cover. Over time, community forestry has been shaped by land reforms and forest policies that institutionalised common property and local governance systems, granted timber rights to communities, instigated permanent forest areas for commercial management, and laid a foundation to respond to changing market opportunities (i.e. payments for environmental services, railroad ties, pole wood, and future carbon credits). Significantly, 16 years of state and international support via the Forestry Pilot Plan further empowered residents and increased local capture of forest benefits. In contrast, recent neoliberal economic and policy changes have promoted parcelisation and privatisation of communal lands, driving some deforestation and weakening governance in vulnerable communities. Corruption, lack of transparency, and contradictory agricultural, forestry, and conservation policies have impeded proper forest-sector investment. This case explores the dynamic human-forest relationship that has evolved and persisted for more than 3 000 years, revealing the resilience of both people and forests.

Prerequisite conditions for sustainable forest management: synthesis of the case studies. Galloway, G. (*University of Florida, USA; ggalloway@latam.ufl.edu*), Katila, P. (*Finnish Forest Research Institute, Finland; pia.katila@metla.fi*), de Jong, W. (*Kyoto University, Japan; wdejong@cias.kyoto-u.ac.jp*), Pacheco, P. (*Center for International Forestry Research (CIFOR), Indonesia; p.pacheco@cgiar.org*), Mery, G. (*Finnish Forest Research Institute, Finland; gerardo.mery@metla.fi*).

A concise synthesis of the 30 case studies included in the volume: *Forests Under Pressure: Local Responses to Global Issues* will be presented. The methodological approach utilized to develop this synthesis will be described. Attention will be drawn to the diversity of case studies included in the volume from two perspectives: (1) Contribution of forests and forest resources to livelihoods; and (2) forest condition. Consistent with the framework provided to the case study authors, prerequisite conditions for SFM are grouped in the following three categories: (1) Policies, institutions and governance; (2) Capacities and socioeconomic aspects; and (3) Research and monitoring. The first part of the synthesis will look across the cases to characterize efforts being made related to each pre-requisite condition. Next, within-case study interactions among pre-requisite conditions will be discussed, and how these interaction influence outcomes of SFM. These interactions will be grouped across the case studies to shed light on the types of interactions that are impacting SFM. This information will be complemented with a concise analysis of influences of regional/global processes on forest related policies and stakeholder behavior in the regions covered by the case studies. The results and implications of these analyses will be presented, along with recommendations for future efforts.

Introduction to the WFSE-project and the new book *Forests under Pressure: Local Responses to Global Issues*. Katila, P. (*Finnish Forest Research Institute, Finland; pia.katila@metla.fi*), Galloway, G. (*University of Florida, USA; G.Galloway@latam.ufl.edu*), de Jong, W. (*Kyoto University, Japan; dejongwil@gmail.com*), Pacheco, P. (*Center for International Forestry Research (CIFOR), Indonesia; p.pacheco@cgiar.org*), Mery, G. (*Finnish Forest Research Institute, Finland; gerardo.mery@metla.fi*).

The presentation will shortly introduce the IUFRO Special Project World Forests, Society and Environment (WFSE) and then focus on presenting the new book produced by the project: *Forests under Pressure: Local Responses to Global Issues.* The presentation will concentrate on the aims of the book and the process and collaborative methods used in producing it. It will

describe the contents of the book and serves as an introduction to the subsequent five presentations that will focus on specific issues in more detail. The book consists of four parts. The first part is an introduction to the book and presents the analytical framework used for analyzing the 27 case study chapters that form the second part of the book. Part three presents a synthesis of the analyzed case studies and analyses of the different conditons and combinations of conditions that seem to foster progress towards sustainable forest management and enhacing forest-related development. The fourth part of the book looks towards the future and relates the case studies and the results of the book to regional and global outlooks and scenarios. The book aims to derive important lessons for policy makers and other relevent constituencies.

Khasi responses to forest pressures: a community REDD+ project from northeast India. Poffenberger, M. (*Community Forestry International, USA; mpoffen@aol.com*).

This paper examines the experiences of ten indigenous Khasi kingdoms in Meghalaya, India who are responding to rapid deforestation by developing a federated sub-watershed management institution that will build the capacity of their traditional governance bodies to conserve and restore ancient community forest lands. The Khasi have protected their forests for centuries, but have been experiencing accelerating deforestation over the past decade due to growing demands for agricultural land clearing, fuel wood, charcoal, coal, and limestone. The Khasi seek to finance this initiative through the sale of carbon offset credits (under REDD+) and through payments for other environmental services (PES) including protecting a major waters source for the state capital in Shillong. Carbon and other PES mechanisms are providing an effective catalyst and programmatic framework for institutional innovation, mapping and boundary demarcation, and long-term planning, with potential funding for mitigation, restoration and income generating activities.

Forest citizenship in Acre, Brazil. Schmink, M. (*University of Florida, USA; schmink@ufl.edu*).

Since 1998, the western Amazonian state of Acre has been the site of ambitious policies to support sustainable forest-based development initiatives. The result is a long-term successful experiment in transformation of the state from an outside-driven development based on conversion of forest to pasture and agriculture to an endogenous, participatory process of development focused on sustainable use and valorization of environmental, economic, social and cultural assets of the local ppoulatons. Both successes and challenges of this unique experience provide valuable lessons in the search for forest-based development approaches. The paper traces the innovations in laws, institutions, public administration and policy to promote forest-based development, alongside the opening of policy-making to citizen input. Data presented from government reports outlining policies, supplemented by available empirical research, show impressive gains in stabilizing defoerstation, expanding forest production, and favorable but uneven socio-economic impacts of the state's forest development programs. The paper discusses lessons learned in Acre for potential application of sustainable development policies over the long term.

Community rights and participation in the face of new global interests in forests and lands – the case of Mozambique. Sitoe, A. (*Eduardo Mondlane University, Mozambique; almeidasitoe@gmail.com*), Wertz-Kanounnikoff, s. (*Center for International Forestry Research (CIFOR), France; S.WERTZ-KANOUNNIKOFF@cgiar.org*), Ribeiro, N., Guedes, B., Giva, N. (*Eduardo Mondlane University, Mozambique; joluci2000@yahoo.com*; *besoguedes@gmail.com; 3ngiva@gmail.com*).

This case study analyses community rights and participation in sustainable forest management (SFM) in Mozambique and the implications of new global interests in forests and lands. It also looks at the conditions and combinations of conditions that seem to foster positive change towards SFM. The study is based on literature review from different sources of information including legal documents, statistics, thematic reports and peer-reviewed articles. The results indicate that while forest and land resources are abundant and customary and statutory rules support local communities' participation in forest and land management, lenient implementation of these regulations jeopardize effective community participation. New opportunities for enhanced community benefits and participation in SFM are arising in Mozambique, but whether Mozambique can fully tap into these will depend on the extent to which key enabling conditions of institutional, informational, and capacity nature can be fulfilled.

A-23 Transitions to sustainable forest management: Economic, social and cultural parameters

Organizers: Jinlong Liu (Renmin University of China), Wil de Jong (Kyoto University, Japan), Yeo-Chang Youn (Seoul National University, Republic of Korea) & De Lu (Asia-Pacific Network on Sustainable Forest Management and Rehabilitation, China)

Land tenure, agrarian change and forest cover: the case of Mexico. Bee, B. (*East Carolina University, USA; bethbee78@gmail.com*), Skutsch, M., Gálvez, J.P., García, G.C., Mas, J., Gao, Y. (*Universidad Nacional Autónoma de México (UNAM), Mexico; mskutsch@ciga.unam.mx*; *jpanequegalvez@gmail.com*; *gcuevas@ciga.unam.mx; jfmas@ciga.unam.mx*; *yangao98@gmail.com*).

Common property scholars have long debated the relationship between property rights and natural resource management. However, this debate has historically centered on the binary construction of property as either common-use or private, which ignores the broad range of institutional arrangements that govern resource access and management. In the case of Mexican forests, *ejidos*, the quasi-common property regime, are often regarded as models of sustainable forest management. Below the surface however, a mixture of institutional arrangements and layered land access and rights shape actual practices of land use and forest cover change. This study contributes to the growing body of scholarship that investigates the relationship between different land tenure types, management strategies and forest cover in Mexico. Specifically, we focus on the relationship between formal property regimes, forest cover and the mixture of institutional arrangements within *ejidos* which reflect differing responses to policies designed to open *ejido* lands to privatization. Utilizing a multi-scale, multi-site, and multi-method approach, we seek to

understand how land use and forest cover change is conditioned by institutional arrangements that include both formal and informal rights and access. These results contribute to a greater understanding of the relationship between property regimes, local institutions, and land use change.

Transition to sustainable forest management and rehabilitation in the Philippines. Camacho, L., Carandang, A., Pulhin, J., Camacho, S., Paras, F., Del Rosario, P., Tesoro, F. (*University of the Philippines Los Banos, Philippines; camachold@yahoo.com.ph*; *papcarandang@yahoo.com*; *jpulhin@yahoo.com*; *sonny_camacho@yahoo.com*; *fdparas@gmail.com*; *peterdelrosario@gmail.com*; *ftesoro927@yahoo.com*).

The Philippines provide an interesting case for studying transition to sustainable forest management (SFM) in the tropical world. There were four cases examined in this study that represent the actual situation of SFM in the country. These cases manifest the complexity of the forest management systems in the Philippines, cutting across various governance dimensions, from the social, political, institutional, economic and environmental aspects. This study shows that forest cover may have continued to increase over the last decade because of increased reforestation and forest restoration in the past two decades. Experiences presented from the Philippine cases exhibit that the transition to SFM is not a linear but a dynamic and complex process. It is influenced by a combination of socio-demographic, economic, politico-institutional, and environmental forces operating at local to global scales. Viewed in the context of the identified key elements of SFM, there are yet major transition gaps that need to be filled out to improve on. These gaps include among others: the need for enabling policies and incentive systems; capable institutions and stakeholders actively engaged and committed in the pursuit of SFM; appropriate systems, tools and guidelines for SFM; and the practice of good forest governance including effective law enforcement.

The indigenous roots of the 1996 Bolivian Forestry Law and implications for the decline in forestry certification. Dockry, M. (*U.S. Forest Service, USA; mdockry@fs.fed.us*), Espinoza, O. (*University of Minnesota, USA; espinoza@umn.edu*), Langston, N. (*Michigan Technological University, USA; nelangs3@mtu.edu*).

Bolivia has been cited as one of the most successful cases of forestry certification. During the 2000s Bolivia had more certified acres than any other tropical country. Despite this success, the number of certified acres has declined by about half. Stakeholders have indicated that the 1996 Bolivian Forestry Law was instrumental in the early success of forestry certification in Bolivia. This paper will discuss the indigenous roots of the 1996 Bolivian Forestry Law and the implications for certification's decline. We use qualitative social science and historical research methods to analyze stakeholder interviews and historical data. We begin with an analysis of the indigenous demands for a Bolivian forestry law in the 1990s. We then analyze current trends of forestry certification and perceptions of the decline from interviews with industry, governmental agencies, non-governmental organizations, and indigenous communities. The paper concludes with a discussion of the implications of changing forest policy, stakeholder perspectives, and challenges for sustainable forest management and certification in Bolivia. These results can inform policy makers and stakeholders about the need to incorporate community perspectives when designing sustainable forestry policy, projects, and support programs for Bolivia and other forest-rich countries.

"No chop um, no kill um, but keep um": Moving *Prunus africana* from an endangered species to everyday tree in Cameroon? Ingram, V. (*Wageningen University, Netherlands; verina.ingram@wur.nl*).

Prunus africana is an Afromontane tree, locally used for fuel, timber and traditional medicine in Cameroon. The bark is also internationally traded as the principal ingredient in pharmaceuticals and health products. Growing international demand has led to concerns of overexploitation of wild stocks, its appearance on the IUCN Red List in 1998 and CITES trade restrictions in 2005. Cameroon was the largest world exporter, but enacted a self-imposed moratorium from 2007 to 2010. High montane degradation and deforestation rates combined with the export suspension negatively affected the livelihoods of around 60 000 people dependent on the international trade but provided a conservation respite to 15 years of intense harvesting, and a chance to reassess the species status and its governance arrangements. In response to these challenges, a national management plan was collaboratively developed by chain actors. The actuality of its endangered status was assessed and routes to more sustainable international trade developed. The results of multi-disciplinary studies underpinning the plan are presented. Governance arrangements (statutory, customary, project, voluntary and market-based, corruption and involuntary international agreements) were found to strongly influence sustainable harvesting and livelihoods. The resumption of exports and continued paradoxical context in which this species is regulated, traded and used, the risks and opportunities of the new governance arrangements and implications for conservation and livelihoods are critically reviewed.

Indonesia's forest management units as agents of social safeguards in REDD+ implementation. Kim, Y. (*Northern Arizona University, USA; ysk@nau.edu*), Bae, J. (*Korea Forest Research Institute, Republic of Korea; forestory@forest.go.kr*), Fisher, L. (*University of Arizona, USA; lafisher@email.arizona.edu*), Bakti, L. (*Northern Arizona University, USA; lb699@nau.edu*).

We will discuss how Indonesia's emerging system of forest management units (Kesatuan Pengelolaan Hutan or KPHs) can be developed as an agent of social safeguards in REDD+ implementation. The KPH system is viewed as a key element of decentralization of forest governance reform for REDD+. National regulations outline the specific tasks charged to KPHs: forest inventory, forest management planning, and communication and coordination with local communities and indigenous peoples. For the KPHs to be effective, they will need stronger financial, administrative and technical support from the national government, as well as administrative support from provincial and district-level governments. Expanding technical and leadership training for provincial and district governments to help them understand potential benefits of KPHs system would encourage integration of the system into the annual budget planning process. The national government can also connect KPHs and REDD+ project developers, so the development and implementation of REDD+ activities can support the KPHs in fulfilling their basic functions as well as the role of social safeguards. To illustrate these points, we examine the KPH in West Lombok, praised as one of the most successful KPHs in Indonesia. We discuss the factors contributing to the KPH's success and offer recommendations for achieving similar successes with other KPHs in Indonesia.

Forest transition in China and interprovincial flow of commodity, population and forestry investment. Li, L., Liu, J. (*Renmin University of China, China; ytlilingchao@126.com*; *liujinlong_jl@hotmail.com*), Xu, L. (*Agricultural Bank of China, China; newxiaogang_0414@163.com*), Xue, H. (*Renmin University of China, China; xuehuidanlinlin@126.com*).

Forest transition depicts a picture of a shift from net deforestation to net reforestation, which played a significant role in carbon sequestration and climate change mitigation. After a long history of forest clearing and degradation, China as a whole has experienced a significant increase in forest cover and volume since the 1980s. Complex biophysical environments and rapid change of social and economic conditions has made China a perfect context in which various proximate forces and paths to forest transition could be assessed. Given the variety of socio-economic, political, and cultural contexts in Chinese provinces, we built a dataset through China's variety of official investigations at provincial level rather than the national scale since 1981, to try to map forest transition in China from the perspective of analyzing flow of commodity, people and public investment across provinces of mainland China, and provide a comprehensive and detailed picture of forest quantity and quality transition during the last three decades. We concluded that forest transition in China is not undergoing a specific pathway, but is a complex process that could only be fully portrayed by a combination of pathways, i.e., economic development, ecological security (forest scarcity) and trade.

Economic development, government intervention, and forest transition in China. Long, H., Liang, M., Liu, J. (*Renmin University of China, China; longhx1986@163.com*; *alexliang2@126.com*; *liujinlong_jl@hotmail.com*).

China has experienced forest transition since 1990s, but there is still controversy on whether an Environmental Kuznets curve exists at the province level, and what drives the forest transition rapidly in such a low per capita GDP level. Empirical results using panel data for 29 provinces during 1981–2008 suggest that the cube of per capita GDP has a positive but limited impact on the forest coverage, indicating S shaped, rather than U shaped relationship exists between forest coverage and per capita GDP. Our results support that the forest transition in China was strongly driven by the increasingly off-farm employment, agricultural productivity, government forestry investments and timber import. The growing economy driven by demographic bonus has dramatically decreased the rural population press in land, promoting marginal farmland both in population inflow and outflow provinces to turn into forest land rapidly, and made it possible for the government to increase the forestry investment on a large scale as well. We argue that the forest transition in China results from interaction of economic development, government intervention and globalization, rather than explained alone by the forest scarcity pathway, economic development pathway, and state forest policy pathway.

How do local communities interpret and shape forest policy intervention? –the case of collective forest tenure reform in China. Luo, Y. (*Northwest A&F University, China; lyfcl@163.com*), Liu, J. (*Renmin University of China, China; liujinlong_jl@hotmail.com*).

The newly implemented collective forest tenure reform in China is a remarkable part of the global trend of forest management decentralization. This paper intends to illustrate how local communities respond to the reform and how different actors interpret it into action under local social-ecological condition at two case study villages selected in Wuyuan County of Jiangxi Province. We found that in the policy implementation of the collective forest tenure reform, various actors such as the local government, communities and households try to deconstruct the policy text with their own knowledge system. The traditional resource management system based on the social customs in the local communities is also effective to solve the collective action problem and contribute to efficient resource utilization. Thus the complexity and robustness of forest tenure combinations may ensure flexibility for sustainable forest management, and accommodated to change of the socioeconomic conditions. This study hopes to promote understanding of the local forest governance and policy transformations during the current process of forest reform in China.

The local level cooperation forms in forestry and their governance: Croatia and Serbia as case studies of southeast Europe. Miovska, M. (*University of Padua, Italy; mmiovska@gmail.com*), Gatto, P. (*University of Padova, Italy; paola.gatto@unipd.it*), Nonic, D. (*University of Belgrade, Serbia; dragan.nonic@sfb.bg.ac.rs*), Posavec, S. (*University of Zagreb, Croatia; sposavec@sumfak.hr*), Pettenella, D., Secco, L., Da Re, R. (*University of Padova, Italy; davide.pettenella@unipd.it*; *laura.secco@unipd.it*; *riccardo.dare@unipd.it*).

The territorial and political restructuring and establishment of new independent countries within the region of southeast Europe resulted with processes of transition, decentralization and land restitution during this period of more than two decades. These processes brought changes in forestry with a significant number of new forest owners of previously so-called "social good" property, against high fragmentation of forest land and unfavorable forest management conditions. The paper analyses the forms of cooperation at small scale level by using a framework based on the concepts of Community Based Natural Resources Management (CBNRM) and of forest governance. The data presented have been collected through in-depth interviews with the cooperation forms' members and with representatives of concerned stakeholders of selected case studies in Serbia and Croatia. The results reveal that some of the forests depend on people organizing themselves to seek for better management and more sustainable use of forest benefits with respect to their small and scattered forest holdings. Internal governance is one of preconditions for good cooperation among the forest owners. However, they face problems such as insufficient extension services and complex procedures for felling approval to be respected, which try to collectively overcome cooperating at a local level.

Economic evaluation of forest management sustainability in Lithuania. Mizaraite, D., Mizaras, S. (*Lithuanian Research Centre for Agriculture and Forestry, Lithuania; ekonsk@mi.lt; stasys.mizaras@gmail.com*).

Sustainable forest management is defined as the stewardship and use of forests and forest lands in a way, and at a rate, that maintains the forest's biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at a local, national, and global levels and that does not cause damage to other ecosystems. Criteria and indicators are used to evaluate forest sustainability. These are tools designed to define, assess and monitor periodic progress towards sustainable forest management in a given country or in a specified forest area. They are

deployed over a defined period of time to demonstrate the individual features of sustainability. But there is deficiency of generalized economic indexes to evaluate the sustainability of forest management. This paper evaluates economic, ecologic and social functions and estimates of economic losses caused by development of protected areas in Lithuanian forest. Research is based on methodology of multi-criteria analysis of sustainable forest management, economical evaluation of forest multi-functionality, analysis of social preferences of citizens. Research is funded by the European Social Fund under Global Grant measure.

Forest common resources and sustainability: Van (forest) Panchayat and forest protection committee in Garhwal, India. Nagahama, K., Saito, K. (*University of Tokyo, Japan; kazuyona@zpost.plala.or.jp; kaoru@nenv.k.u-tokyo.ac.jp*), Rakwal, R. (*Tsukuba University, Japan; plantproteomics@gmail.com*).

The idea of establishing Van (Forest) Panchayats originated in conflicts between people and the state government for control of resources at the beginning of the 20th century. Nevertheless, there was a steady decline in the practice, and a quantitative and qualitative decline of the once dense and well-managed forests in the Kumaon. This study pays attention to new Van Panchayats in Garhwal via the question: to what extent have local institutions achieved sustainable forest management successfully? The intention of this study is to clarify actual forest management and utilization, and analyze the perceptions within forestry in relation to the protection committee.To achieve our goal, field surveys were conducted in August 2011, 2012 and October of 2013. Result of interviews revealed the requirements or revision of the micro-plan, and (1) no change in most of the protection committee members during the last seven years, (2) unfair selection of the protection committee members and chairperson, and (3) proper utilization of forest products. In the case of the third point, for example, villagers consumed firewood daily and did not shift to using liquefied petroleum gas provided by the government under various schemes to increase access to modern amenities; this is also necessary for forest conservation.

Exploring the future of timber resources in the high forest zone of Ghana. Oduro, K. (*Forestry Research Institute of Ghana, Ghana; kwameoduro@gmail.com*), Arts, B., Mohren, G. (*Wageningen University, Netherlands; bas.arts@wur.nl*; *frits.mohren@wur.nl*), Kyereh, B. (*Kwame Nkrumah University of Science and Technology, Ghana; kyerehb@gmail.com*), Hoogstra-Klein, M. (*Wageningen University, Netherlands; Marjanke.Hoogstra@wur.nl*).

Ghana's forests, particularly the timber resources, face an uncertain future, because of high deforestation rate, a rapidly declining timber resource base, rapid population growth and increasing demand for timber. This paper explores the future development of timber resources in Ghana by constructing scenarios and considering options policy-makers could take to ensure sustainable future development of the timber resource. Data was collected by reviewing the literature and consulting experts. The scenarios follow the deductive approach, exploring the potential interactions among key driving forces as selected by experts. The two most important driving forces for the future of timber resources selected by the experts were forest governance and resource dependency. Four plausible scenarios were developed: legal forestry scenario with emphasis on maintaining the resource base to meet high demand; forest degradation, a business-as-usual scenario; forest transition, with emphasis on expanding the resource base; and timber substitution scenario seeking to provide wood substitutes to conserve the resource base. The scenarios provide insights for policy making and strategic planning for forest resource management in Ghana. To ensure a sustainable future for timber resources, policy reform is needed, focusing on land and tree tenure, revenue capture, benefit-sharing schemes and satisfying the domestic demand for timber.

Public participation in forest restoration and urban forest management in South Korea. Park, M., Yeo-Chang, Y. (*Seoul National University, Republic of Korea; mpark@snu.ac.kr; youn@snu.ac.kr*).

South Korea has experienced successful forest restoration and oriented sustainable forest management since forest transition. South Korean forests are managed not only by strong state policy but also by participation by private actors. This paper is aimed at identifying social actors participating in the forest restoration and management activities and analyzing policy on forest cooperation between public and private sectors. It attempts to interpret social factors in Korea forest restoration depending on the theory of public participation. Through document analysis and interviews, two types of public participation in forest management were investigated. The one is 'Sanlimgye' as a social organization for community forest management, which took part in the national forest restoration programme, was examined in the period of the First and Second National Forest Development Plans (1973–1987). The other is partnership between citizens and local government in urban forest design and management since the 1990s. Two types of public participation do contribute to a better understanding of how the community could play a principal role of forest management over time. We think the Korean experiences could be informative to other countries in designing forest restoration and management policy.

Transition to sustainable forestry management and rehabilitation in Japan. Tachibana, S. (*University of Tsukuba, Japan; tachibana.satoshi.gn@u.tsukuba.ac.jp*), Shiga, K. (*University of Tokyo, Japan; shiga@anesc.u-tokyo.ac.jp*), Ota, M. (*Embassy of Japan in Indonesia, Japan; masohta80@hotmail.com*).

According to Forestry Agency (1971), forest area (forest and tree cover) in Japan changed from 17.7 million ha in 1886, 25.2 million ha in 1890, 22.2 million ha in 1915, 23.5 million ha in 1939, 19.6 million ha in 1945, to 25.6 million ha in 1960, and has been stable at around 25 million ha since the 1960s. We analyzed the causes of this forest transition using previous studies and statistical reports. We summarized the socio-economic factors that have influenced forest transition in Japan as follows. (1) Policy: Forest Law in 1897, Forestry Law in 1951 accompanied by the Forestry Planning System, and expansive afforestation measures from the 1950s to the 1970s had significantly positive influence. (2) Social issues: Population increase had a negative impact. Depopulation of rural areas has influenced on forest management negatively. (3) Land utilization: Agricultural land use had significant negative influence. Urbanization might have had impact to a certain extent. (4) Economic issue: Timber import had a positive impact. (5) Energy: Fuelwood consumption had a negative impact.

Study on the intelligent management of ecosystems based on the complex system theory. Wen, Z., Zhao, Q., Zhu, X., Lu, L. (*Nanjing Forestry University, China; zmwen@njfu.edu.cn*; *zhao5190@126.com*; *jingren1980@hotmail.com; lvliu@njfu.com.cn*).

Ecosystem management reflects human's behavior of utilizing and protecting environments and natural resources scientifically and sensibly. Sustainable development relies on renewable resources, especially the rational use of biological resources. Hence ecosystem management is an important approach to the sustainable development. The paper aims to study intelligent management of ecosystems comprehensively. The ecological data in the study area were obtained by remote sensing and other wireless sensors. Through analyzing these data, the paper discussed the adaptive management model of forest ecosystem based on multi-agent system theory. The paper also constructed the aggregation and segmentation algorithm of forest ecosystem in flexible scales and calculated the dynamics of uneven-aged forests providing ecological services so as to form strategy model of optimizing algorithms taking multi-agent into account. On this basis, the paper tried to draw up a multisectoral social accounting matrix. After examining parameters and analyzing variance of the data on the social matrix, a multisectoral model of ecological economic system would be developed to illustrate various impacts of ecosystem management on the economy in the same area.

Comparative analysis of forest transitions in nine Asian countries – an economic modeling. Yeo-Chang, Y. (*Seoul National University, Republic of Korea; youn@snu.ac.kr*), Liu, J. (*Renmin University of China, China; liujinlong_jl@hotmail.com*), de Jong, W. (*Kyoto University, Japan; wdejong@cias.kyoto-u.ac.jp*), Junyeong, C. (*Seoul National University, Republic of Korea; jheywai@gmail.com*).

There has been continuous deforestation in the world since the industrial revolution began in the 1760s. Deforestation caused critical problems such as biodiversity loss, soil erosion, and climate change. To cope with such environmental problems, policy makers nationally or internationally tried to avoid deforestation by deploying legal, financial and information tools or programs such as reforestation and participatory forest management. The change in forest cover from decreasing to increasing pattern is called forest transition. In this paper, we will build up economic models for explaining forest transition so as to find out substantial factors which lead to forest transition. With such models we can predict the status of forest coverage with some scenarios of key variables which may be controlled by policy interventions. For empirical study, data for modeling were collected from nine Asian countries, namely China, India, Indonesia, Japan, Laos, Malaysia, South Korea, Philippines, and Vietnam. Results from this research can help policy makers in the forest sector design policy measures for sustainable forest management, especially for avoiding deforestation and fostering forest restoration in developing countries.

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Paradigm shift of forest management of Bangladesh from production to service-oriented forest. Al Amin, M. (*University of Chittagong, Bangladesh; prof.alamin@yahoo.com*).

The British colonial approach is still the core of forest management of Bangladesh, however, recent policies of forest management incorporating social aspects and considering diverse dimensions of human in the forestry sector with various international commitments by conventions and treaties, led the forest management of Bangladesh to a huge shift on policies from earlier ones. This study critically reviewed all forest policies and acts of the country and focused on newly adopted management strategies by the forest department to uphold the forest from the "specialized shop" to "emporium of diverse functions and services". The major shift lies on the reserve forests of the country (where people are not allowed to get in, unless they are permitted), which are now converted to national parks and wildlife sanctuaries with a provision to manage by the people. Those that live around the forest and forest officers are now as advisors to inform the management of the forest. This study puts forward an outline of how a century-long traditional forest management policy is changing its way from production forestry to people-oriented environmental service forestry. Moreover, this study quantifies cover changes and sketches future forests with newly adopted management strategies for paradigm shift of forest management options.

Rural people's perception of forest resources conservation in Ekiti State, Nigeria. Arowosoge, O., Olujobi, O. (*Ekiti State University, Nigeria; yemisoge@yahoo.co.uk*; *olujobioj@yahoo.com*).

The involvement of rural communities in sustainable forest conservation cannot be underestimated, particularly now that the forest reserves which serve as habitat to wild biotic resources are highly degraded. To determine the factors that can contribute to sustainable forest resources conservation, this study examines the perception of the rural communities around three forest reserves in Ekiti State. Data were collected from a random sample of 240 households through questionnaire administration and interviews. Data collected were analysed using descriptive and inferential statistics. Respondents recognized the importance of conserving the forest for natural resources and biodiversity ($\chi^2 = 5.84$, df = 11, $p < 0.05$); economic benefits ($\chi^2 = 4.14$, df = 11, $p < 0.05$); and for cultural purposes ($\chi^2 = 4.01$, df = 11, $p < 0.05$). Using the Likert scale, the top three perceptions of the rural communities are: (a) rural communities' participation in forest management and involvement in decision making with mean of 4.23; (b) provision of alternative income generating activities and incentives (4.01); and (c) promotion of environmental conservation education programmes (3.13). Formulating policies that could ensure a participatory approach involving the indigenous people living around the forest while improving their livelihood are essential.

Socio-economic and cultural aspects of forest transition in Kuningan District, West Java, Indonesia. Damayanti, E., Prasetyo, L. (*Bogor Agricultural University (IPB), Indonesia; e11yn.d4mayanti@gmail.com*; *lbprastdp@yahoo.com*).

As one of the developing countries that experienced severe deforestation over decades, some places in Indonesia have been turning to reforestation. Damayanti, *et al*. (2013) revealed that deforestation started from Java Island to Sumatera Island, then to Kalimantan, Sulawesi, and Papua Islands. However, reforestation started in a scattered manner in each island. In Java, West Java Province is the province that already experienced forest transition. The objective of this study was to find out the characteristics of forest transition in Kuningan District, West Java, Indonesia. Semi-structured interviews with an extended-questionnaire and interview guide were employed. The study revealed that most of the people in Kuningan District engaged in agricultural activities and also part-time farming. Farmers and non-farmers (except peasants) own lands and they prefer to plant trees in their lands. Planting trees has become the culture of Kuningan people, especially for fruit trees, such as mango, (*Mangifera indica*), jack fruit

(*Artocarpus heterophyllus*), sukun (*Artocarpus altilis*), salak (*Salacca zalacca*), banana (*Musa* spp.), papaya (*Carica papaya*), coconut (*Cocos nucifera*), etc. Just recently, when timber prices were rising and the term "private forest" was introduced, the people started to plant timber trees for economic reasons.

Underlying causes of forest transitions in Indonesia. Damayanti, E., Prasetyo, L., Kartodiharjo, H. (*Bogor Agricultural University (IPB), Indonesia; e11yn.d4mayanti@gmail.com*; *lbprastdp@yahoo.com; hkartodihardjo@yahoo.com*), Purbawiyatna, A. (*The Indonesian Ecolabelling Institute (LEI), Indonesia; nalakng@yahoo.com*).

After experiencing deforestation, some countries in Europe (e.g. Scotland, France) and Asia (e.g. Korea, Japan and China) have passed reforestation processes. The process from deforestation to reforestation is called forest transition. The forest transition will occur in certain countries if one of following conditions were achieved: (a) concentration of agricultural land on better soil quality, resulting in forest growth on abandoned poor land; (b) rural exodus due to agricultural land decrease and more land released for growing; (c) small holder agricultural intensification and emerging markets for agricultural input and output; and (d) log scarcity/timber shortage that creates a market incentive to plant trees. By using GIS, land cover changes in the period of 2000, 2003, 2006, 2009, and 2011 were analyzed. At the national level, Indonesia is considered as a deforestation country; however, the deforestation among places was varied. Several provinces and districts already passed the deforestation phase and turned to reforestation. This was because of Indonesian diversity in terms of biophysical condition, social, economy & culture, uneven development stage throughout the country, and various policies issued by district governments. Further study at Kuningan District revealed the process of forest transition. Therefore, we suggested that forest transition in Indonesia should not be analyzed at national level.

Simulator for the cost integral analysis of reforestation projects. Hernández-Díaz, J., Wehenkel, C., Pompa-García, M. (*Universidad Juárez del Estado de Durango (UJED), Mexico; jciroh@ujed.mx; wehenkel@ujed.mx; mpgarcia@ujed.mx*), Perez-Verdin, G. (*Instituto Politecnico Nacional, Mexico; guperezv@ipn.mx*), Prieto-Ruiz, J. (*Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), Mexico; jprietoviv@yahoo.com*).

It is usually considered that reforestation concludes when the plant produced in the nursery is placed in the definitive planting site, and usually it is sought to minimize the unit cost per hectare reforested. This approach is incomplete, since in the long run many factors influence the overall cost of a reforestation project, and not only the related with the short-term cost of each hectare planted. It is therefore important to develop efficient planning tools that allow to foresee and to efficiently compare the whole project's potential costs and benefits, before they occur. In this paper we present a cost simulator which considers technical aspects as: the origin and quality of the seed, site preparation, distance to the planting area, percentage of surviving, need to replace dead plants, increment, morphic coefficient, individual size of the areas to be reforested, maintenance in subsequent years to reforestation, and other factors. Taking into account these aspects, this simulator allows the estimation of expected unit costs per hectare and per the entire project, both in local currency and in U.S. dollars. Another advantage is that it quickly allows one to simulate these costs in various scenarios, and therefore facilitates decision making in reforestation projects.

Performance of joint community patrolling at Lawachara National Park, Bangladesh. Islam, M. (*University of Queensland, Australia; wasiulislam7@yahoo.com*), Khatun, T. (*Khulna University, Bangladesh; md.wasiul.islam@gmail.com)*, Sadath, M. (*Georg August University, Germany; mnsadath@yahoo.com*).

The people living inside and surrounding the Lawachara National Park (LNP) stimulate a pressure on the natural resources. Joint Community Patrolling (JCP) is a self-motivated initiative where the local communities are legally permitted to protect the forest jointly with the Forest Department under various projects. This initiative was spontaneously accepted among the local people due to the commitment of withdrawal of forest cases and support to alternative income generating activities (AIGA). This study aims to assess the performance of JCP in LNP following face-to-face interview of different stakeholders. Overall, 75% members of the JCP groups shared their benefits through social forestry operations whereas cow fattening occupied a major share in AIGA. Illicit felling was reduced remarkably after the initiation of JCP efforts during 2005–06. The study also identified that a lack of proper awareness hampered the economic progress of the area. LNP has a number of entry points that obstruct its protection. So, the demarcation of boundaries and ensuring protection are desired especially for core and buffer zones. The concerned license issuing authorities should be strict in formulating a framework to regulate various wood-based industries surrounding the LNP. Income from tourism in and around the LNP must be distributed transparently for community development.

Diversification of pathways for forest transition in China – based on province-level panel data. Liang, M., Liu, J., Long, H. (*Renmin University of China, China; alexliang2@126.com*; *liujinlong_jl@hotmail.com*; *longhx1986@163.com*).

There is an argument on whether there is an Environmental Kuznets curve (EKC) in China and what are the main determinants that drive forest transition in provinces of China. By using cross-provinces panel data, we find that there are 6 main types of forest change path, some provinces depict a very obvious EKC but others are not. Secondly, provinces with the same level of economic development do not certainly go along the same transition track, even two are very geographically close. In conclusion, economic determinants can only explain a limited part of reasons for forest area changes, and consequently determinants which drive forest transition not only refer to economics, but also include factors of other aspects. As a result, it is inappropriate to analyze forest transition with a uniform model and pattern, especially for a country, such as China, that has such a large territory where each province is different. Consequently, we should pay more attention to evaluating the impacts of non-economic determinants, such as forest tenure, traditional culture and administrative regulation, etc.

Gender difference in forest management: temporal and cross-cultural perspective in aboriginal communities in India and Canada. Singh, M. (University of British Columbia*, Canada; monika.singh@alumni.ubc.ca*).

Women and men have different ways of accessing natural resources; in case of forest-dependent communities, accessing forest resources. Changes in these roles may take place due to various reasons, for example outside intervention of different policies and

programs that require people's participation. This paper provides results from two case studies; in Gujarat, India, and in British Columbia, Canada. In the Indian case, a community forestry program was introduced in 1991 with the aim of regenerating degraded forests with community involvement. I carried out a survey with the same households in two time periods (1996 and 2011), on use, access and control over forest resources. In the Canadian case, I conducted interviews with a coastal First Nation that focused on values and perceptions on sustainable forest management (SFM). Using both examples, I reflect on the importance of inputs and participation of women and men in designing forest programs in the global South and North, and a few challenges associated with processes of implementing forestry programs.

A-24 Smallholders and forest landscape transitions: Locally devised development strategies of tropical America

Organizers: Benno Pokorny (University of Freiburg, Germany) & Wil de Jong (Kyoto University, Japan)

Employment and income generation in the non-timber economic activities in the Brazilian Amazon. Ferreira Filho, J.B.S. (*University of São Paulo, Brazil; jbsferre@usp.br*), Fachinello, A. (*Federal University of Santa Catarina, Brazil; fachinello@hotmail.com*).

In this paper we develop a Social Account Matrix (SAM) for the Brazilian Amazon region, with a focus on non-timber forest activities. The Amazon SAM distinguishes 12 activities related to the forest in the Amazon, and allows a detailed picture of jobs and income creation in those sectors. The linkages of those sectors with the rest of the economy are also addressed, as well as the degree of processing of forest products, both for local use and exports (to the rest of the world and the rest of Brazil). The SAM is used to derive SAM-based multipliers which highlight the interconnection of those forest sectors with the rest of the economy, allowing the analysis of their economic potential for income and jobs creation in a general equilibrium setting. Results show the limitation of those activities in terms of jobs and income creation in the Amazon, in contrast to the importance of the timber sector. Labor multipliers in some primary activities were found to be large, pointing to the importance of organizing their supply chain. Multipliers associated with forest products processing industries were also found to be large, highlighting the importance of developing further those sectors.

The role of smallholders in a green economy: the case of Peru. Guarin, A., Scholz, I. (*German Development Institute, Germany; alejandro.guarin@die-gdi.de; imme.scholz@die-gdi.de*).

This paper addresses the question of whether, and how, smallholder production contributes to the so-called green economy (or green growth), an economic model that explicitly considers the unaccounted for goods and services provided by ecosystems, as well as the negative externalities of human action. In this framework, the value of forests goes beyond timber and non-timber products to include the critical role of biodiversity and carbon sequestration, which is why payments for avoided deforestation (such REDD programs) play an important role. In the Peruvian Amazon, smallholder farmers appear to sit uncomfortably in this framework: they are allegedly one of the main drivers of deforestation through the expansion of subsistence agriculture. Despite broad assumptions, little is actually known about the real potential of smallholder farming for growth, inclusiveness and sustainability (the three pillars of a green economy). We review studies about smallholder economy in the Peruvian Amazon and rely on original interviews to address three main issues: (1) What is the evidence for the causes, motivations and results of deforestation in the Peruvian Amazon? (2) What is the evidence for the productivity, value generated, and environmental impact of smallholder farming? (3) What are the distributive effects of current REDD programs?

Forest management by smallholders in Western Amazon: towards more integrated approaches. Pacheco, P. (*Center for International Forestry Research, Indonesia; p.pacheco@cgiar.org*).

Significant reforms were undertaken in the past to promote sustainable forest management in the Western Amazon countries (i.e. Bolivia, Peru, Ecuador) including measures such as adopting instruments for regulating forest resource use, clarifying forest tenure rights and putting in place systems for illegal timber supply verification. These attempts have, however, not attended the demands from smallholders that have continued using the forests and engaging to the markets often in informal ways due to the difficulties to legalize their forestry operations. This paper explores the situation facing smallholders in their attempts to undertake forest management. The analysis is based on fieldwork undertaken in 2012 and 2013 in Ecuador, Bolivia and Peru. This paper suggests an integrated framework to move forward our understanding of the required policy approaches and steps towards more sustainable and inclusive forest management as part of broader economic and livelihood strategies undertaken by local actors. The latter entails not only to give more explicit attention to some dimensions of forest management, mainly those related to finance and business models, that have received little attention so far, but also to look at sustainable forest management as part of more integrated management perspectives of farms, community lands and landscapes.

Collective action for forest management: institutional challenges for enhanced social-ecological systems of the "environmental agrarian reform" in Anapu, Brazilian Transamazon. Porro, R. (*Embrapa Eastern Amazon, Brazil; roberto.porro@embrapa.br*), Miyasaka Porro, N., Menezes, M. (*Federal University of Pará, Brazil; noemi@ufpa.br; marlon@ufpa.br*), Bartholdson, Ö. (*Swedish University of Agricultural Sciences, Sweden; orjan.bartholdson@slu.se*).

This paper examines socioeconomic outcomes after five years of community forest management in a Sustainable Development Project (PDS) in Anapu, Brazilian Transamazon. The PDS is a tenure modality integrating land reform and environmental conservation. In 2007 families at the PDS Virola-Jatobá were advised by public agencies to perform forest management through a community-company partnership. Operations were conducted in 3 000 ha and near 50 000 m^3 of timber extracted, generating revenues of US$ 2 million to the local association. Yet, recent federal regulations determine that private companies should no longer control forest management in PDS areas, and families have to adjust their strategy. The article presents a temporal

assessment of collective action based on key stages in the trajectory of land access and forest management since families' initial struggle for land. It verifies impacts of the initiative on PDS-Virola-Jatobá social structure. Finally, it analyzes prospects for a system under direct coordination of producers' organizations. Changes in management are seen as positive as long as the state supports proper adjustment of local capacity, what is unlikely in the short term. As most of the families reached the limit of allowable land clearance, effective forest management is critical for these newly formed social groups to consolidate their land occupation and properly manage natural resources.

Frontier landscapes in the Peruvian Amazon: options by smallholders along the forest transition curve. Robiglio, V. (*World Agroforestry Center-ICRAF, Peru; v.robiglio@cgiar.org*).

The purpose of this research is to compare and contrast smallholder natural resource management strategies along the forest transition curve in the department of Ucayali (Peru). District land cover maps and deforestation rates are used to establish a forest transition curve for the region. Secondary spatial data, statistics and expert information are used to describe the gradient of factors and environmental conditions the curve symbolizes. Demographic, agricultural, forest, market statistics and government plans are analysed to characterize local development patterns and assess the correspondence between frontier configuration (i.e. forest fragmentation pattern) and identified development contexts. Primary household and focus group data on livelihoods strategies, local ecological knowledge and technological packages adopted by communities in selected districts are used to characterize production systems, understand how their combine in livelihoods strategies within each development context/frontier. Based on preliminary results and expert consultation selected production systems are discussed to understand if/how they vary along the frontier landscape curve, offering an assortment of locally fine-tuned alternatives of standard development models/technologies.

Traditional perspectives on ecology and timber extraction in a bamboo-dominated forest: A complementary knowledge base for sustainable management. Rockwell, C. (*Center for International Forestry Research*, *Peru; rockwell_cara@yahoo.com*), Kainer, K. (*University of Florida, USA; kkainer@ufl.edu*).

Bamboo-dominated forests of southwestern Amazonia cover a tremendous area of approximately 180 000 km^2. Nonetheless, relatively little information on this system has been documented in the literature, in terms of local knowledge and management. To identify constraints of timber harvesting and implications for smallholder management systems in this region, we evaluated available scientific data, traditional local knowledge, and relevant community experiences in forest management in Acre, Brazil. All informants interviewed had been involved with timber management activities from 4–10 years, and all indicated that tree removal by logging crews favored bamboo expansion and increased fire risk – views that correspond with the scientific literature on anthropogenic disturbances and bamboo forests. Yet, these same informants identified the important role that the bamboo-dominated forest type plays in their land management strategies, including providing nutrient-rich soils for shifting agricultural crops and suitable habitat for game animals. We also analyzed existing local data for tree species composition to assess local forest value. We provide suggestions about how these complementary bodies of knowledge can be put into practice for the purpose of sustaining the natural resource base within the context of local communities.

Opportunities and perceptions of smallholders regarding their potential to contribute to forest landscape transitions under REDD+: two case studies from Mexico. Skutsch, M., Paneque Gálvez, J., Salinas Melgoza, M., Borrego, A. (*Universidad Nacional Autónoma de México, Mexico; mskutsch@ciga.unam.mx; jpanequegalvez@gmail.com; ma.masm@gmail.com; armoniab@gmail.com*), Bee, B. (*East Carolina University, USA; bethbee78@gmail.com*), Mas, J., Gao, Y. (*Universidad Nacional Autónoma de México, Mexico; jfmas@ciga.unam.mx; yangao98@gmail.com*).

In Mexico, REDD+ is being presented as a win-win policy that will enable forest communities to benefit financially and diversify their income sources while preserving and increasing their forest carbon stocks through more sustainable management. Although in Mexico REDD+ is expected to be led by its States, it is expected that forest communities will have opportunities to tailor their own approaches. In this context, locally devised strategies to contribute to and benefit from REDD+ will depend on local opinions about what the opportunities under REDD+ could be. However, to date there is little understanding about what opportunities exist in reality for forest communities to contribute to forest landscape transitions under REDD+, and even less about how forest smallholders perceive these opportunities. To address such a gap, we assess (1) smallholders' perceptions about their opportunities in REDD+, (2) what strategies they are currently envisaging for participation, and (3) what the trade-offs and synergies with other dimensions of local development appear to be. The paper reports on on-going research in two areas of Mexico, the basin of the Ayuquila River in Jalisco, and the Monarch Butterfly Reserve in Michocan, where pilot REDD+ projects are underway.

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The role of forests, fallows and fisheries in household income generation and flood shock coping in the Peruvian Amazon floodplain. Cotta, J. (*University of Copenhagen, Denmark; jcotta@earthlink.net*).

This study contributes detailed quantitative data related to natural resource contributions to subsistence and cash incomes in the Ampiyacu-Apayacu basin. It also highlights the importance of resource harvest for household shock coping following a severe flood, which is especially relevant in light of the increasing frequency and intensity of extreme weather events related to climate change worldwide. In-depth household surveys quantified annual household incomes from all sources in eleven villages in 2011 and structured questionnaires assessed natural resource-based coping following a severe flood in 2012. Key products relied upon to cope with economic flood impacts included *Mauritia flexuosa* fruits, *Astrocaryum chambira* handicrafts, *Lepidocaryum tenue* roof thatch, *Euterpe precatoria* palm heart, wild game, timber and fish. These products are particularly valued after the flood due to the inefficiency of mutual assistance in the midst of widespread livestock and crop staple losses. Resource harvest is influenced by shock intensity, typical household livelihood portfolios, ethnicity, and proximity to resources and markets. Interventions to improve smallholder shock resilience for forest-dependent populations should consider landscape heterogeneity and specific resource user types. Particular attention should be paid to households characterized by high vulnerability (e.g., residents with only flood-vulnerable cultivation) and limited availability/diversity of environmentally-sourced coping resources.

Projections for small and medium size forest enterprises in Chile. Grosse, H., Gysling, J. (*Instituto Forestal, Chile; hgrosse@infor.cl; jgysling@infor.cl*).

Chilean forest development is based on the current 2.5 million ha of planted forests (*Pinus radiata*, *Eucalyptus globulus* and *Eucalyptus nitens)* belonging to large and small/medium size enterprises (SME), 58% and 42% of total planted area, respectively. However, native forests, mainly second growth forests, are a potential development focus that could be of special value when State-promoted silviculture treatments allow quality wood supply to forest industry. While large enterprises planted forests development and associated industrial development have been both of high technological level, mainly from the silviculture and genetics point of view, SME have a slower technology adoption, their planted forest yields are 30% lower, and they are facing the need to increase value added to move from sawn wood to more valuable products. For facing SME's new challenges, trade associations and public-private alliances have been built up to deal with workforce and SME personnel training on matters such as silvicultural technologies, forest products diversification and added value incorporation, goal achievements which demand improved technology programs, stronger SME association, and appropriated legal framework and public policies.

Not just smallholders: the underlying drivers of deforestation in Nicaragua's Bosawas Biosphere Reserve. Hansen, L., Innes, J. (*University of British Columbia, Canada; hansen.lisa.c@gmail.com; john.innes@ubc.ca*).

Having sufficient agricultural production whilst maintaining forest area and biodiversity is a global conundrum. In protected area landscapes experiencing high forest loss and degradation via the advance of agricultural frontiers, indeed these problems are quite pressing. Agricultural solutions to deforestation problems (i.e. land sharing and land sparing theory) might help to preserve the remaining forest, however, solutions to slow the advancement of the agricultural frontiers by rural smallholders must consider not only the proximate, but also the underlying drivers of deforestation which include complex interactions of social, environmental, economic, political, cultural and technical processes and events that underpin the modes and rates of agricultural expansion/deforestation. We present the results of a mixed method research approach using spatial analyses, historical literature review, focus groups and key informant interviews designed to identify the underlying events and processes responsible for deforestation in the Bosawas Biosphere Reserve in the municipality of Siuna, Nicaragua. The landscape encompases both a closed and open frontier, with different settlement histories, periods of deforestation and land uses. As such we present historical deforestation drivers by early settlers and present day push and pull factors of migration by thousands of peasants who now settle in illegal areas of the reserve and a national park.

The role of southern Brazilian traditional community forests (*faxinais*) in Atlantic Forest conservation. Moro, R. (*Ponta Grossa State University, Brazil; moro.uepg@gmail.com*), Pereira, T. (*Federal University of Paraná, Brazil; tkpereira@live.com*), Machado, N. (*Secretaria da Agricultura e do Abastecimento do Paraná, Brazil; neurimachado@seab.pr.gov.br*), Comin, M. (*Federal University of Paraná, Brazil; comin.marcel@gmail.com*)**.**

Faxinal is a traditional land organization form of production critically threatened by agribusiness. It consists of the collective animal pasture within the *Araucaria* forest understory and low impact forestry management. These community forests compound some of the last preserved areas of the Atlantic Forest in the South Brazil Highlands, deserving the status of ARESUR (*Área especial de uso regulamentado)* – a controversial conservation unit not yet completely recognized that rewards the land owners for their commitment in preservation. Some researchers argue that these efforts are useless because this way of life does not protect forest integrity. In order to evaluate the importance of this agrosystem we have performed a phytosociological survey in four typical faxinais. We identified 69 families and 123 species with and average density of 1,789 ind/ha. The most representative families were Myrtaceae, Lauraceae, Salicaceae, Aquifoliaceae, and Sapindaceae. The Shannon's index ranged from 2.92 to 3.27, and medium Pielou evenness was 0.80. *Casearia* species (*C. decandra, C. ineaquilatera, C. obliqua,* and *C. sylvestris*), *Campomanesia xanthocarpa*, *Cinnamodendron dinisii*, *Podocarpus lambertii*, *Eugenia pluriflora*, *Ilex paraguariensis,* and *Myrcia hatschbachii* had the higher importance values. The results showed that efforts to preserve the faxinais community forests are consistent to the conservation strategies for the Atlantic Forest resilience.

Strengthening sustainable forest management in the Colombian Amazon through in situ wood processing. Polanco, C. (*Universidad Distrital Francisco José de Caldas, Colombia; cpolanco@udistrital.edu.co*), Pacheco, M. (*WWF Colombia, Colombia; mpacheco@wwf.org.co)*, Otavo, E. (*Corpoamazonia, Colombia; eotavo@corpoamazonia.gov.co*)**.**

The Amazonian forests account for over 70% of the forest cover of Colombia. Traditionally forest harvesting processes have been limited to very few woody species (10 out of the total of 300) including outstanding woods as *Cedrela odorata*, *Cariniana decandra*, *Scleronema praecox*, and *Manilkara bidentata*. The traditional system is to process the timber using a chainsaw without adding value, and at the discretion of the sawyers, to supply the regional and national market in a manner that is largely inefficient and illegal, as these practices generate volume losses close to 80% of the standing timber. With funds from the European Community, the "Amazonia Viva" project began work to implement a sustainable forest management plan, previously developed by Corpoamazonia. This study evaluated the feasibility of wood processing center, which could improve the income of the surrounding communities, grouped into two associations, which are strengthening their management level through the project, besides contributing to sustainable forest management sustainable. Among the results discussed are various configurations of machinery, technical feasibility for in situ wood processing, the social benefits of the alternatives and the overall profitability of the project.

New roles of indigenous peoples as productive actors linked to the forest sector of Bolivia. Rivera Coria, W. (*National Federation of Municipal Governments of Bolivia, Bolivia; riveraw@gmail.com*).

Since the time of colonialism, indigenous peoples, originally farming people, have undergone processes of adaptation and transculturation, although many have managed to preserve their traditional culture, organization and production methods, which are now protected by international agreements. Bolivia is probably the country which has best succeeded in internalizing the corpus of indigenous rights in its legislation, although these peoples still live in a state of poverty on subsistence level despite

being a population group the majority of which has strong ties to forests. By means of the so-called "Revolución Productiva Agropecuaria" (agricultural production revolution) that has been going on for some time, the government promotes unprecedented reforms designed to converting these peoples into productive actors. The present paper measures the approaches of these reforms by means of inductive analysis. It looks at their contents and compares legislation and public policies, making reference to the main socioeconomic and historic aspects and indicators related to exploitation and conservation of forests in Bolivia. The paper identifies to which extent the weakness of the existing institutional framework, the lack of mandatory character of the forest and environmental regulations in force and, the inadequate harmonization of the set of rules that underlies these reforms may constitute a risk for forest sustainability in the country.

A-25 Reforming forest tenure and governance for mitigating climate change and improving people's livelihoods

Organizers: Runsheng Yin (Michigan State University, USA) & Shashi Kant (University of Toronto, Canada)

Understanding tenure security in the implementation of reforms: clarifying concepts and methods. Banjade, M. (*Center for International Forestry Research, Indonesia; mrbanjade@gmail.com*).

Forest tenure reform is defined as a shift in formal policies and institutional arrangements to recognise and enforce the rights of people depending on forest resources. The existing literature on reform implementation highlights security of rights as a decisive factor for forest conservation and equitable livelihoods. However, there is conceptual confusion in the understanding of security. Some authors refer to the content of rights, others to the assurance of rights based on perception. In this article we argue that tenure security should be understood through both policy and the experience of everyday practice by women and men from different socio-economic and cultural backgrounds. In addition, perception is insufficient, as the risks might span beyond people's lived experience. Thus tools and methods for understanding tenure security require further clarification of the concepts and notions of tenure security and risks. Based on research undertaken for over a decade by the Centre for International Forestry Research across Asia, Africa and Latin America, this paper develops a mixed-method framework—combining qualitative and quantitative methods with participatory action research—for a nuanced understanding of claimed and perceived aspects of tenure security through the study of forest tenure reform implementation.

Role of devolved governance in enhancing incentives in participatory forest management in Kenya. Kagombe, J., Mbuvi, M. (*Kenya Forestry Research Institute, Kenya; jokagombe@yahoo.com; mtembuvi@gmail.com*).

Past natural resources policies and laws in Kenya have emphasized the role of government, with communities and other stakeholders given nominal roles. Community participation was introduced in Kenya through Forests Act of 2005. Despite the communities continued participation, they are yet to benefit fully from their participation. This inequity is expected to end under the new constitution that clearly spells out that the people of Kenya should benefit equitably from the sustainable exploitation, utilization and management of natural resources. In addition it devolves power to 47 county governments. This paper reviews the participatory forest management framework and scenario arrangement under the county government. It addresses incentives available and how they can be enhanced for benefit to central government, county government, community and other stakeholders. Additionally, it provides a scenario of how value addition to traditional benefits from the forests and payment for environmental services, for products like water, biodiversity, ecotourism and at the international level for carbon credits through schemes like REDD+ and other climate change initiatives could be institutionalized to enhance benefits. Devolved governance can increase incentives if it provides an equitable balance between livelihoods and forest management, and between national government, local government, communities and other stakeholders.

Promoting REDD+ through community forestry in Lombok Island, Indonesia. Nurrochmat, D., Massijaya, M., Suratijaya, I. (*Bogor Agricultural University, Indonesia; dnrochmat@yahoo.com; mymassijaya@yahoo.co.id; suratijaya@yahoo.com*), Abdulah, L. (*Forestry Research & Development Agency (FORDA), Indonesia; lutfyalam@gmail.com*).

The economic crisis in 1998 caused massive illegal logging in Lombok Island, Indonesia. Illegal logging practices started to decrease in 2002 due to strong operations to combat them. At the same time, increasing frequency of floods and landslides in Lombok Island also enhanced the awareness of people to protect forests. This study confirmed that community participation is an important factor to protect forests. Some people involved in ecotourism activities at Gunung Rinjani National Park and the others participated in agroforestry program in the park's bufferzone and production forests. Since 2010, a REDD+ project has been initiated by Indonesian government in cooperation with Korean investor and local community in Lombok Island through establishment of community forestry. The main activitties of the REDD+ project were empowering capacity of local community to manage forests in more sustainable way, e.g. through utilization of non-timber forest products, cultivation of crops beneath forest stands, and rehabilitation of degraded forest lands. This study identified direct and underlying causes of deforestation and formulated appropriate strategies to achieve sustainable forest management. This study also concluded that increasing carbon stock was gained when the community forestry scheme had been succesfully implemented.

Forest tenure rights, REDD+ and livelihoods in Thailand. Onprom, S. (*Kasetsart University, Thailand; ffforsro@ku.ac.th*).

This paper seeks to investigate the linkages between forest rights, REDD+ policy and livelihoods of forest communities in Thailand. In Thailand, the conflicts over forest resource access between state and forest dwelling communities have occurred for centuries. Forest communities have no legal rights to access forest land and resources located nearby their villages. At present, the Royal Forest Department has proudly promoted the so called 'state-led community forest' throughout the country. Some technical and financial support has been allocated to targeted forest communities. However, the rights of local people to resources in the

forests are still limited as there is no legal recognition of community rights to forest resources. More recently, the forest sector has planned to introduce an international mechanism, REDD+, to its policy and implementation. This plan has been supported, technically and financially, by the World Bank and is expected to launch the first phase in 2014. Of course, the implementation of REDD+ will involve forest communities who have been seen as one of the drivers of forest degradation and deforestation, although this is disputed. In this paper, I argue that the benefits of REDD+ initiative to forest communities are likely to be limited. The result of my paper is based on document research and case study.

Private forestry today and tomorrow in Central and Eastern Europe. Siry, J. (*University of Georgia, United States; jsiry@uga.edu*), Zasada, M. (*Warsaw University of Life Sciences (SGGW), Poland; Michal.Zasada@wl.sggw.pl*), Skorupski, M. (*Poznań University of Life Sciences, Poland; maskorup@up.poznan.pl*).

Following World War II, communist governments in Central and Eastern Europe nationalized the majority of private forests, and only in some countries small private forests remained and were allowed to be managed. While most forests in the region remain state owned, the role of private forests is growing as countries have returned some of the nationalized forests to its former owners. In some countries of the region private forests already play an important role in timber production and trade. Frequently attributed to private forests concerns with overcutting and unsatisfactory management raise worries regarding their sustainability and largely influence the continued debate regarding their future. We examine private forestry legislation, regulations and assistance programs, identify likely causes of these problems, and discuss policies that may assist in the development of this sector. In this context, we also provide information about any relevant developments in state owned forests, regional wood markets, climate change mitigation initiatives and other existing or proposed regulations within the individual states and the European Union that may have a bearing on private forestry in the region.

China's forest tenure reforms in the new century: what remains to be pursued and how to achieve it? Yin, R. (*Michigan State University, USA; yinr@msu.edu*).

Since 2003, a new round of forest tenure and institutional reforms has been undertaken in China, featuring both further devolution of the use rights of collectively owned forestland and the relaxation of government control over private forest operations. While some major changes have taken place, a lot more needs to be implemented properly and many other adjustments must be made in order to improve the efficiency, productivity and functionality of the forest ecosystems. So far, however, limited attention has been devoted to assessing whether the measures taken are adequate, and elucidating what remains to be pursued and how to accomplishe it. This paper intends to fill these knowledge gaps from the theoretical and practical perspectives of institutional economics and forest policy. It is hoped that these efforts will contribute to the long-term success of China's latest initiatives as well as the international deliberation of forest decentralization and institutional transformation.

A-26 Impact of tenure arrangements on forests, livelihoods and gender dynamics

Organizers: Purabi Bose (CIAT, Colombia), Anne Larson (CIFOR, Peru), Han van Dijk (Wageningen University, Netherlands), Bimbika Sijapati (CIFOR, Indonesia).

Influence of tenure and gender on livelihood values and management of NTFPs in Burkina Faso. Bessike Balinga, M., Zida, M. (*Center for International Forestry Research, Burkina Faso; mpbalinga@yahoo.fr; m.zida@cgiar.org*), Zougouri, S. (*University of Ouagadougou, Burkina Faso; sita_zougouri@yahoo.fr*), Karambiri, M. (*University of Bobo Dioulasso, Burkina Faso; karambirimawa@yahoo.fr*).

Faced with economic or climatic shocks, rural livelihoods rely on non-timber forest products (NTFPs) for revenue, food security and medicine. This is particularly true of vulnerable groups including women, children and migrants. Unfortunately, this sector appears to lack an appropriate framework for effective stakeholder inclusion, and equity in benefits sharing. Despite existence of national policies, customary rules and tenure arrangements often provide the framework within which NTFPs are accessed and managed. Consequently, although state legislation seems neutral, there is a disconnect between the "good intentions" of legislation, and customary laws. Using focus group discussions and resource person interviews, this study analyses the perceptions of key stakeholders, common practice, and gendered roles in the Southern region of Burkina Faso. It concludes that parallel processes have evolved both within traditional tenure systems and national legislation, that attempt to reduce the inherent inequities, but without a bridge between these two processes, all attempts to strengthen security or ownership of land rights, could in certain instances prove counter-productive. Improving our understanding of the stakeholder perspectives and the functioning of these processes is therefore a vital step towards improved equity and inclusion of all stakeholders, within sustainable management processes for NTFPs.

Forest tenure, collective rights and gender dimensions in India, Uganda and Bolivia. Bose, P. (*International Center for Tropical Agriculture (CIAT), Colombia; purabibose@gmail.com*).

To what extent the forest tenure reforms create intended or unintended impact on the gender relations? This paper examines the implications of who has access to forest land and forest resources, and how. More explicitly this study focuses on the different institutional mechanisms at the community level. Using mix methods we compare three case studies each from indigenous communities in India, Uganda and Bolivia. The preliminary data collection was done between 2011 and 2013. The overall findings indicate that forest reform policy though introduced in the study areas with an intention to provide collective rights, but lacked institutional mechanisms. In India the forest-dependent tribal people's claims for collective forest rights receives less recognition as compared to individual tenure rights. In Uganda the legislation promotes collective rights, but the traditional authorities often limit the access rights of marginal men and women to forest resources. Compared to India and Uganda, in the Bolivian tropical forests the participation of local community is active when there are direct economic benefits, which limits the role of women in decision-making. In brief, this study provides an overview of how forest tenure policy is translated in local level management of forests.

Mainstreaming gender into Nepal's forest strategy. Ghimire, M. (*Ministry of Forests and Soil Consertation, Nepal; ghimire.madhu@gmail.com*).

Gender mainstreaming has been an important pillar of the forestry sector of Nepal to advance gender equality and equity in forestry society. This is reflected in the growing prominence of gender strategies and their programs, the emergence of compelling approaches for gender integration, and the development of indicators for tracking performance. With reference to specific attentions given to integrate gender considerations in preparation and implementation of new national forestry strategy, this study examines the extent to which gender has been mainstreamed into policies, plans, programs and projects, identifies key issues, challenges, and gaps in the inclusion of gender and discusses approaches and methods to address and overcome them.This study is based on primary information, experiences, literature and documents of various government and non-government stakeholders. The study reveals that despite the efforts to mainstream gender in forestry, it is however notable that implementation is remarkably weaker. The forestry sector is still male-dominated in the civil service. Excepting community-based forests, the policy provisions for gender mainstreaming are in most cases not backed up by relevant legal provisions and operational framework. Finally, a gender responsive framework on new strategy formulation is presented with a number of potential areas for improvement.

How forest tenure mediates forest based rural livelihoods: observations from a global study on forests and poverty. Jagger, P. (*University of North Carolina, USA; pjagger@unc.edu*), Luckert, M. (*University of Alberta, Canada; marty.luckert@ales.ualberta.ca*).

Recent trends in forest policy have led to a shift in the ownership and management of forests away from state actors to communities and individuals. The influence of who owns and manages forests on the ability of smallholders to generate both subsistence and cash income from forests is a critical policy question in many developing countries. Using a global dataset on forests and poverty, we analyze the influence of formal ownership, level of enforcement, and extent of congruence between formal owners and users on the amount of income sourced from forests for 8,000 households in roughly 30 countries in the tropics. We find that state owned forests provide the highest incomes both on per household and per hectares bases. Conversely, community forests offer the lowest forest incomes. We also find that high enforcement and a high degree of congruence between formal owners and users are negatively associated with forest income. Our findings suggest that reforms focused on devolving ownership and management away from state forests, and reforms that stress high enforcement and clarity of property rights may reduce the amount of income derived from forests. This is particularly important for poor households, as forest income reduces income inequality between households.

Gender participation in mangrove conservation and rehabilitation: the case of four Philippine mangrove project areas. Lapis, A. (*Ecosystems Research and Development Bureau, Philippines; acbl2002@yahoo.com*).

The study looked into the gender roles/participation in the community-based management of plantation and natural stands of mangrove – a component study on the "Assessment of Mangrove on its Potential to Mitigate Climate Change: Biomass and Carbon Sequestration of Selected Philippine Mangrove Forest". Women, just like men, enjoy their rights and privileges to access and control over various resources and benefits but to a lesser degree. If women are to be highly engaged in developmental projects, access to and control over tools, inputs, credit, land, labor markets, and technology should be increased, or should be more or less equal to that of the men. The project conducted surveys through focused group discussion in four study sites namely: Bauang, La Union; Tortugas, Balanga, Bataan; Mabini, Bohol and Pinabacdao, Western Samar. Seven gender tools were employed in the activity, including; a) village mapping; b) daily time routine; c) access and control profile; d) gender analysis activity profile; e) involvement in the mangrove project; f) project and community-related problems; and g) impacts/benefits from the mangrove project.

Challenges and opportunities for women's participation in the management of communal dorests: experience from Nicaragua's indigenous territories. Larson, A. (*Center for International Forestry Research, Peru; a.larson@cgiar.org*), Alwang, J. (*Virginia Tech, USA; alwangj@vt.edu*), Hernandez, X. (*Universidad Nacional Autónoma de Nicaragua, Nicaragua; xochiltexue@gmail.com*), Marchena, R., Muller, P., Pikitle, A., Wilson, C. (*Instituto de Investigación y Desarrollo* (*Nitlapan-UCA), Nicaragua; wifi087@gmail.com; pemotini7@yahoo.com; pikitle.alex@yahoo.com; cefewilson@yahoo.com*).

This paper analyses the results of policy action research starting in 2010 in Miskito and Mayangna communities of Nicaragua's North Atlantic Autonomous Region (RAAN). The goal of the project is to understand sex-differentiated use, decision making and perceptions regarding communal forests and encourage more meaningful and equitable participation. Methods include a survey with 300 randomly selected respondents from 11 communities, focus group discussions, participant observation and the facilitation of adaptive collaborative management processes over a two-year period. The survey found that a much higher percentage of men than women participate in both harvest and sale of eight forest products; firewood sales were the only exception. Nevertheless, women were more likely to control the income from five products. Men were consistently more likely than women to agree with statements asserting that women are involved in forest decisions across a variety of fora, and more likely to agree that women are "adequately included." Though 66% of women also agreed that they were adequately included, in-depth qualitative research found high levels of discontent, among both women and men, regarding community participation, and identified a variety of common and gender-specific obstacles. The analysis of results from multiple methods suggests ways forward.

The significance of supporting structures for enhanced participation of women in forest management. Siripurapu, K., Geores, M. (*University of Maryland at College Park, USA; kanna@umd.edu; mgeores@umd.edu*).

Unlike the state promoted Joint Forest Management Programme (JFM), the self-initiated Community-based Forest Management (CBFM) of Odisha has provided women the much needed space, support, and flexibility, presenting them the opportunity to participate more effectively in the decision making and forest management. Although many suggestions were incorporated into the JFM guidelinesfor enhanced participation of women, through passing many resolutions, their implementation had been

confined mostly paper due to absence of supporting structures which could create a conducive environment to enhance the participation of women in the JFM programme. In contrast to the JFM the presence of supporting structures like forest federations, and exclusive women forums/federations in the self-initiated Community-based Community Forest Management of Odisha, has not only provided the much needed space and support but also presented an opportunity for enhanced participation of women in decision making and forest management.

Dryland forest tenure, political conflict and gender dynamics in the Sahelian zone. van Dijk, J. (*Wageningen University, Netherlands; han.vandijk@wur.nl*).

Dryland forest tenure has received relatively little attention. However, dryland forests provide crucial products to sustain livelihoods of pastoralists and agro-pastoralists in the Sahel. Most attention has been given to acces to pasture, wood and gums in dryland areas. The gender dynamics of forest tenure have been largely neglected, since cattle, pasture and collection of gums has been pre-dominantly the domain of men. Particularly in conflict situations such as in Mali, Chad and Darfur non-timber forest products, fire wood and incense are crucial livelihood sources for women. However, during conflicts women are often denied access under the threat of gender-based violence. This paper will focus on women's use and rights to forest resources in the Sahelian drylands and its dynamics in conflict zones. It will conclude that under these conditions more attention should be given to safeguarding women's rights on forest resources.

A-27 International to local forest governance: taking stock of theories, methodologies and findings

Organizers: Lukas Giessen (University of Goettingen, Germany), Bas Arts (Wageningen University, Netherlands), Florian Kraxner (International Institute for Applied Systems Analysis, Austria) & Constance McDermott (University of Oxford, UK)

Forest governance: a practice based approach. Arts, B. (*Wageningen University, Netherlands; bas.arts@wur.nl*).

'Forest governance' is a concept that has recently emerged from public administration and forestry sciences. It analyses the public, private and mixed governing of a diverse set of issues, including deforestation, biodiversity loss and illegal logging. Its main theoretical base consists of two mainstream policy models: rational choice and neo-institutionalism. However, since these models rest upon problematic conceptualisations of 'the social', this paper proposes a practice-based approach, based on authors such as Bourdieu, Giddens, Latour and Schatzki. In doing so, it goes beyond some of the old dualisms in social theory, such as subject and object, nature and culture, and agency and structure. Three sensitising concepts – situated agency, logic of practice and performativity – will be introduced to understand social practices related to forest governance. In addition, the paper identifies a number of methodological guidelines for the practice-based approach. Finally, some cases of participatory forest management will be introduced to show the relevance and application of this practice based approach.

Local forest governance assessed through Social Network Analysis: comparison of three case studies in Italy, Bosnia Herzegovina and Montenegro. Da Re, R., Secco, L. (*University of Padova, Italy; riccardo.dare@unipd.it*; *laura.secco@unipd.it*), Pisani, E. (*University of Padova, Italy; elena.pisani@unipd.it*), Avdibegovic, M., Hasanovic, A. (*University of Sarajevo, Bosnia and Herzegovina; mavdibegovic@gmail.com; adnana.hasanovic@foper.net*), Ingold, K. (*University of Bern, Switzerland; karin.ingold@ipw.unibe.ch*).

In natural resources governance, there is a growing awareness on the importance of being able to manage multidimensional networks which involve a multitude of actors representing different levels (from local to international; vertical integration) and various (public and private) sectors (horizontal integration). The organizations which play key roles in local development based on forest resources need to involve actors of civil society in decision-making processes, and to form new networks of collaboration and information exchange. At local level, governance assessment systems seldom consider the analysis of networks as an instrument to better address policy making, and Social Network Analysis (SNA) is prominently used in descriptive studies. In our work, SNA tool has been applied in three case studies (protected forest areas, in Italy, Montenegro and Bosnia-Herzegovina). Indices, including network density and cliques analysis, typical of SNA, have been calculated as proxy indicators for evaluating key aspects of governance capacity (e.g. level of efficiency and participation). The snowball technique was applied to identify stakeholders, data were collected through face-to-face interviews in 2012 and 2013, and networks were graphically represented. Results show that SNA is important to assess the role of main actors and to evaluate the policy process in local forest governance.

The evolving role of secondary-level institutions and their continued legitimacy: community and producer associations under FLEGT and REDD+ in Ghana and Mexico. Hajjar, R. (*University of British Columbia, Canada; reem.hajjar@gmail.com*).

The role of forest associations (secondary-level institutions that support and represent groups of forest producers and communities) continually evolves to meet new demands from their constituents. Diversification into new activities brings with it new governance issues, interests, organizational logics and capacity needs. The sustained viability of an association is determined largely by whether it can achieve legitimacy to operate in new spheres, judged by how people perceive its legitimacy and its abilities in potential new roles. This study looked at the evolving role of forest associations as they become part of national REDD+ and FLEGT architectures, as well as the continued legitimacy associated with this role. Using an empirical approach, interviews were held with various forest stakeholders in Ghana and Mexico to determine the sources of legitimacy from which associations draw upon, differentiating between process and outcome-based legitimacy. Field work will be completed by December 2013. This study offers guidance on appropriate architectures that adequately represent and include local forest users in these national and global mechanisms, contributes to a better understanding of multiple interacting authority structures in an evolving multi-level governance system, and adds to the body of knowledge describing institutional strategies for gaining and maintaining legitimacy.

Constructing a materialist conception of discursive institutionalism to examine institutional change in forest policy: the case of the assisted migration of species in Canada. Klenk, N. (*University of Toronto, Canada; nicole.klenk@utoronto.ca*), Larson, B. (*University of Waterloo, USA; blarson@uwaterloo.ca*).

The proposal to move species beyond their historic range ("assisted migration") challenges some of the conservation norms guiding sustainable forest management in North America. Despite perceived risks, the province of British Columbia, Canada has developed an assisted range expansion policy enabling the movement of western larch over 1000 km north of its current range (where provenance tests suggest it will survive). Our paper draws on 52 semi-structured interviews with government researchers and policy developers and implementers to explore institutional change in the guiding norms and practices of sustainable forest management in British Columbia and, more broadly, Canada. Through the lens of Vivien Schmidt's theory of discursive institutionalism, our analysis suggests that the policy development process reflects significant institutional change that layers new understandings of genetic conservation in forestry onto long-standing economic interests. That said, policy developers downplayed the novelty of this policy to obtain a social license to move western larch beyond its range despite anticipated objections from conservationists. We also observed a slower pace of policy development on assisted migration of species elsewhere in Canada due to several contextual factors that limited the impetus to gain a social license for the use of assisted migration. We discuss the implications of discordant policy discourses for forest governance.

Russian forest policy development: new experience based on stakeholders' involvement approach. Kulikova, E. (*European Forest Institute, Finland; elena.kulikova@efi.int*), Shmatkov, N. (*WWF Russia, Russian Federation; nshmatkov@wwf.ru*).

Until recently, Russia, which holds 20% of the World's forest cover, did not have its forest policy document formulated as a "negotiated agreement among government and other stakeholders on a shared vision on forests (and trees) and their use" (FAO, 2010). Based on a joint WWF-Federal Forestry Agency (FFA) initiative, the Public Ecological Council under FFA approved in November 2100 the start of the Russian Forest Policy development through a participatory process together with interested authorities, academia, NGOs and the forest private sector. By surveys and comparative analysis, WWF Russia investigated several countries' forest policies (Finland, Canada, Sweden) as well as used methodological materials from the FAO Guidelines for developing effective forest policy as examples and ideas to be followed. We made available for the public. Special working group representing stakeholders was established. As a result, the process can be considered as transparent, majority of issues important for various interested groups are included into the policy text which is officially approved by the Government. The Forest Policy is planned to be a 'constitution' of the Russian forest sector, forest legislation and programs for the sector's development should be in compliance with it.

Stakeholder opinions on bioenergy in Norway: conflicting perceptions of challenges and opportunities. Lindstad, B. (*Norwegian University of Life Sciences, Norway; berit.lindstad@umb.no*).

Bioenergy is high on the political agenda in Norway and other European countries, and debates are on-going as to the environmental effects of increased use of forest biomass for energy. As part of a European project, we conducted exploratory interviews among Norwegian stakeholders to collect opinions on forest management, forest functions and policy frameworks related to the political objectives of increasing use of bioenergy. In this paper we report and discuss variation in perceptions across fourteen organisations on the challenges for biodiversity and potential loss of carbon from intensified use of bioenergy, as contrasted to other stakeholders focusing on opportunities in mitigating climate change. Based on framing theory, we discuss how stakeholders apply different frames in descriptions of the current situation and for making sense of the organisations' standpoints. We show how the apparent (dis)agreement on the attraction of wood as a renewable energy source is reflected in the noticeable (dis)agreement on the forest situation.

The assessment of the Forest Ecological Compensation System in the southern China. Long, H., Tu, C., Liu, J. (*Renmin University of China, China; longhx1986@163.com; 411933630@qq.com; liujinlong_jl@hotmail.com*).

With the purpose of extending the protection to forest resource, the Forest Ecological Compensation System was initiated in China in 2001. This paper explores the governance and performance of this system. We carried out a survey of local forestry officials, village cadres, villagers, and state-owned forest farm workers from three countries in southern China, through which the stakeholder perceptions of Forest Ecological Compensation System governance quality, institutional legitimacy, and ecological and social impact were evaluated. It was found that the villagers have had far less opportunities for participation than the local officials and villager cadres in the decision-making process of the scope of ecological forest and the amount of compensation, especially in collective forest lands managed by the community. The villagers who managed forest lands expressed higher dissatisfaction in the system and expect to raise the amount of their compensation. Issues related to transparency and equality of the system were highlighted by all stakeholders as the fund is delivered by bank card of household. The system has made a contribution to the ecological improvement, but neglect social and economic benefits for local farmers. We draw conclusions that the forest ecological compensation system should improve its standard to subside the households' financial loses and extend public participation in decision making processes.

Participatory forest governance in Ibero-America: social and political impacts of the Model Forests approach. Lorenzo Lemire, J., Carrera, F., De Camino, R., Villalobos, R. (CATIE*, Costa Rica; josique@catie.ac.cr; fcarrera@catie.ac.cr; rcamino@catie.ac.cr; rvillalo@catie.ac.cr*)**.**

A Model Forest is a landscape-level approach focused on people working together voluntarily in partnership towards a common vision of the human sustainable development of a large territory in which forest ecosystems play an important role. In the Ibero-American region, there are currently 29 Model Forests in 15 countries, which means that the approach is having a potential impact on the management of over 30 million hectares and on more than 6 million people. The emphasis is usually placed on environmental and economic benefits, whereas this research examines the main social and political impacts which emerge from the analysis of the reports submitted by the Model Forests to the regional network secretariat during the last decade and the data collected through interviewss and monitoring activities. The study indicates that Model Forests constitute effective platforms for

the application of international agreements, public policies and State programs at the local level, and that they are able to influence decision-makers through advocacy. The paper reviews the success stories of several Model Forests in this regard. Finally, even though the Model Forests process is still at its early stages, the study shows how it can drive long-term sustainability and social change in the communities.

Forest footprints and the implications for equity in forest governance. McDermott, C. (*University of Oxford, United Kingdom; constance.mcdermott@ouce.ox.ac.uk*).

This talk reviews demand-side research on forest footprints and assesses the implications for social equity in forest governance. It defines footprints research as the examination of the linkage between the consumption of particular commodities in one part of the world and impacts on people and resources (including forests) worldwide. This includes the field of "life cycle assessment" (LCA) that measures environmental and social impacts across entire global value chains. We argue this demand-side perspective can provide a new and contrasting lens for evaluating local to global performance that is at odds with current supply-side focused governance strategies. For example, a holistic consideration of global footprints might shed critical light on trade-based strategies aimed at "ratcheting up" environmental performance that create barriers for local producers and reinforce global inequalities. On the other hand, a narrow, single product perspective on footprints could reinforce these inequalities by prioritizing production efficiency over resource distribution. We therefore argue for the importance of diversity in footprints research as a means to fully probe the link between social equity and forest governance.

Examining equity in forest governance: implications for REDD+ and other payments for ecosystem services schemes. McDermott, M. (*Rutgers University, USA; mmcdermott@AESOP.Rutgers.edu*), Schreckenberg, K. (*University of Southampton, United Kingdom; k.schreckenberg@soton.ac.uk*), Mahanty, S. (*Australian National University, Australia; sango.mahanty@anu.edu.au*).

This paper draws on political philosophy (theories of justice) to develop a multi-dimensional framework for analysing equity in forest governance in general, and in the context of payments for ecosystem services schemes, such as REDD+, in particular. By specifying the interrelated components of equity at local to global scales, the framework guides the assessment of how equity at the local level is affected by shifts in national and international policies and political-economic context. Our framework identifies three dimensions forming the content of equity. The first, distributive equity, addresses the distribution of benefits and costs. The second, procedural equity, refers to decision-making. These are linked by the third dimension, contextual equity, which incorporates the pre-existing conditions that limit or facilitate access to decision-making procedures, resources and, thereby, benefits. The framework then asks how these dimensions are shaped by three framing parameters: the target group and scale, the goals (if any) with respect to equity, and, crucially, how and by whom the decisions about the content, target and aims of equity are taken. Through the examination of four case studies in Bolivia, Uganda, Cambodia and India, we highlight features of forest governance that can either reproduce inequity or help to overcome it.

Institutional work: community-based organizations as change agents in public lands governance in the American West. Moseley, C., Abrams, J., Davis, E. (*University of Oregon, USA; cmoseley@uoregon.edu; jabrams@uoregon.edu; ejdavis@uoregon.edu*).

During the twentieth century, the combined power of the state and private capital provided much of the normative direction and cultural identity for rural communities in the American West. However, what is most apparent today is not the stability of these traditional institutional forms but rather their retreat, dissolution, and transformation. New actors have entered this political landscape, introducing novel natural resource governance models. One example is the rise of community-based organizations (CBOs)—nonprofit organizations oriented towards rural communities that were or continue to be dependent on government-owned forests. We investigate the potential for CBOs to influence the political institutions of forest governance. We see CBOs as both deeply embedded in decayed social and political institutions and engaged with diverse new networks that seek to change these old institutions. These organizations perform "institutional work" within a highly constrained environment that is nevertheless susceptible to change due to the weakening of the Forest Service and timber industry. Their work centers on filling institutional voids that state and corporate actors formerly occupied. They are opportunistic and nimble, are able to take state, private, and civil society roles to fill these voids, and act as the state when needed to advance their visions.

Forest relevant actions to the three Rio Conventions. Obersteiner, M., Kraxner, F. (*International Institute for Applied Systems Analysis (IIASA), Austria; oberstei@iiasa.ac.at; kraxner@iiasa.ac.at*).

This paper provides an analysis of forest relevant actions to the three Rio Conventions and the formulation of the post-2015 Millenium Development Goals. Specifically, scenario results from data-rich analytical tools conducting policy impact assessments are presented to: a) map the forest related relationships between the UNCBD, UNFCCC, and UNCCD; b) identify the synergies and trade-offs of forest management strategies in reaching the Aichi, post-Kyoto and zero net-degradation targets; c) assess the costs and benefits of forest policies that support these targets; d) provide input to the formulation of a consistent set of new environmental targets touching on forests for the post-1015 MDG process; and, e) support science-based policy implementation of forest related issues at the global and national level.

Posters

Alternative pathways to sustainability – a framework for comparative forest policy analysis. Beland Lindahl, K. (*Luleå University of Technology, Sweden; karin.beland.lindahl@ltu.se*), Sandström, C. (*Umeå University, Sweden; camilla.sandstrom@pol.umu.se*).

Global change is affecting the conditions for future forest governance and management in all forest producing nations. Changing institutional frameworks in combination with increased demand for a broader range of materials and services pose new challenges

to existing forest governance models and their mechanisms for balancing competing interests. However, different countries seem to respond in different ways, some being better equipped than other. In this paper we develop an analytical framework to compare the potentials of different national forest governance models to respond to current sustainability challenges. We draw on the STEPS Pathways approach to explore how sustainability is conceptualized and how governance systems are organized to manage synergies and tradeoffs. Pathways to sustainability are understood as alternative trajectories for knowledge, interventions and change which prioritize different goals and values. The resulting framework is operationalized by using the Swedish forest governance model as an example. We discuss how the framework can be used to identify strengths and weaknesses of different models, and what the approach has to add to existing comparative frameworks which focus more on 'macro-level' policy objectives than methods for trade-offs. A purposive comparison of existing forest governance models may enhance learning and policy exchange.

International influences on national forest policy: analyzing stakeholder coalitions and their argumentation in the revision of Finnish Forest Act. Harrinkari, T., Katila, P. (*Finnish Forest Research Institute, Finland; teemu.harrinkari@metla.fi; pia.katila@metla.fi*), Karppinen, H. (*University of Helsinki, Finland; hkarppin@mappi.helsinki.fi*).

This study focuses on the influences of global and European Union forest and environmental policies on the national level forest policy by analyzing the revision of the Finnish Forest Act. The objectives of this study are 1) to identify and describe the different coalitions taking part in the revision process and 2) to analyze how the international influences were reflected in the different coalitions' positions and argumentation and finally 3) to assess how these effects are visible in the revised Forest Act. For the purposes of the study the Advocacy Coalition Framework was combined with the four-pathways framework presented by Bernstein and Cashore, which suggest that international influences can diffuse to national level through four possible pathways: 1) international rules, 2) international norms and discourse, 3) markets, and 4) direct access to domestic policy-making processes. The data is twofold; written documents on the forest law revision process and interviews of persons that were involved in the process. This presentation combines the results of these two analyses and identifies advocacy coalitions and the diffusion paths of international influences on the revision of the Finnish Forest Act.

Forest governance: a study on perception of actors involved in forest management in the State of Paraná (Brazil). Hoeflich, V., Galiciolli, R., Dos Santos, A. (*Federal University of Paraná, Brazil; vitor.ufpr@gmail.com; rene@galicioli.com.br; ajsantos.ufpr@gmail.com*).

The sustainable management of forest resources is recognized internationally as important for balancing the interests of production, conservation and protection. The objective of the study was to analyze the perception of the social actors related to the dimentions of forest governance. The methodological framework for assessing and monitoring forest governance associated with its principles and pillars was applied. The main perceptions of social actors involved indicated that: forest legislation is complex and is difficult to apply; there was no consensus on the effectiveness of the procedures adopted on forest management; forest legislation is neither transparent nor flexible in its operation; legal instruments are needed nationwide to execute actions at the state and local forest level; the penalties applied to forest planning issues do not meet the main goal which is to regulate the responsible use of forest resources; forest legislation does not identify a transparent framework for the implementation of forest policy instruments and does not present information that allow either autonomy or an effective monitoring of performance evaluation of their management bodies; there is not a clear definition of the responsibility of the forest management agencies and the priority of the forest issue is not clear.

Brazilian forest governance: trends, obstacles, and a proposal to be implemented. Hoeflich, V., Heimann, J. (*Federal University of Paraná, Brazil; vitor.ufpr@gmail.com; jaquelineheimann@yahoo.com.br*), Peters, E. (*Ministério Público do Paraná, Brazil; edsonlpeters@gmail.com*), de Souza, M. (*Brazil; maraambiental@hotmail.com*).

The management of forest resources has economic and environmental importance, but requires a balance between economic and conservation interests. The paper analyzes the autonomy of state-members to improve forest governance and decentralized actions. The study is based on the principles of forest policy and governance. The principal results and recommendations are as follows: the decentralization of forest management started with the Law of Public Forest Management, which transferred jurisdiction to the state environmental agencies; the edition of the Environmental Code in Santa Catarina and the decentralization of its forest management; the proposal of a decentralized forest management agency, suggesting the creation of a Brazilian Ministry of Forests. As conclusion, was stated that the process of decentralization is necessary, giving to the state-units autonomy to conduct their own forest policies. According the governance pillars and principles proposed by international agencies, the Brazilian forest governance must take into account a continuous analysis of the Forest Code; an increasing participation and capacity for action of all stakeholders related to the sector and to make more efficient the enforcement of forest laws. It is suggested to implement procedures performed in countries with significant forest importance, such as Finland, Germany and the United States.

Complexity of forest tenure issues and China's collective forest tenure reform. Liu, J., Long, H. (*Renmin University of China, China; liujinlong@ruc.edu.cn; longhx1986@163.com*).

Since the 1980s, decentralization has become a major feature of forest governance around the world, and China is a unique country in this respect. Two case studies have shown the high complexity of forest tenure issues, which involve power structures, customary regulation, cultural heritage, and conflicts of interests within and between communities in the era of globalization and marketization. Bundles of rights can be arranged differently with different forest categories and different kinds of production of one piece of forest. Power arrangements of forest use and ownership on the ground are arenas of conflict and struggle. There is no easy way to determine which kind of tenure is best. A great gap exists between the policy needs of local peoples and policy interventions by the government. Rights to forests cannot just be granted to the farmers. It is concluded that the success of forest tenure reform requires: social mobilization and capacity building; intensive piloting to clarify the mission, strategy, principles and processes of the reform; development of a holistic and integrated reform agenda; and wide stakeholder engagement and cross-sector cooperation.

Examining the impact of governance on the effectiveness of forest protected areas: a systematic review of the evidence. Macura, B. (*University of Padova; biljana.macura@studenti.unipd.it*), Pullin, A. (*Bangor University, United Kingdom; a.s.pullin@bangor.ac.uk*), Secco, L. (*Universty of Padova, Italy; laura.secco@unipd.it*).

Current governance modes of forest protected areas are multilevel and complex, with a variety of actors, different levels of power sharing, various formal and informal rules and vested interests. However, there is no synthesis of information on how different local governance modes and day-to-day decision-making processes may influence forest protected area effectiveness in terms of producing desired conservation outcomes. Given the rapid growth of the conservation and natural resource governance literature, there is potential value in synthesis of the existing information across-cases. Systematic review is a methodology developed to synthesise, appraise and communicate large amount of information, in a systematic, transparent and repeatable way. Here we present results of a systematic review conducted following Collaboration for Environmental Evidence Guidelines, synthesising the available qualitative and quantitative evidence from a large number and variety of literature sources, both peer reviewed and grey literature, to assess relative effectiveness of different forest proteced area governance modes with respect to multiple social and ecological outcomes.The results call attention to the research gaps in the field of natural resource and conservation governance, provide input for future policy formulation and synthesise information to facilitate grounding of managers' decisions on available scientific evidence.

Forest policy re-mix: is history bound to repeat itself in the selection and implementation of forest policies and instruments across Latin America? McGinley, K. (*U.S. Forest Service, United States; kmcginley@fs.fed.us*).

Many Latin American countries are experimenting with new environmental policy instruments and designs that harness the strengths of markets, networks, information and other resources and actors to encourage better forest management. Yet, throughout the region, as elsewhere around the world, public policy design and development patterns have deep roots that shape current decision making practices and oftentimes result in entrenched pathways to instrument selection and implementation. These governance pathways or modes are particularly significant to the prospects of selecting and implementing new instruments or designs. This presentation reviews the policy frameworks for promoting sustainable forest management in several countries in Latin America using a policy classification framework that not only examines the types of policy instruments selected by policy makers but also the major, more enduring modes of governance that may significantly influence policy and instrument selection and implementation. The analysis permits a better understanding of historically-driven governance and instrument preferences and pathways across Latin America, which is crucial for identifying instrument additions or policy (re)designs that are compatible with existing modes of governance, and for identifying windows of opportunity for measurable and effective policy changes.

The Atlántida platform: a civil society effort promoting good governance in the Honduran forestry sector. Molina, M., Cruz, M. (*Fundacion MaderaVerde, Honduras; ymolina@maderaverde.org.hn; mcruz@maderaverde.org.hn*).

In January 2013 Honduras and the European Union began negotiating a Voluntary Partnership Agreement (VPA) within the Forest Law Enforcement Governance and Trade (EU FLEGT) Action Plan. Several nongovernmental organizations and small forestry producers in the country have started to organize their own civil-society "platforms" to understand the VPA process and contribute more effectively to the overall improvement of forest governance in Honduras. The Atlántida Platform on the North Coast launched an investigation in more than 22 forest-dependent communities into the main concerns and expectations related to the VPA. Although the Government of Honduras had officially acknowledged the importance of stakeholder involvement, no real participative process had been developed until now, when a position document that emerged from this investigation was included in the agenda of the second round of negotiations between the Government of Honduras and the EU, held in Brussels in October 2013. This paper makes the case that practical, collaborative steps to strengthen civil society participation in forestry issues would contribute to a more inclusive and productive consultative process, increasing the likelihood that the VPA negotiations will become an effective tool for promoting forest governance in the Honduran forestry sector.

The analysis of forest governance and social capital: theoretical and methodological links, gaps and overlaps. Pisani, E., Secco, L., Da Re, R., Masiero, M., Gatto, P., Pettenella, D. (*University of Padova, Italy; elena.pisani@unipd.it); laura.secco@unipd.it; riccardo.dare@unipd.it; mauro.masiero@unipd.it; paola.gatto@unipd.it; davide.pettenella@unipd.it*), Górriz, E. (*European Forest Institute -EFIMED, Spain; elena.gorriz@ctfc.es*).

Since the 1990, governance and social capital have increasingly attracted the attention of theorists and applied researchers in relation to environmental resources management. They are often considered key-factors for rural development at local level. In forestry, the two concepts have been explored mainly in relation to community forests and participatory approaches. Forest governance and social capital are clearly interconnected and their respective realms of analysis are partially overlapping and linking, while some significant gaps exist. On the basis of a literature review and a comparison among empirical evidences from case studies in Europe and other regional contexts, theoretical and conceptual links, gaps and overlaps between the two themes are identified and discussed in order to understand whether, to which extent and under which conditions changes in social capital might induce variations into forest governance arrangements and their performances (and vice-versa). A methodological proposal for identifying and measuring forest governance-social capital reciprocal effects is presented. The proposed methodology is a combination of Social Network Analysis and governance assessment indicators. Results attest there is a bidirectional relationship (not always positive) between forest governance capacity and quality of social capital in local forestry networks.

State of the principles of good forest governance in Paraguay. Quevedo Fernandez, M. (*Universidad Nacional de Asuncion – Facultad de Ciencias Agrarias, Paraguay; lauraqbp@gmail.com*), Folmann, W., Hoeflich, V., Berger, R. (*Federal University of Paraná, Brazil; willfoma1@yahoo.com.br; vitor.ufpr@gmail.com; berger.ufpr@gmail.com*).

Forest governance is considered to be good if it is characterized by the participation of stakeholders, transparency in decision making, responsibility for the decisions, an effective and efficient management of resources and a just distribution of resources and benefits. With the aim better understanding the current state of principles of good forest governance in Paraguay, a study was carried out using a questionnaire designed with the SERVQUAL method. Each question was evaluated on a scale from 1 to 9 and N, with 1 referring to the worst possible level and 9 to the best possible level, and N indicating that no information could be

given. The questionnaire was distributed to 46 key stakeholders. The data analysis was carried out by means of calculating the arithmetic mean of the responses. As a main result of the work it could be observed that key stakeholders evaluated efficacy with an arithmetic mean of 3.83, efficiency with 4.31, justice with 3.81, participation with 4.12, responsibility with 3.96 and, finally, transparency with 3,74. There was a difference of 42% between transparency and efficiency, which received the lowest and highest scores, respectively.

Trans-Atlantic governance of sustainable solid wood bioenergy supply chains. Smith, C., Murray, J. (*University of Toronto, Canada; tat.smith@utoronto.ca; jessica.murray@mail.utoronto.ca*), Thiffault, E. (*Natural Resources Canada, Canada; Evelyne.Thiffault@RNCan-NRCan.gc.ca*), Kittler, B. (*Pinchot Institute for Conservation, USA; bkittler@pinchot.org*), Fritsche, U. (*International Institute for Sustainability Analysis and Strategy, Germany; uf@iinas.org*), Junginger, M. (*Utrecht University, Netherlands; h.m.junginger@uu.nl*), Berndes, G. (*Chalmers University of Technology, Sweden; goran.berndes@chalmers.se*), Stupak, I. (*University of Copenhagen, Denmark; ism@ign.ku.dk*).

Governance of trans-Atlantic trade in wood pellets to satisfy European demand for sustainable bioenergy has been evaluated to identify if potential barriers to export trade from North America to Europe might arise as a result of conflicts among multiple levels of governance mechanisms that include state and provincial forest management regulations, voluntary certification schemes and EU Renewable Energy Directive (RED) proposed binding sustainability criteria. Analysis of Canadian forest governance schemes indicated the intent of most proposed RED criteria is met by Canadian management systems despite conflicts of terminology, as in the case of the proposed RED 'primary forest' criterion. The proposed RED greenhouse gas balance criterion is not met in Canada, but may be in the future through development of government-administered or voluntary systems. Trans-Atlantic dialogue is needed to resolve conflicts in policies. Opportunities exist to engage actors in North America and Europe involved with policy formulation, development and deployment of bioenergy supply chains from forests to European consumers. Research must remain focused on sustainable forest management so that policy is science-informed and critical gaps in knowledge regarding sustainability criteria of forest bioenergy supply chains are filled.

Challenges to multi-level sustainability governance of forest bioenergy and impacts for production and trade – global stakeholder views and experiences. Stupak, I. (*University of Copenhagen, Denmark, Denmark; ism@ign.ku.dk*), Joudrey, J., Smith, C.*; tat.smith@utoronto.ca*), Pelkmans, L. (*VITO, Belgium; luc.pelkmans@vito.be*), Goh, C. (*Utrecht University, Netherlands; c.s.goh@uu.nl*), Chum, H. (*National Renewable Energy Laboratory, USA; helena.chum@nrel.gov*), Englund, O. (*Chalmers University of Technology, Sweden; oskar.englund@chalmers.se*), Junginger, M. (*Utrecht University, Netherlands; h.m.junginger@uu.nl*), Cowie, A. (*University of New England, Australia; annette.cowie@une.edu.au*).

In many regions of the world, different governance mechanisms have recently emerged to ensure biomass and bioenergy sustainability. A myriad of related public and private regulations have existed for decades, including international agreements, jurisdictional legislation, certification schemes and mandatory or voluntary best practice guidelines for local levels. We conducted a global survey among stakeholders along the whole bioenergy supply chain to examine their views and experiences on challenges related to 1) the multi-leveled governance to which they are subjected, 2) the impacts on their production and trade, 3) the most urgent needs to improve or adapt certification schemes. The survey revealed significant support in the forestry sector for adopting mandatory regulation to ensure sustainability, with private certification as an acceptable means for demonstrating compliance. A significant minority was skeptical about additional sustainability requirements for the sector. The forestry sector was more confident than the energy sector that the certification schemes which they already apply are effective, but still saw opportunities for developments. Most respondents had so far experienced no changes or positive changes to their bioenergy-related production or trade after the introduction of new sustainability governance. We discuss our findings within the context of a globalized economy and suggest new research.

One methodology, two realities: partnering with indigenous peoples in the Peruvian Amazon. Vasquez Fernandez, A., Kozak, R., Innes, J. (*University of British Columbia, Canada; ecomundo.andrea@gmail.com; rob.kozak@ubc.ca; john.innes@ubc.ca*).

In April 2013, the Peruvian ombudsman's office registered 154 socio-environmental conflicts related to extractive activities. The recently adopted Peruvian law (29785) concerning the indigenous people's rights to prior consultation explicitly states that, "indigenous peoples will participate in the processes of consultation through their associations that represent them," and, "the process of dialogue will be between the state's representatives and the indigenous peoples' representatives". But, questions remain. Most notably, how will this 'process of dialogue' be held between two different (western vs. indigenous) worldviews, value systems, and languages? Through a partnership with six indigenous communities from the Peruvian Amazon and the associations that represent them, researchers (including three indigenous cultural advisers) conducted in-depth interviews with the Asheninka and Yine-Yami people and developed an innovative methodology for the collective construction of data that is culturally sensitive and consistent with their realities. Based on these experiences, seven key principles were noted that are essential to the process of interaction with indigenous peoples and for providing a trusting and respectful environment in which community members can express their views and effectively participate in decisions affecting their futures. This methodology can be adapted for working with other indigenous groups in the Peruvian Amazon.

A-28 Ineffective international forest policy? The role of forest information, international law and politics

Organizers: Lukas Giessen (University of Goettingen, Germany), Georg Winkel (University of Freiburg, Germany), Christoph Kleinn & Peter-Tobias Stoll (University of Goettingen, Germany)

Millions of trees and multiplicities of meaning: on the framing of 'forests' in international policy discourse(s). Cettie, S., Winkel, G. (*University of Freiburg, Germany; scott.cettie@ifp.uni-freiburg.de; georg.winkel@ifp.uni-freiburg.de*).

International forest policy is exceedingly complex in terms of both the natural and social sciences. Despite certain degree of consensus with regards to the problem definition (including, for example, deforestation, loss of biodiversity and livelihoods), international policymakers are able to find little common ground in terms of how to concretely address these problems in an integrated manner. In an effort to reduce the complexity inherent to forest policy processes, we aim to develop an understanding of 'discursive fragmentation' in the international forest policy sector and theorize its possible implications for future policy processes. To this end, we performed a comparative analysis of global forest policy discourses and their interrelations at the intertextual, intersubjective and interdiscursive levels. This analysis is operationalized by, first, identifying five primary discourses operating in the International Forest Regime Complex (Civic Environmentalism, Ecological Modernization, Sustainable Development, Industrialism, and 'Limits to Growth'). Using this typology, the 'framing of forests' as an issue area is critically examined under each of the 5 discourses identified. The primary analysis will be performed using Foucault's 'archaeological method' and will be buffered by theoretical insights from semiotic ecology as well as empirical insights drawn from interviews with numerous international forest policy experts.

Building the analytical toolkit in international forest policy: social psychology and the Value-Belief-Norm Theory. Edwards, P., Kleinschmit, D. (*Swedish University of Agricultural Sciences, Sweden; peter.edwards@slu.se; daniela.kleinschmit@slu.se*).

In political science, the focus of analysis is on the state of other organisations as actors that often have specific interests and positions attributed to them. The state or organisation's interests or positions are also influenced by the people representing them. From a long series of observations and interviews from the legally binding agreement on forests in Europe process, we find that in a number of cases, the individual interests of the representatives' influence the way the state or organisation presents its position. We argue that a pure political science or international relations perspective may not be sufficient to fully evaluate actor interests and potential conflicts: The introduction of social psychologists and the application of 'new' theories such as the Value-Belief-Norm Theory are necessary to fully understand the dynamics of state/organization and individual actor behaviour in international forest negotiations. This social-psychological aspect becomes increasingly interesting and important due to the 'small' nature of international forest policy with a core group of individuals, where some may be looking to increase their influence in tandem with the rising profile of international forest policy.

Horizontal and vertical fragmentation of the international forest regime: (in)effective for whom? Giessen, L. (*University of Goettingen, Germany; lgiesse@uni-goettingen.de*).

International forest policy consists of a number of forest-related elements of an international forest regime. This regime is fragmented in two ways. Horizontally, there exist a number of international regimes from various policy sectors competing for regulating forests globally. Vertically, global and regional regimes also exist for influencing the world's forests. This paper aims to analyze both aspects of such fragmented international forest policy and asks for whom such existing arrangements are ineffective and who potentially benefits from it. It illustrates findings from a joint research project on the international forest regime. The paper concludes that the broader interest coalition of forest utilization still benefit from the fragmented character.

Continued evolution of Australian forest-climate change policies. Harper, R. (*Murdoch University, Australia; r.harper@murdoch.edu.au*), (*CO2 Australia, Australia; chris.mitchell@co2australia.com.au*).

Forests have continued to play a major role in Australia's national climate change mitigation responses. Accounting for reduced rates of deforestation and increased afforestation/reforestation allowed Australia to meet its first commitment period (2008–2012) target in the Kyoto Protocol (KP) despite significant emissions growth in the economy. Major developments since the last World Congress have included: (1) Legislation to manage carbon in the economy and to allow access of carbon credits from reforestation and forest management (Carbon Farming Initiative, CFI). A new (2013) national government has pledged to rescind the carbon legislation, but retain aspects of the CFI; (2) A likely acceleration of deforestation in some Australian states, including both natural forests and short-rotation pulpwood plantations; (3) Inclusion of forest management in Australia's reports to the second round of the KP; (4) Exclusion of natural forest residues from the national renewable energy scheme; and (5) The termination of the sub-national Greenhouse Gas Abatement Scheme. Despite approaches to forest carbon mitigation having been broadly similar between political parties in the past, distinct changes in approaches are becoming apparent. This is a continually evolving area and this paper will describe recent developments, the impact of these policies on climate change mitigation and key considerations for other jurisdictions.

National forest monitoring programs as data providers to forest related policy processes. Kleinn, C., Fehmann, L. (*University of Goettingen, Germany; ckleinn@gwdg.de*; *lfehrma@gwdg.de*), Morales, D. (*FAO, Italy; david.morales@fao.org*), Niebuhr, A. (*University of Goettingen, Germany; almut.jenke@forst.uni-goettingen.de*).

It is generally accepted that decisions can be taken best good information on the subject at stake is available, leading to what is called "informed decisions" and that better information leads to better decisions. However, this particular link has not yet been scientifically evidenced and among the major goals of large area forest monitoring is usually to generate maximize precision. In the long history of national forest inventories (NFI), remarkable advances have been achieved regarding monitoring techniques, including measurement devices, estimation algorithms, remote sensing integration and spatial explicitness and models and data management. Since long, NFIs have a multi-purpose character and are referenced in many policy contexts. However, it appears that the technical optimization of forest inventory projects towards improved information, and the utilization of such information in decision processes are largely unconnected. There appears to be a science-policy divide of which it is not entirely clear how deep and wide it is. Here, we analyze the link between NFIs and national / international policy processes and point to the FAO initiative to develop voluntary guidelines for national forest monitoring. These guidelines may help supporting NFI planning, for experts both with technical and policy background.

Impact analysis of China's forestry economic policy from the consensus reached in forest-related climate conferences. Liang, Y., Cao, Y., Wang, Y., Zhu, H. (*Northeast Forest University, China; 3262526@qq.com; cyklk@163.com; cydklk@163.com; 1512678643@qq.com*).

Due to global climate change, forests and forestry have gained peoples' great attention. Climate change conferences and the results of their negotiations had great impact on the Chinese timber trade. This research reviews and analyzes the courses of these major international climate change conferences. We take an intensive look into the spirit and common views expressed during these conferences, and analyze the structure of several major timber trading countries. The following conclusions were reached throught the research: (1) the consensus decisions made through the climate change conferences have had a significant impact on China's forestry policy, promoting several essential ecological projects in China both on the macro and theoretical level; (2) research and theory on forest carbon sequestration have been enhanced; (3) these conferences have resulted in increased forestation and forest management activities, and improvement in the implementation of logging bans.

International forest policy: Who is to define the objectives and the evaluation criteria? Lindstad, B. (*Norwegian University of Life Sciences, Norway; berit.lindstad@umb.no*).

Global forest processes have a reputation for not being very effective. This paper intends to discuss how effects and effectiveness of forest policy processes depends on how the objectives are defined, and what criteria are used for evaluating the effectiveness. With increasing numbers of policy processes – focusing on various forest related challenges and opportunities, the number of objectives – and the possible conflicts between them – is increasing. In this situation, effectiveness can vary from low to high – depending on analytical choices and assessed for various objectives. Evaluations focusing on biodiversity versus climate change, or wood production versus recreation will give different results. This requires effectiveness studies to be stating objectives and evaluation criteria clearly. It may be more important who is defining the objectives and deciding on the evaluation criteria – than what are actual effects.

International forest issues, FLEGT and potential directions. Liu, J., Long, H. (*Renmin University of China, China; liujinlong_jl@hotmail.com; longhx1986@163.com*), Li, X. (*Shanghai Ocean University, China; Xinli@shou.edu.cn*).

International forest issues refer to the decline of quantity and quality of forests, its environmental, economical and social development consequences, and internationalized, politicized and complex processes of these issues. International forest issues have been about more than forests and forestry, and have included political and development issues with involvement of politics. The paper analyzes the differentiation among themes of national sovereignty, financial mechanism and environmental-sound technology transfer between the developing countries and developed countries. It also evaluates the driving factors, including GDP, richness of forest resource of nations, domestic environmental movements especially in developed countries, that lead to different positions on international forest issues. Dialogue among various interests group, including in Africa, the Amazon region, and small island nations, has not yet lead to common understanding and compromise on the elements of international forest issues. Forest Law Enforcement, Governance and Trade (FLEGT) and Voluntary Partnership Agreement (VPA) processes essencially preclude the possibility of consensus on international community on forest issues, leading to the likely death of UNFF in 2015. Furthermore, this paper suggest that the Chinese government enhance its support of "think tanks" and research on international forest issues, to develop a strategy and strategic actions to participate in international forest issues with China's Wisdom.

A comparative study of international forest policy issues in Germany, Poland and Sweden. Logmani, J. (*University of Goettingen, Germany; jlogman@gwdg.de*).

After the Rio Earth Summit in 1992, an international forest regime (IFR) evolved, which consists of forest relevant political processes of intergovernmental cooperations with implicit or explicit principals, norms, rules and decision-making procedures. From the political science perspective an international forest regime could be defined as the sum of international forest policy issues (IFPIs). The objectives of the study are a comparison of specific domestic forest related policies in Germany, Poland and Sweden by means of current international forest policy issues and the identification of empirical examples of an effective regime influence. Interests of international and domestic actors and institutions using IFPIs, supported or blocked by national bureaucracies, define the intensity of the IFR-influence. The theoretical approach utilizes 4 pathways for describing the influence of the IFR on domestic levels. These pathways have the aims to sort IFPIs into 4 categories and to observe with these categories the field of action of domestic bureaucratic politics: international rules, international norms and discourses, creation of or interventions of markets and direct access to domestic policy processes.

A-29 The knowledge that counts – analyzing science policy interactions in forest policy

Organizers: Michael Böcher (Georg-August-University Goettingen, Germany) & Georg Winkel (University of Freiburg, Germany)

The RIU-model as framework for analyzing science policy interactions in environmental and forest policy. Böcher, M. (*Universiy of Goettingen, Germany; mboeche@uni-goettingen.de*).

Since a direct "linear" scientific knowledge transfer from science ("truth") to political practice ("power") does not seem to be possible, I suggest an alternative model of the science-policy-interface. This model describes science-based policy advice as the connection between research (R), integration (I), and utilization (U) – the RIU-model. Within this, scientific knowledge is produced in the science system (Research), and science-based problem solutions are utilized within politics by political actors and stakeholders (Utilization). Between the two spheres there is no "automatic" connection that leads to a linear application of science in policy making. Rather, the RIU-model highlights the important sphere of "integration", a step that lies between science and utilization. Integration means the orientation of research toward political and practical problems with the aim to describe and solve them. Integration is a bi-directional process: On the one hand the demand of specific political actors for science-based

problem solutions has to be detected and used to define research questions. On the other hand scientific research results have to be selected and abstracted by relevance in order to serve as supply for the demand of political actors. The fruitfulness of the model will be demonstrated by using cases from environmental and forest policy.

Application of Bayesian belief networks to science based policy development. Brienesse, M. (*Ontario Ministry of Natural Resources, Canada; mike.brienesse@ontario.ca*).

An example of using Bayesian belief networks (BBN) to develop evidence based forest policy in Ontario, Canada is used to demonstrate the utility of this technique for both policy development and adaptive management. A Bayesian belief network is a probabilistic graphical representation of how different variables interact to influence a given outcome. BBNs offer a framework for reconciling empirical and expert knowledge, testing assumptions, and documenting uncertainty. Once developed, the BBN can be used to explore uncertainty and risk associated with various policy options in a decision analysis framework. As the eventual policy decision is implemented the BBN serves as a series of hypothesis that can be tested in an adaptive management framework. Research and monitoring efforts can be targeted to areas of high uncertainty and high sensitivity. As new information becomes available the BBN can be updated using standard procedures, and policy decisions revisited as required. This ensures not only that research is relevant, but that researchers can see a clear process for incorporating results into decision processes. The graphical form and clear presentation of assumptions allows a non-technical audience (public, stakeholders, executives, politicians, etc) to understand and comment on how evidence is being used in policy decisions.

Actionable knowledge for forest owners associations in Slovakia. Dobšinská, Z., Šálka, J. (*Technical University Zvolen, Slovakia; dobsinska@tuzvo.sk; salka@tuzvo.sk*), Sarvasova, Z. (*National Forest Centre, Slovakia; sarvasova@nlcsk.org*).

The research project APVV -0057-11 VYNALES (Research of the impact of non-state forest ownership on forest related policies) is an example of the interface between science, research and practice. It presents a comprehensive approach to actionable knowledge resulting in the formulations of recommendations for beneficiaries, namely forest owners associations in Slovakia. The applied research procedures are based on the current necessity to gain relevant information about the representatives of the non-state forest sector in Slovakia, to fill in information gaps, to provide discussion material for the associations' representatives and to enforce their priorities through direct applied outcomes, supported by scientific research. The innovation of the project lays firstly in its participatory approach to policy research with the involvement of the beneficiaries, the possibility to monitor the research directly and steer the results and outputs, and secondly, in the usefulness of the outputs, which will be new for practitioners and transferred directly into practice by the beneficiaries. The recommendations for the non-state forest associations in Slovakia will serve as a basis for improving their activities and further development. The project results will contribute to the enhancement of knowledge and possible improvements in the policy agenda setting for non-state forest subjects.

Under the veil of science: a history of state management of Ghana's High Forest zone. Hansen, C., Lund, J. (*University of Copenhagen, Denmark; cph@ifro.ku.dk; jens@ifro.ku.dk*).

This paper examines the way forest science and knowledge has been used in Ghana to legitimate the power of the central state over forests, and timber resources in particular. It analyses how science has been invoked to authorize management decisions aimed at sustainable forest management, notably the felling cycle, the framework of large and small grained protection measures and the yield formula and scientifically based forest inventories. The paper focuses on the period from 1989 to the present and is based on analysis of narratives as presented in reports, letters, speeches and newspaper articles. The paper finds that narratives of sustainable timber management based on scientific silvicultural principles have been maintained throughout the period despite mounting evidence of the opposite. The paper thus argues that various forms of official ignorance have been carefully maintained to avoid systematic reassessment and policy learning and ultimately allowing state officials to maintain control over the resource.

Publicly-funded forest research in Canada: discriminating between strategic, tactical and technical policy relevance. Hickey, G. (*McGill University, Canada; gordon.hickey@mcgill.ca*), Klenk, N. (*University of Toronto, Canada; nicole.klenk@utoronto.ca*), Morin, G. (*McGill University, Canada; graeme.morin@mail.mcgill.ca*).

The need for accurate and timely decision-relevant information has been identified as a prerequisite for successful policy decisions. Equally important is the need to adequately 'frame' contextual, environmental and situational issues, questions, and concerns so as to generate clear and concise decision-relevant information. The goals of this paper are: 1) to clearly define each 'level' in the planning hierarchy, or management problem area, for the benefit of decision-makers and researchers; 2) to identify the nature of the scientific input required by decision-makers within each tier of forest policy, planning and management; 3) to evaluate the ability of publicly-funded research to meet the needs of the hierarchical tiers of decision-making, focusing on the case of the Sustainable Forest Management Network in Canada (SFM Network); and finally, 4) to provide suggestions and recommendations for forest researchers and decision-makers seeking to improve the public impact of forest research. Our results provide a more nuanced understanding of the science-policy interface and the importance of assessing the policy relevance of knowledge production in relation to different tiers of management planning.

Forest biodiversity in climate change adaptation; what is the role of IPBES and IPCC? Samsudin, Y. (*Global Garden Consulting, Indonesia; yusuf.bahtimi@gmail.com*), Bridgewater, P. (*Joint Nature Conservation Committee, United Kingdom; Peter.Bridgewater@jncc.gov.uk*).

The Intergovernmental Panel on Climate Change (IPCC) defines climate change adaptation as "….adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects…." (IPCC, 2007). While biodiversity change (including loss) is a significant result of climate change it is also one of the major factors driving climate change. Parties in the climate change negotiations proposed a mechanism to reduce the emissions from deforestation and degradation of forests known as REDD, later adding conservation and sustainable forest management, renaming it REDD+. The relationship between forest biodiversity and climate change has been widely seen in terms of mitigation, yet it also has a major role in climate change

adaptation. Considering the breadth of biodiversity-related conventions, the newly formed Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES) should have a role bridging the gap between the scientific underpinning and the development of policy for each of these bodies. The IPCC and the IPBES are science-policy interfaces so can add extra value to REDD+, not only through the developing policy on climate mitigation, but also through adaptation activities undertaken by the many intergovernmental bodies working on the issues.

Is forest research in accord with the strategic challenges of the forest sector? A case study on Finland. Seppälä, R., Saarikko, J. (*Finnish Forest Research Institute, Finland; ristojseppala@gmail.com; jarmo.saarikko@metla.fi*).

The purpose of the study was to examine how forest research in Finland is directed and how it should be directed in order to support the development of the forest sector. The classification of research disciplines was based on the international Forest Decimal Classification system. Two variables were used: the number of peer reviewed publications and the number of researchers. The results showed that the strongest disciplines based on the number of publications are ecology and biology representing 42%. As for the number of scientists, silviculture is number one with 24%. The weakest category is research on markets of forest products with the respective shares of 2 and 4%. After all, the real issue in forest research in Finland is not so much an excess or a lack of certain type of research but rather the implementation of existing research results. Nevertheless, more policy-oriented research is needed and more emphasis should be placed on technological and socio-economic aspects. The current dominance of empirical biophysical sciences in forest research is increasingly questioned by funders and other customers. However, there is a danger that an excessive customer orientation leads to short-term thinking and alleviation of basic research.

Governing uncertainty in forest management: forest counselors' handling of risk and uncertainty after extreme events. Lidskog, R., Sjödin, D. (*Orebro University, Sweden; rolf.lidskog@oru.se; daniel.sjodin@oru.se*).

How do forest counselors provide advice when faced with a situation associated with great uncertainties? What role do knowledge and values have in their advisory practices, and how are they balanced? These kinds of questions are of growing importance, partly because of the increased complexity of a globalised world and partly because of greater awareness of climate change and its consequences. This paper takes this as its point of departure when analyzing how forest counselors provide guidance in extreme cases. Two empirical cases are analyzed, both associated with a hurricane that hit south Sweden, resulting in damage to 270 000 hectares of forest and 75 million m^3 of windthrown trees. The first case concerns how forest counselors handled uncertainties in their advice on how to handle the windthrown forest, which faced a great risk of a major insect outbreak (bark beetle). The second case concerns how forest counselors handled uncertainties concerning the reforestation of the area. In conclusion, the implications of the way the forest counselors managed uncertainties are discussed, not least in relation to the general issue of sustainable forestry.

A-30 Achieving policy integration across fragmented domains: Forest policy perspectives

Organizers: Karl Hogl (University of Natural Resources and Life Sciences, Austria) & Daniela Kleinschmit (Swedish University of Agriculture Sciences)

Integrating multiple environmental regimes: land and forestry policies under broader democratic reforms in the Bolivian tropical lowlands. de Jong, W. (*CIAS, Kyoto University, Japan; dejongwil@gmail.com*).

Bolivia experienced major governance reforms driven by significant policy changes in the land and forestry sectors, simultaneously with broader reforms to improve democracy and enhance social participation. The reforms themselves and their implementation have been documented in much detail, and their results have been recorded and analysed. This paper focuses on the northern Bolivian tropical forest region, an area whose economy, and thus people's livelihoods rely dominantly on forestry production. The major reforms that have affected this region are an important process of forest tenure reform along with the establishment of a new administrative category that provided legal status to the region's many rural settlements. The new settlements received enormous large forestlands as communal property so that they could continue developing agro-extractive activities in order to support their livelihoods. The case of democratic reforms linked with land and forestry reforms in northern Bolivia makes it possible to discuss environmental policy integration in a tropical context, and thus to review some of the key postulates that have been formulated on PI and EPI, but which are to date largely based on empirical experiences from northern hemispheres.

Multi-level governance of forests in a changing climate: international influence on Swedish forest policy. Holmgren, S., Kleinschmit, D. (*Swedish University of Agricultural Sciences, Sweden; sara.holmgren@slu.se; daniela.kleinschmit@slu.se*).

The governance of forests is multi-level and conventional boundaries between international and domestic forest governance are increasingly destabilised. Marketization processes, discourses, actors, and institutional dimensions of forest use, protection and management are adopted, 'translated' or rejected in different locations depending on pre-existing institutional context, discourses, and actors. In this paper we explore how and why international regimes influence or not influence Swedish forest policy when it comes to role of forests in climate change, and vice versa. Drawing on Bernstein and Cashore's (2012) 'four pathways of international influence on domestic policy change' and Bacchi's (2009) conception of policy as discursive practice, we analyse policy programs of the international climate and forest regime and Swedish policy programs linking forest and climate change. We expect that our findings will demonstrate how the 'timber production paradigm' characteristic for Sweden is challenged as values of non-timber products and services are increasingly acknowledged e.g. through REDD+. Additionally, institutionalised values that promote timber production in Sweden will endorse the roles of growing forests and the carbon sequestration capacity of wood products in climate change mitigation. This position can further be expected to be conveyed abroad through state actors, social and environmental NGOs, industrial and forest owner associations.

Multistakeholder approach for the development of new national forestry sector strategy in Nepal. Lamsal, R. (*Ministry of Forests and Soil Conservation, Nepal; ramplamsal@gmail.com*), Kanel, K. (*Resource Identification and Management Society, Nepal; keshavkanel@gmail.com*).

The multistakeholder approach, which is an effective participatory tool, has been promoted in the forestry sector of Nepal, and applied to a wide range of structures and levels for improving governance, developing partnerships and networks, and realization of shared vision among different stakeholders. Based on primary data, practical experiences, relevant literature, this study assesses the conceptual, institutional and operational aspects as well as strengths and challenges of the multistakeholder approaches in developing forestry sector strategy and provides an overview of the key lessons learned. The findings of the study reveal that the multistakeholder approach promotes confidence, trust, sense of ownership, commitment and sustainability, thereby supporting the realization of shared vision; minimization of conflicts and enhancement of resource leverages. Nevertheless, problems on power dynamics, accountability and lobbying for narrow organizational interest rather than holistic perspective still persist. The development process of new forestry sector strategy has emphasized for establishing and strengthening multistakeholder approaches at various levels for more effective and efficient management of forest resources; developing appropriate policy tools and techniques on re-orientating forest management approaches, and strengthening existing capacity of key stakeholders by developing communication and leadership skills, improving access to knowledge and sharing of good practices.

Study on forest policy coordination and cooperation: take a case of collective forest tenure reform in China. Liu, J., Yuan, M., Zhang, Y. (*Renmin University of China, China; liujinlong_jl@hotmail.com; foreverjane2006@126.com*; *zhangyiwen@ruc.edu.cn*).

Considering that forests play a great linkage role between environment and development issues, forest policy has become part of public policy, requiring both cooperation and coordination. This paper constructs an analytical framework based on the "positive coordination" and "negative coordination" theory of Scharpf and Metcalfe's classification of policy coordination between government departments. The conclusion is that forest policy coordination and cooperation at the central level lies in Level Three, Four and Five and in the transitional range of negative negotiation and positive negotiation. At the grass-roots level, it lies in Level One and in the condition of non-coordination. Within forestry administrative sectors, forest policy coordination and cooperation lies in Level Five and Six, and the full coordination and cooperation has been almost achieved. In non-forestry administrative sectors, however, forest policy coordination and cooperation lies in Level One and with no coordination at all. Between forest and non-forest sectors, and between various levels of non-forest sectors, policy coordination and cooperation requires further enhancement. The forestry sectors should encourage more interest groups to participate in the policy-making process, pay more attention to promoting the capacity of less competitive groups and enhance the coordination with non-forestry sectors.

Forests in the non-forest policies: how much room is left to forest decision making? Robert, N., Martinez de Arano, I. (*European Forest Institute, Spain; nicolas.robert@efi.int; inazio.martinez@efi.int*), Muys, B. (*KU Leuven University, Belgium; bart.muys@ees.kuleuven.be*).

Forests provide multiple goods and services and foresters are not the only one who know it! In fact, forests are becoming increasingly valuable and face critical societal challenges, notably climate change, biodiversity conservation, renewable resources for a growing population and wellbeing. The transition towards of a greener economy will have multiple implications on the forests as an array of policies are pushing for an increased use of renewable materials in buildings and of biomass for energy, enhanced carbon sequestration to mitigate global warming, stronger and more effective protection of biodiversity future regenerations. This also implies a strong risk of increased fragmentation in forest policies that are also layered in Europe from the European to the national and the regional levels. In this paper, we review relevant European Union (EU) policies that are having or could have a significant impact in European forests and forestry activities. These are the climate and energy package, nature and biodiversity protection, agricultural and rural development…, and we address the question of the role instruments such as the EU forest strategy or the possible legally binding agreement on forest in Europe can play to ensure the sustainable provision of ecosystem services by forests.

Integration of bio-energy policy – a multi-sectoral frame analysis. Sjöstedt, V., Kleinschmit, D. (*Swedish Agricultural University, Sweden; viveca.sjostedt@slu.se; daniela.kleinschmit@slu.se*).

This paper explores the extent to which bio-energy policy is integrated across the three main sectors affected (forestry, agriculture and energy), with the focus on sector perceptions. It also investigates the coherence of integration between the different sectors by identifying consistent and conflicting perceptions of the sectors. Cognitive policy integration linked with frame theory was used as the theoretical framework. Frame analysis on 354 articles published in sector journals between 2001 and 2010 revealed the dominant economic frames of bio-energy coherently used in all three sectors. It also identified environmental frames as conflicting with the objective of increasing bio-energy from forest products. This led to the conclusion that integration of bio-energy policy is perceived as threatening environmental objectives already integrated in the three sectors.

The need for forestry to understand and respond to indirect impacts of climate change. Wallgren, O., Olsson, O. (*Stockholm Environment Institute, Sweden; oskar.wallgren@sei-international.org; olle.olsson@sei-international.org*).

In both research and policy, the challenge of adapting to climate change has so far mainly been framed as a domestic, territorial concern. For commercial forestry it is however likely that the impact of climate change will not manifest primarily as direct changes driven by local climate change and weather events, but as indirect effects from aggregate impacts elsewhere in the world. Forestry products are traded internationally and the whole system is subject to the impacts of global climate change. Forestry decision makers are, however, poorly equipped to deal with this emerging change. Dominating policy frameworks concerning e.g. climate change, land use, resource management and risk management are not aligned. In addition, methods to provide consolidated analysis of aggregate indirect impacts are missing. This presentation makes conceptual contributions regarding the indirect

impacts of climate change affecting commercial forestry, and explores to what extent present policy affecting forestry in select countries is sufficiently addressing this new challenge. Drawing on interviews with Swedish decision makers in forestry and an analysis of strategic documents analyzing the future global context for Nordic commercial forestry, conclusions are drawn on the need for changes to both policy and decision-making practices.

The European forest policy paradox – how policy integration fails through practices of sectoral polarization. Winkel, G., Sotirov, M. (*University of Freiburg, Germany; georg.winkel@ifp.uni-freiburg.de*; *metodi.sotirov@ifp.uni-freiburg.de*).

Policy integration is a challenging process that involves the renegotiation of interests, beliefs, and sectoral policy boundaries. In this paper, we introduce the European forest policy as an arena that is characterized by a policy (dis)integration paradox. On the one hand, the need for better coordination and integration of fragmented policies is frequently expressed. On the other hand, little has been achieved in terms of policy integration despite several initiatives. Drawing on 49 semi-structured interviews with European forest policy makers and participatory observation, we firstly assess effects of and reasons for the disintegration paradox, and secondly the strategic importance of distinct forest policy initiatives that are legitimized by the need for better policy integration. Our data demonstrate that the forest policy (dis)integration paradox can be explained by different factors, with economic interests, sectoral and institutional competition being most important. Under such circumstances, policy integration serves as frequently used rhetoric to consolidate sectoral interests, however, substance-wise, it is simply not happening.

A-32 Innovative forest and environmental legislation for better diversity

Organizers: Peter Herbst (Villach, Austria) & Rastislav Sulek (Zvolen Technical University, Slovak Republic).

Forest genetic resources in the Amazon tropical forests – legal forestry framework, divergences of use and considerations for conservation. Bentes Gama, M., Oliveira, V. (*Brazilian Agricultural Research Corporation (EMBRAPA), Brazil; michelliny.bentes-gama@embrapa.br; vania.beatriz@embrapa.br*).

Over the last two decades there has been increasing recognition that some tree species from the Amazon tropical forests have other important values and uses besides timber. The non-timber theme has then become of major interest for investigation and policy making, giving also a chance to establish a new era of environmental laws, with specific orientations to promote the sustainable use of these natural resources. For various reasons, the promotion and application of these legal frameworks to promote people's livelihoods and forests conservation are still considered as challenges today. Forest peoples are the main suppliers and stewards of non-timber products in the tropics. However, these people are very poorly positioned to become the main beneficiaries of their own economy. The need to empower and strengthen community organizations and future leaders' capacities in the development of a sustainable agriculture-forest use is a priority to promote real changes. Overcoming these current weaknesses can be a strategy to realign and encourage the use of appropriate environmental regulations and provide viable solutions regarding the rights and needs to use non-timber resources simultaneously in these areas.

Historical reasons behind the State domination of forest ownership in Turkey. Birben, U., Gunes, Y. (*Cankiri Karatekin University, Turkey; birben@karatekin.edu.tr; gunesy81@yahoo.com*).

As of 2012, with respect to the Turkish Forestry Statistics, forestlands have an area of 21.678 ha covering 27.6% of the country's land area. According to the Forest Law still in force, the forests in Turkey are divided and managed into three catecories in terms of ownership and management. When the classification of the Forest Law taken as a base, these categories are: 1) State forests, 2) Private forests and 3) Forests belong to public legal entities other than the State. Although three types of forest ownership are recognized in the Forest Law, almost all of Turkey's forests are under the control and supervision of the State (State forest ownership dominates more than 99.9% of the total) and are managed by the General Directorate of Forestry based on the principle of sustainable forest management. However, the privately owned forest areas are less than one-thousandth of all forest area (about 18 000 ha) in Turkey. Thus, the purpose of this study is to explain the historical reasons behind the State Forest Ownership by taking into account both the Ottoman Empire and Republic era. In this study, occurred changes in forest policy and its implementations, important legal regulations, changes in forest ownership regime and the society's responses to those changes during the historical process will be explained by the statistical data available and selected events.

Legal framework of community forestry of indigenous peoples in the Amazonian countries: a comparison of national land and forest laws. Carrillo Yap, S. (*University of Göttingen, Germany; siulang.muchik@gmail.com*).

A difficulty for community forestry in the Amazonian countries is the conflict because of the land and forest rights of the indigenous communities. The objective of this presentation is to analyze this problem in the national laws of four countries of the Amazon region (Bolivia, Brazil, Ecuador and Peru) and to look at their consistency with international agreements signed by these countries. The national laws – following the colonial pattern – separate the right to the land from the right to the forest resources, giving property rights and use rights respectively. At the same time indigenous peoples defend their right to territories, which implies property rights over their lands and forests. Moreover, the community forest management plans limit the application of forest-related traditional knowledge, which is a right recognized in the national laws of these countries. International agreements recognize not only the land and forest resources rights of indigenous peoples, but also their rights to continue their own way of life, to maintain their cultures and to subsist. The application of these agreements requires giving control over lands and forest resources to the indigenous peoples, which shows the inconsistency of some state laws with the international agreements.

Locating the status of forest laws amongst other law disciplines. Menģele-Stillere, L. (*State Forest Service, Latvia; ligamenstill@inbox.lv*), Herbst, P. (*Villach, Austria; hp@net4you.at*).

In law-based States, law regulates all branches of human life, including forest management. Forest Law comes from the cross-roads of forest science and law science. This paper focuses on one question: what is Forest Law and to which legal discipline

does it belong? Forest is a part of nature and at the same time property unit. That causes debate whether Forest Law belongs to Environmental Law or Property Law. Many features show that Forest Law is a part of Environmental Law. The main objective of the Forest Law is to ensure sustainable forest management through creating legal frame and mechanism of balancing different interests. Legal norms must be made taken into account as well as economic interests and the interests of forest owners, but these interests cannot be the dominant ones. The situation in practice sometimes is different. Forest Law belongs to Public Law because Forest Law seeks to protect the public interests – forest protection and maintaining a high-quality environment is part of this. Further, it is important to note that Forest Law is influenced by other legal disciplines, not only public law. Civil law, criminal law and many other branches of law regulates some issues connected with forests.

Challenges of the forest and environment legislation for better biodiversity in Albania. Muharremaj, E. (*University of Tirana, Albania; emuharremaj@gmail.com*).

Forests in Albania are composed of various formations and types, and are rich in biodiversity. During the prolonged period of transition, wide forest areas, including some national parks, have been damaged by illegal logging and fire. This study has used the explorative research method, analyzing the forest legal framework, and the way it is being implemented, through field observations. It is also an explanatory research explaining the reasons for the current situation of forests in Albania. The existing legal framework does not clearly define the roles and responsibilities of actors. There are contradictions between the laws on forest and environment and they are not being properly implemented. The research shows that the reduction of the forest area has not been reflected in the statistical data. There is a need for a new forest inventory and cadastre and a periodical inventory. In order to meet the actual challenges, the proposed new law on forests should stipulate the separation of the managing from the controlling functions, further decentralization, and full participation of the community, harmonized with the other laws and the EU directives. More support is needed by trans-boundary projects for the protection of the forest ecosystems and diversity.

Sources of contradictions in forest and nature protection legislation. Sulek, R. (*Zvolen Technical University, Slovak Republic; rastislav.sulek@tuzvo.sk*).

Recently, numerous theories and opinions about relations between forestry and nature protection have been developed, resulting in a number of different conceptions of management of forest resources. The professionals and, nowadays, also general public tend to prefer such management that would meet fulfilment of all economic, ecological as well as environmental forest functions. However, such management needs to be based on sound and innovative legislation that would provide enough space for harmonization of possible conflict between forestry and nature protection. The objective of this paper is to identify and analyse possible sources of contradictions between forest and nature protection legislation using examples of different valid forest acts and nature protection acts on the national level. Consequently, the possible reduction of such contradictions is examined and proposals *de lege ferenda* are suggested in the case of respective analysed legislation. The special attention is paid to the issues of property rights, access rights, compensation of forest owners, process of declaration of nature protection areas, administration and control of different activities and effective use of public financial sources. Finally, general recommendations for harmonization of objectives of all interested parties dealing with management of forest resources are proposed.

Legally binding agreement on forests in Europe – a conventional negotiating process? Ventrubova, K. (*Czech University of Agriculture Prague, Czech Republic; ventrubova@fld.czu.cz*), Poliakova, L. (*Forest Resources Agency, Ukraine; Lpolyakova@ukr.net*), Herbst, P. (*Villach, Austria; hp@net4you.at*)**.**

The process of an Intergovernmental Negotiating Committee for a Legally Binding Agreement on Forests in Europe (INC-Forests) was launched by the 2011 Forest Europe Ministerial Conference on the Protection of Forests in Europe, held in Oslo, Norway. Ministers responsible for forests met to take far-reaching high-level policy decisions concerning the continent's forests. The main goal of the article is to compare and contrast the negotiation process on a legally binding agreement on forests in Europe (LBA) with other similar negotiation processes, and thus to confirm or disprove a hypothesis "Negotiations on the LBA are proceeding in a way comparable to other similar negotiating processes". A common view of the hypothesis is that the relatively difficult negotiating process on the LBA obtains a normal progress just like other political processes. Comparison of already established processes, such as on one hand the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity – examples under UN auspices, and on other hand the Carpathian Convention – an example of a regional convention, should show that there is a general common development of negotiating processes in the field of sustainable development.

A-33 Richer economies, better environmental policies? Analyzing the "environmental question" in forest policy in OECD countries

Organizers: Georg Winkel (University of Freiburg, Germany), Cassandra Moseley (University of Oregon, USA) & Metodi Sotirov (University of Freiburg, Germany)

On how to gain discursive agency in environmental conflicts – exploring policy discourses on illegal logging. Leipold, S. (*University of Freiburg, Germany; sina.leipold@ifp.uni-freiburg.de*).

Environmental policy attempting to address the trade of illegally logged timber has gained some popularity over the past years, particularly in OECD countries. After the USA introduced the first policy against illegal logging, the 2008 Lacey Act amendment, the European Union followed in 2013 with the EU timber regulation. Given that the US and the EU are two of the largest timber importers worldwide, this development has considerable impacts on global trade flows as well as the management of forests outside the regulating state's own territory. Consequently, several scholars have explored the global effects and possible future impacts of these policies. Fewer studies exist, however, on the conflicts surrounding their creation and implementation within the

OECD countries themselves. This paper will explore these conflicts by applying a discourse approach. Specifically, it asks (1) how different stakeholders construct their own role in the policy discourse (their discursive agency) and (2) how this shapes specific policy definitions and responsibility ascriptions in illegal logging policies across different national contexts. These questions will be explored empirically in the USA and Germany, drawing upon policy documents and a comprehensive set of semi-structured interviews with policy makers.

Payments for forests: characterizing benefits and governance in the context of watershed payments for environmental services in Europe. Leonardi, A., Pettenella, D. (*University of Padova, Italy; alessandro.leonardi@unipd.it; davide.pettenella@unipd.it*), Smith, L. (*University of London, United Kingdom; l.smith@soas.ac.uk*), Robert, N. (*European Forest Institute, Spain; nicolas.robert@efi.int*), Bennett, G. (*Forest Trends' Ecosystem Marketplace, USA; GBennett@forest-trends.org*).

Globally, watershed payments for environmental services (WPES) make-up the second largest ecosystem service market after carbon. Driven by the negative impacts of climate change and economic development for water quantity and quality provision, hydrological services are assuming a leading priority among forest-based ecosystem services. Indeed afforestation tends to be among the most rewarded management practices under contracts aiming to achieve additionality in upstream water storage, water quality protection and flood risk mitigation. Through a comparative analysis of twenty case studies we characterize the role of forest in term of legal, institutional, economic and social benefits and governance mechanisms associated with WPES in Europe. With regard to the latter, although conventionally PES is seen as a market-based tool, most existing WPES in Europe fundamentally depend on public bodies that act as intermediaries. European WPES are thus best described as "PES-like" schemes implemented by public entities, often acting in a rather complex institutional framework. Long term durability depends on the ability of integrating different source of funding, starting from existing subsides, private investments and service beneficiaries funds. Innovative governance models and operational instruments for WPES implementation are needed (such as network-contracts to facilitate the participation of the high number of forest managers).

The combat against illegal logging – Are new policies game changes or merely symbolic? Ottitsch, A. (*University of Cumbria, United Kingdom; Andreas.Ottitsch@a1.net*).

Over the past decade both the US and the EU have seen considerable developments in policies aimed at ensuring the legality of forest products on their markets. This has led to the development of new institutions and new requirements for actors along forest sector supply chains. Some earlier studies have claimed tangible results from such policies in terms of changing trade flow patterns, yet as these also coincided with economic crises in major markets, their conclusiveness has been disputed. This paper combines qualitative and quantitative approaches aimed at evaluating the impacts of policies such in the US and Europe. At formal levels both policies have similar objectives, yet as typical outputs of their respective polities they show considerable differences as regards their informal elements and effects. Having evolved out of processes which started back almost two decades ago, they are remarkable also as relevant actors have been able to keep the issue on the agenda by linking to upcoming new developments. In this context they can be studied as prime examples for agenda setting in which interest groups – from the environmental as well as industry spheres – have been able to fit long established positions into new discourses.

Forest biomass and biodiversity: which conflicts arise from contrary environmental goals? Schumann, C., Pyttel, P., Rothe, A. (*University of Applied Science Weihenstephan-Triesdorf, Germany; christina.schumann@hswt.de; patrick.pyttel@hswt.de; andreas.rothe@hswt.de*).

The recent German energy policy includes a reduction of CO_2 emissions and an increase in consumption of renewable energies. Besides other biomass, wood is one of Germany's most important source of bioenergy. In the year 2012 the amount of forest wood used for energy supply exceeded the amount used as material for the first time in decades. Due to this trend massive conflicts arise between stakeholders regarding the sustainable use and supply of forest goods and services. This paper discusses (1) the current state of development on how increasing utilization pressure on Central European forest ecosystems is perceived by different stakeholders; (2) which conflicts arise from this development between stakeholders; and (3) which silvicultural adaptations are realized as a consequence of increasing fuel wood demands. Workshops and interviews with stakeholders, surveys with fuel-wood producers and consumers in three model regions (rural districts) covering a geographical gradient and different forest associations in combination with a broad literature review revealed multiple concerns over the increasing use of forest biomass. Our findings have indicated a perception change regarding forest utilization, gaps in legal settings and strategies that provide energy based on forest biomass, and to mitigate the loss of biodiversity.

Changes in environmental governance and illegal logging policies: the case of the European Union's timber regulation. Sotirov, M. (*University of Freiburg, Germany; metodi.sotirov@ifp.uni-freiburg.de*).

The EU Timber Regulation was adopted in 2010. This piece of environmental regulation laid down prohibits of placing illegally harvested timber on the EU market, and obligations of economic operators who place timber products on the EU market to exercise "due diligence". Little research has been done focusing mainly on the impacts in developing countries. The current paper seeks to trace the process of formulation and implementation of the EU-TR within the EU which is mostly comprised of OECD countries. Based on interviews and document analysis, the paper seeks to shed light on this puzzling case of an environmental regulatory policy with major economic impacts on forestry. The paper argues that EU-TR policy represents a unique case of major change in environmental policy with differential impacts on forest policy. This policy arose out of an "unholy cooperation" between traditionally opposed actor networks of environmental groups and commodity-oriented forest industry supported by policy brokers from EU and national authorities. The main causal mechanism has been the building of "Baptists and Bootleggers'" coalition between those actor networks based on apparent overlap of environmental groups' moral arguments (e.g., negative ecological impacts from illegal logging) and forest industry's vested economic interests (e.g., market expansion).

Institutional mimicry, shifting values and diverging policy paths: comparing forest environmental policy evolution in Germany and the United States. Winkel, G. (*University of Freiburg, Germany; georg.winkel@ifp.uni-freiburg.de*), Moseley, C. (*University of Oregon, United States; cmoseley@uoregon.edu*).

In the last 25 years, forest politics in many industrialized countries has been marked by significant conflict. Confrontation between industrial and environmental actors has triggered different institutional responses. In this paper, we compare forest political conflict and policy evolution in Germany and the US. Our work combines institutional analysis with process tracing. We focus on status and change of federal forest institutions and paradigms. In both countries, conflicts between the traditional forest sector and the environmental movement intensified in the early 1990s. There are many similarities in the paradigmatic roots of the forest sector and the environmental movement in both countries. In addition, since the 1970s, a set of similar political institutions developed to address environmental conflicts. Yet, interestingly, these similarities did not result in a similar evolution of forest policy. In the US, federal forest policy underwent significant paradigmatic changes while in Germany forest policy remained largely stable. To conclude, we explore major triggers for change and stability of forest policy, and consider how our findings may relate to other countries.

A-34 Forestry education serving science and practice

Organizers: Piotr Paschalis-Jakubovicz (Warsaw University of Life Sciences, Poland), Siegfried Lewark, University of Freiburg, Germany) & Yemi Adeyeye (IFSA/Bangor University, UK)

Introduction of sustainable forestry best learning and practice into Russian forest higher education: NGOs' approaches. Kulikova, E. (*European Forest Institute, Finland; elena.kulikova@efi.int*), Belyakova, A., Shmatkov, N. (*WWF Russia, Russian Federation; abelyakova@wwf.ru; nshmatkov@wwf.ru*).

The concept of sustainable forest management (SFM) is not very well known and widely applied in Russian forest sector. One of the reasons is that there are no enough well-trained specialists to ensure sustainability of forest resources use. By surveys and analytical studies, WWF Russia investigated status of higher education in forestry at the national level focusing at the SFM issues to be included into educational programmes as well as teaching capacities related to it. It was discovered that professional education in forestry is not quite sufficient. Forest universities are underfinanced and lack young teachers. Very few textbooks and training materials have been developed lately. Low awareness of university teachers on modern global and regional environmental challenges and sustainability of forest management from social and economic prospective makes it impossible to transfer this knowledge to practitioners. Universities have limited opportunity on knowledge exchange within Russia and abroad. Based on the results obtained, WWF Russia developed training programs and textbooks on SFM and voluntary forest certification which now are applied in 19 forest universities. We facilitate study tours for universities' staff to enterprises and model forests in Russia and internationally to raise its awareness of the best training and forest management practices.

IUFRO Learning Initiatives – a necessary tool for lifelong learning of forestry graduates? Bijak, S., Paschalis-Jakubovicz, P. (*University of Life Sciences, Poland; szymon.bijak@wl.sggw.pl; Piotr.Paschalis@wl.sggw.pl*), Stereńczak, K. (*Forest Research Institute, Poland; K.Sterenczak@ibles.waw.pl*).

Constant knowledge and skills extension and improvement seem to be essential for modern graduates if they want to succeed on the labour market. The IUFRO Learning Initiatives (LI) is a set of educational events that are supposed to enable postgraduates to upgrade their abilities through short but intensive courses. The event topic includes the most relevant and up-to date issues, while the specially designed program uses advanced teaching techniques (e.g. case studies, focus group discussions). We describe experiences gained during two LI editions held in Poland (on precision forestry) and Turkey (on forests in climate change) in 2012 and 2013 respectively. Participants' attitudes and expectations as well as their assessment of teaching and organisational aspects were discussed and compared. Diverse cultural and professional background of participants and lecturers provided a wide range of opinions about aspects of proposed courses. Curricula, additional activities or meals often have to consider different beliefs or attitudes of people who attend LI, regardless of their role in the event. The less formal atmosphere, field trips to attractive places and meetings with local forest practitioners, were greatly appreciated and should be obligatory part of the course programme.

Curriculum reengineering – the key to skill-based future forest education. Heinimann, H. (*ETH Zurich, Switzerland; hans.heinimann@env.ethz.ch*).

Forest education has been drawing critisism that has not been developing student's skills that will be required in future job markets. Higher education institutions have responded in different ways. Some merged forest degree programs with environmental science programs, whereas others tried to maintain and adapt forest-specific programs. Whereas curriculum development was for a long time a process of "light" adjustment, the current challenges require a fundamental different approach, which we call "curriculum reengineering". Our hypothesis is that a systemic process that follows the systems engineering philosophy is a promising approach to thoroughly redesign curricula, consisting of a (1) requirements analysis, (2) conceptual design, (3) learning activity design, (4) curriculum assessment, (5) implementation, and (6) follow-up. The presentation explains the systemic approach to curriculum development, and presents the outcomes of the requirements analysis, which are called "qualification profiles". Our systemic approach is expected to create a "whole that is more than the sum of its parts", hopefully contributing to overcome redutionistic approaches that have been focusing on repackaging "old contents" in new shells, such as "distance education", "e-learning", or "open education resources".

Recommendations for forestry science education in North America: results from the Berkeley Summit on Forestry Education. O'Hara, K., Gilless, K., Helms, J., Standiford, R. (*University of California-Berkeley, USA; kohara@berkeley.edu; gilless@berkeley.edu*; *helms@berkeley.edu; standifo@berkeley.edu*).

In May 2014, a 2-day meeting on forest science education in North America was convened with a group of approximately 60 educators, administrators, public and private land managers, extension specialists, and others. The meeting used new survey data on forest science education in a series of working sessions to address key issues facing forest science education in North America. The meeting worked on eight key areas affecting forest science education in North America: 1) Curricular issues such as the content of forestry education programs as compared to programs in other natural resource disciplines; 2) The emerging role of distance-education in forestry; 3) The future of masters-level programs for forest managers; 4) The importance and future development of accreditation of forest science education; 5) Future employment trends for graduates of forest science programs; 6) The organizational structure of forest science education in programs at research universities; 7) The role of international education opportunities; and 8) Evaluating the importance of and enhancing student diversity in forest science education programs. Intensive work groups focused on these issues to develop recommendations for forest science education in the USA and Canada, but with applications to forest science programs in other parts of the world.

Need for new learning approaches in an evolving world: an example dealing with climate change. Peyron, J.-L. (*ECOFOR, France; jean-luc.peyron@gip-ecofor.org*).

Traditional higher education is embedded in formalized frameworks that are prepared in advance and formally agreed upon before the actual implementation of their contents in practice. Their structure is sometimes an obstacle towards an overall vision that is generally required in practice. They are renewed periodically and generally every 4 to 10 years. The time lag is several years between the conception of teaching contents and their implementation. Finally, educational contents are often far behind up-to-date considerations and still more behind future conditions that have to be expected. This drawback has been addressed in the frame of the Iufro learning initiative developed in September 2013 in partnership with the University of Artvin (Turkey) on the subject of climate change. Among the contributions, one was organized towards a computer-based session using a model, still under development on a spread sheet. This model aimed at thinking about different aspects of adaptation (trends and crises, warming intensity and initial date of stands), different aspects of mitigation (carbon sequestration, storage and substitution), and the integration of adaptation and mitigation strategies. This approach allowed broadening the scope about climate change and forest management, and anticipating what should be done facing climate change.

Competency surveys – what can empirical surveys and economic models tell us about competency requirements in working life? Rekola, M. (*University of Helsinki, Finland; mika.rekola@helsinki.fi*).

Competence surveys (CS) are typically empirically oriented studies asking former students, graduates or employers their opinion about which competencies and experiences are important in education and/or working life. For instance, Schuck (2009) asked faculty members from 8 European universities to rate (on a scale of 1-5) 30 generic and 41 subject-related competences. Arevalo et al (2010) analysed 1) the importance of the competency for the employment of the graduates and 2) the level of development achieved in competency by current graduates, both related altogether to 42 competences. Based on the gap between 1) and 2) it was interpreted where are the needs for improvements in curricula. The present study discusses the theoretical structure of competencies behind empirical measurements. On the one hand, competencies can be seen as inputs of production that employers are demanding in. On the other hand, they can be viewed as goods or services that graduates are supplying for in labour markets. The various theoretical economic models for demand and supply are presented. For example, a non-compensatory model may indicate a threshold for a competency that graduates have to meet in order to be accepted as valid employees. These models and their implications to empirical CS are discussed.

Changing the perception of a natural resource education program: a case study at Virginia Tech. Smith, B., Winistorfer, P. (*Virginia Tech, USA; rsmith4@vt.edu; pstorfer@vt.edu*).

The urbanization of America and the millennium generation have greatly impacted enrollment in traditional natural resource programs in the United States. This research investigated the perceptions of stakeholders of a leading natural resource program including alumni, employers, students, university faculty and administrators to identify current perceptions of the program and issues that could help direct future programming efforts. Over 700 stakeholders responded that CNRE at Virginia Tech was perceived as a high quality "traditional" natural resource program, but changes would need to be made in order to increase enrollment from the next generation of high school students. This presentation will present the findings of this research and what the College did to start to implement the changes necessary to attract a new type of student.

The role and tasks of research on labour psychology in the ergonomic education of foresters. Sowa, J. (*University of Agriculture in Krakow, Poland; rlsowa@cyf-kr.edu.pl*)**.**

Analyses of forest work processes in the world show an increasing share of operators' mental workload when performing multiple technological operations. Research shows that constantly progressing modernisation of forest work performance results in operators' ever smaller physiological workload whereas their mental workload during work increases considerably. The increase in mental workload in forestry is particularly significant in those work positions where operators use modern multi-operational machines. The present study is an analysis of the role and tasks played by the results of research on labour psychology in the contemporary ergonomic education of foresters. It has been shown that the development of research on mental workload in forestry is not sufficient even in developed countries. In countries with a smaller development of forest technology, the issues of labour psychology are usually not an important element of the ergonomic analyses of work processes. Analyses of foresters' higher education also show an insufficient level of ergonomic education in labour psychology. The conducted analyses have resulted in the proposal to introduce necessary amendments to the educational programmes, making it possible for forestry graduates to analyse and optimise machine operators' mental workload occurring during forest work.

A-35 The social education of foresters

Organizers: Lisa Hansen (IFSA/University of British Columbia, Canada) & Louise Fortmann (University of California at Berkley, USA)

Solving problems in forest landscapes: definition, practice and barriers of transdisciplinary research. Angelstam, P., Elbakidze, M. (*Swedish University of Agricultural Sciences, Sweden; per.angelstam@slu.se; marine.elbakidze@slu.se*).

Translating policies about sustainable forest management as a social process and sustainability outcomes into the real world of landscapes as social-ecological systems involves several challenges. Hence, applied research policies advocate improved innovative problem-solving capacity. One approach is transdisciplinary research that integrates different disciplines, as well as researchers and practitioners. Drawing upon 14 experiences of problem-solving in forest landscapes, we used group modelling to map perceived barriers and bridges for researchers' and practitioners' joint knowledge production and learning towards sustainable forest landscapes. The analysis indicated that the transdisciplinary research process is influenced by (1) the amount of traditional disciplinary formal and informal control, (2) adaptation of project applications to fill the transdisciplinary research agenda, (3) stakeholder participation, and (4) functional team building/development based on self-reflection and experienced leadership. Focusing on functional green infrastructures in forest landscapes as a common denominator for the delivery of ecosystem services and thus human well-being, we discuss how to diagnose social-ecological systems, and use knowledge production through collaborative learning as treatments.The term integrative landscape approach captures this.

Social dynamics and integrative methods in forestry science education. Baerlocher, B., Mühlethaler, U. (*Bern University of Applied Sciences, Switzerland; bianca.baerlocher@bfh.ch; urs.muehlethaler@bfh.ch*).

Nowadays research methods are still strongly divided into natural and social sciences. However, all sustainability-related fields require integrative methods as sustainability always contains the societal dimension of how people want to shape their future. The conference title therefore implies that the integration of social science into forest science is a necessity. This applies to both forest research and forestry education. The Forest Division of the School of Agricultural, Forest and Food Sciences has recently launched a major in "Forests and Society" for its BSc programme in Forest Science with the aim to develop more appropriate methods, including social science perspectives, for research and forest science education. The undergraduates learn that urban woodlands are increasingly characterized by high social value which leads to conflicts between different forest-user groups, forest managers and authorities. Our experience is that future forest professionals need basic knowledge of societal dynamics and integrative methods. Furthermore, we have observed that women in particular are attracted to social topics in Forest Science studies. Therefore, the integration of social science could also lead to more equality in the male-dominated forestry industry. My presentation will focus on interrelated models which integrate social and natural science perspectives, and the future of interdisciplinary forest science research and education.

Teaching foresters about gender, property and why they matter. Fortmann, L. (*University of California-Berkeley, USA; louise.fortmann@gmail.com*).

Using examples from Africa, Indonesia, and North America, the importance of gender, local knowledges, and property to forestry practice will be demonstrated. Based on 30 years of teaching social aspects of forestry in the U.S., Europe and Africa, processes for teaching these topics will be explored.

Barriers to updating university forestry curricula. Innes, J. (*University of British Columbia, Canada; john.innes@ubc.ca*).

One of the major challenges facing the inclusion of adequate amounts of social science in a forestry degree is the accreditation requirements of professional forestry associations. These often pay lip service to the social sciences, but fail to fully integrate social sciences in the curriculum. For example, the requirement to demonstrate writing skills is often met through the provision of a single course, rather than ensuring that writing is included at all stages of a program. Forestry programs also face a considerable number of other barriers to the inclusion of social sciences. Amongst these is a preference from existing faculty to ensure that the natural sciences are adequately covered. Another problem relates to recruitment of social scientists into a forestry faculty. Such individuals may end up being isolated from others in their discipline, and thus may have difficulty attracting collaborators and even in obtaining research grants. The different approaches to publishing may also be a barrier: foresters in the natural sciences publish mainly through research papers, whereas the primary outlet for social scientists may be books. Resolving these difficulties requires a change in approach that is only just appearing in some forestry faculties.

Promoting gender competence of forestry students – experiences from GenCom international spring school. Karmann, M. (*Forest Stewardship Council – FSC International, Germany; m.karmann@fsc.org*), Dr. Lewark, E. (*University of Freiburg, Germany; siegfried.lewark@fobawi.uni-freiburg.de*).

There is a special need for gender competence in natural resources management, in particular, when land use questions or inheritance patterns are touched. This need for gender issues in curricula like forest sciences and environmental governance has been addressed in a learner oriented international spring school of two weeks in 2011 and 2012 at the University of Natural Resources and Life Sciences, Vienna (BOKU), and at Warsaw University of Life Sciences, with coordination from University of Freiburg, students from these three universities as well as from Swedish University of Agricultural Sciences. Following earlier gender courses with a different format, this course was based in parts on experiences from the IUFRO research group Gender and Forestry and the Team of Specialists on Gender and Forestry, which concluded that the current situation of gender equality and gender balance in the sector is reflected by the gender situation in the institutions providing education, research and extension. The spring school has been supported as a MOODLE e-learning course, set up at BOKU. It has been organized as an Erasmus Intensive Programme through an EU grant. Results of students' evaluations included: general satisfaction with the courses; much gender theory wanted; majority of participants were female; mastering of English language was already excellent before the course; workload was generally considered adequate; the spring school has been recommended to other students.

Facilitating social learning to improve collaboration between forest managers, stakeholders and communities. Kocher, S., Rodrigues, K., Ingram, K., Lombardo, A. (*University of California Cooperative Extension, USA; sdkocher@ucanr.edu*; *karodrigues@ucanr.edu; kcingram@ucanr.edu; amlombardo@ucanr.edu*).

To be successful, foresters, land managers, and scientists must learn how to work with stakeholders and communities. Ideally they possess skills that facilitate dialog, promote mutual learning, and foster collaboration on forest management goals and methods. In 2013, the University of California Cooperative Extension's (UCCE) hosted a series of facilitation workshops for forest managers and stakeholders to improve collaboration skills as part of the Sierra Nevada Adaptive Management Project (SNAMP)(http://snamp.cnr.berkeley.edu), a cross disciplinary study of forest fuels reduction treatments on national forests in the Sierra Nevada of California. UCCE conducts outreach to engage communities and stakeholders in SNAMP through interactive techniques, including science meetings with researchers, agencies and public; presentations to community groups; field trips; and management and facilitation workshops. Facilitation workshops use a 'train-the-trainer' model with curriculum on process constraints, framing collaborative projects, meeting logistics, group dynamics, understanding interactions, dealing with difficult behaviors and reducing conflict. Staff from federal and state forestry, fire, wildlife and research agencies, local conservation and non-profit organizations is attending and report that the training is timely and relevant to issues they face. Evaluation shows that SNAMP has fostered learning about forest science and management and has improved relationships between stakeholders, agencies and scientists.

Does counseling matter? An analysis of forest advisors' influence on forest management practices. Lidskog, R., Sjödin, D. (*Orebro University, Sweden; rolf.lidskog@oru.se; daniel.sjodin@oru.se*).

Forest advisors have a central role in the implementation of the Swedish forest policy and research has shown that forest owners have great confidence in forest counselors. At the same time, research has shown that forest owners' have an ambivalent attitude towards the advice they receive from forest counselors. Thus, there is a lack of knowledge of whether forest counseling matters or not, which is the point of departure for this paper, which investigates to what extend and in what ways forest counseling matters. Through an interview study of public, corporate and private forest counselors, the study analyzes forest advisers' activities and self-understanding. By applying Bourdieu's theory of practice, the field dynamic of the forestry sector and the social position of forest counselors are mapped. The study finds that the relationship between forest counselors and forest owners is a relationship between actors with different access to knowledge capital; theoretical knowledge; as well as practical, embodied knowledge. This finding explains why forest owners' may ask for and listen to forest counselors' advice, while not letting these advices guide their forest management practices.

A-36 From data to knowledge, geospatial tools and information access

Organizers: Carla Heister (Yale University, USA), Dave Vanderzanden (U.S. Forest Service), Gillian Petrokofsky (Oxford University, UK) & Kevin Megown (U.S. Forest Service)

Ground-truthing validation for a near real time deforestation monitoring system in the Ucayali Region, Peru. Coca Castro, A., Tello, J., Reymondin, L., Paz, P. (*International Center of Tropical Agriculture (CIAT), Colombia; a.coca@cgiar.org*; *J.J.TELLO@cgiar.org; terra.i.ciat@gmail.com; paulapaz1101@gmail.com*).

The Terra-i tool is a near real time monitoring system that has been detecting natural vegetation loss from 2004 to the current over the Latin-American and Caribbean region. With the aim to demonstrate the tool's consistency, a ground-truth validation is needed for better understanding the land cover and land-use changes that the tool is able to detect. The objective of this study was to classify land use and land cover types and to characterize changes, particularly deforestation patterns, between the detections of 2011 and 2012 from Terra-i system in the influenced areas from eight human settlements distributed along the Ucayali River and Federico Basadre highway in the Ucayali region, Peru. Around 60 field sample sites were validated and a large dataset of material were recorded including geo-referenced photos, surveys and landscape descriptions. The preliminary results showed contrasting dynamics according to the settlements type (near to river or road), being evident the presence of large scale activities such as oil palm and cacao plantations in the sites near to the highway. In addition, the ground data and preliminary analysis indicated a high consistency of the Terra-i tool to detect changes due to both human and natural causes.

Observatory for forests of Central Africa : the tool for local data collection and regional reporting. de Wasseige, C. (*Observatoire des Forêts d'Afrique Centrale, Democratic Republic of the Congo; cdewasseige@observatoire-comifac.net*), Nasi, R. (*Center for International Forestry Research, Indonesia; r.nasi@cgiar.org*), Mbitikon, R., Tadoum, M. (*COMIFAC, Cameroon; mbitikonraymond@yahoo.fr; tadoum@yahoo.fr*), MacDicken, K. (*FAO Forestry Department, Italy; Kenneth.MacDicken@fao.org*), Mayaux, P. (*Joint Research Center, Italy; philippe.mayaux@jrc.ec.europa.eu*), Hiol Hiol, F. (*Observatoire des Forêts d'Afrique Centrale, Cameroon; fhiol-hiol@observatoire-comifac.net*), Johnson, S. (*ITTO, Japan; johnson@itto.int*), Leticia, P. (*FAO, Italy; Leticia.Pina@fao.org*), Ahimin, O. (*ITTO, Gabon; ahiminolivier@yahoo.fr*), Steil, M. (*World Resources Institute, USA; MSteil@wri.org*).

In Central Africa, data availability about the state of the forests and the forest sector has always been a critical issue. Directly placed under the authority of COMIFAC (*Commission Ministérielle des Forêts d'Afrique Centrale*), the OFAC (*Observatoire des Forêts d'Afrique Centrale*) is a unique regional observatory to monitor forest resources (10 countries, 187bn ha of rain forests). OFAC annually collects, verifies, harmonizes data through a network of partners and disseminates information through a web-based information system, including a geospacial data repository (http://observatoire-comifac.net/index.php). These data are analyzed by experts to produce the "State of the Congo Basin Forests" reports. Subjects like, forest cover, biodiversity, forest economy, climate negotiations are regularly monitored. Others are occasionally treated in detail, e.g., ecosystem services, forest zoning, informal sector. OFAC already published reports in 2006, 2008 and 2010. The forthcoming 2013 edition, is authored by about 200 experts coming from governmental services, scientific institutions, NGOs and the private sector. The regular edition of this document acts as a landmark of the successful international partnership about tropical forestry in Central Africa. Recently, COMIFAC, FAO-FRA and ITTO signed an agreement to reduce the reporting burden and improve the consistency of national and regional reports.

Embed a librarian in your research group. Heister, C. (*Yale University, USA; carla.heister@yale.edu*).

Research groups would benefit from including a librarian/informationist within the group to be a go-to member for expertise in background research gathering, in development of data management plans, in database creation, in interdisciplinary approaches to research questions. Embedded librarianship can be project-based (defined time period) or programmatic (ongoing). Computerization of information/data resources has not simplified the research process but has added another layer of discovery options and complexities. Librarians have strong Internet discovery skills, organizational skills, and knowledge of research methodologies. Any forestry research project would profit from having an embedded librarian.

Forest atlas of the United States. Perry, C., Wilson, T. (*U.S. Forest Service, USA; charleshperry@fs.fed.us; ty_wilson@yahoo.com*).

The United States has a tremendous forest resource—more than 300 million hectares of native and planted forests managed by public and private landowners for forest products, wilderness, wildlife habitat, and other purposes. Over the past 150 years, basic surveys of United States forests have evolved into a rigorous national forest inventory (NFI) program that is used to share information about the status and trends of these forests. Recent advancements make it possible to create maps from NFI data and other spatial data, such as digital elevation models and satellite imagery. The Forest Atlas of the United States uses these maps to highlight the value of our Nation's forest in a novel manner. In the atlas, we explore these questions and many more: Where do forests grow? What else lives in forests? What shapes forests? What benefits do forests provide? What is in the future for our forests? This project represents a strategic partnership between several different parts of the USDA Forest Service, integrating NFI data with remote sensing and GIS applications. Here we review the content included in the atlas and highlight the use of maps, graphics, accessible text, and images to communicate forest ecosystem services with the public.

Bringing the science back into literature reviews of science. Petrokofsky, G. (*University of Oxford, United Kingdom; gillian.petrokofsky@zoo.ox.ac.uk*).

Forestry in the 21st Century faces two substantial challenges: the elevated rate of change in the wider social, economic and environmental context for forests and forestry; and. the changing expectations about the type and value of ecosysem services that forests should deliver. Science from forestry and boundary disciplines, such as agriculture and development, is called on to provide relevant and credible information to inform emerging policy and practice. This involves using existing research more effectively, in addition to developing new research. Arguably there will be even greater need to consolidate existing research evidence, which is growing exponentially, in the form of literature reviews. Typically, however, the lack of transparent method and reproducibility of traditional literature reviews renders them fundamentally unscientific. Systematic reviews, described as 'critical links in the great chain of evidence', aim to overcome problems inherent in single studies, randomly selected from a huge body of literature, by examining studies that have been selected and analysed according to strict, transparent protocols and methods that follow a recognised scientific approach. Case studies of ongoing systematic reviews illuciate how a scientific approach to literature reviews can add value to past knowledge and infrm future research programmes.

Western U.S. climate change GeoBrowser. Schrader-Patton, C. (*U.S. Forest Service, USA; cschrader@fs.fed.us*).

Climate change challenges us to focus on resilient ecosystems, ones that can continue to function in the face of unprecedented climate change—unprecedented both in the magnitude and speed of change. Resource managers are increasingly being asked to document how management activities affect and are affected by climate change. Future climate forecasts center around general circulation models (GCMs) that simulate the temperature and movement of air masses around the planet. Unfortunately, these models are inappropriate for use at regional scales. To address this issue, scientists have developed methods to downscale these GCMs. Downscaling generates regionally relevant data through statistical modification of the GCM or dynamically by using GCM-generated outputs as the inputs for a local regional climate model. A consortium of federal agencies provided funding to develop west-wide downscaled climate data for planning and impact studies at regional scales. The resulting effort from CIG produced thousands of 5-km resolution data layers using three different climate models. We developed the West-Wide Climate Change GeoBrowser to give users an accessible first look at this complex dataset and compare outputs from the three models. The GeoBrowser is intended to be complementary to a site called EcoShare, where all data are available for download.

Landscape Change Monitoring System to support all lands and owners for the continental United States, Hawaii and Alaska. Schwind, B., Megown, K., Quayle, B. (*U.S. Forest Service, USA; bschwind@fs.fed.us*; *kamegown@fs.fed.us; bquayle@fs.fed.us*).

The Landscape Change Monitoring System (LCMS) project will generate and/or provide access to an unprecedented source of geospatial data and summary information that describes the timing, location, extent, severity, and trajectories of landscape changes for the continental United States, Alaska and Hawaii. The project will leverage the nearly 40 year record of Landsat Thematic Mapper data archived by the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center. LCMS will provide a full geospatial data and information product suite for all mapped disturbances. Processed imagery, continuous and thematic disturbance data, disturbance boundary delineations, mapping/visualization products, and statistical summaries will be available through webbased applications.

Providing critical geospatial information through enterprise systems – a U.S.Forest Service experience. Vanderzanden, D., Megown, K. (*U.S. Forest Service, USA; dvanderzanden@fs.fed.us; kamegown@fs.fed.us*).

Reliance on enterprise information systems to support research programs as well as operational information requirements has become widespread across the science and resource management communities. Organizational policies and IT investment strategies have promoted the use of such systems as a primary means of discovering, accessing, and utilizing large volume information stores that are not efficiently or cost-effectively managed across multiple locations. More significantly, enterprise information systems can create opportunities for accessing and analyzing data that were previously difficult to assemble and not

practicably available to many users. The ability to quickly access histories of spatial data and exploit temporal sequences is but one compelling utility that is now more available to a broader audience. The U.S. Forest Service has implemented an enterprise approach to publishing imagery and other geospatial assets that has changed the capability of its workforce and established a new expectation for data availability and use. This paper examines the U.S. Forest Service experience in providing critical information assets through enterprise information systems and explores how this will continue to drive the availability of geospatial data and influence thinking about landscape analysis and characterization.

A forest lands information system in support of sustainable management and use of forests. Vogiatzis, M. (National Cadastre & Mapping Agency, Greece; *MVOGIATZ@KTIMATOLOGIO.GR*)**.**

In Greece, forests and forestlands managed by the Forest Service cover about 60% of the country but they have not yet been definitively mapped in a systematic and scientific way. Forests and forestlands boundary delineation and land status (forest/non-forest) is fundamental for an effective public lands administration, cadastre development, physical and spatial planning. This lack of forest spatial data, information and knowledge is caused by the absence of a comprehensive policy on land management over time. Efficient and effective forest and forestlands information infrastructure is required to serve protection and sustainable management of forests and forestlands and meet emerging challenges, such as climate change, biodiversity protection, urban expansion and catastrophic wildfires. In this paper, we introduce a holistic approach for an effective forests and forestlands management and monitoring through the development of authorized forest maps and a national forest lands information system based on Geographic Information Systems (GIS) and Information Communications Technology (ICT). The current initiatives, the required institutional and organizational arrangements and system design as well are discussed. The system will enable access and dissemination of reliable and up-to-date forest data and information both to public and government, in support of sound decision making and sustainable development.

A-37 Knowledge exchange and communication of forest research for human and community well-being

Organizers: Cynthia Miner (U.S. Forest Service), Jurij Begus (Slovenia Forest Service), Guy Smith (NRCan- Canadian Wood Fibre Centre) & Alejandra Real (National Forestry Corporation, Chile)

A systematic, evidence-based review of key issues facing Oregon family forest owners. Creighton, J., Johnson, J., Carlson, D. (*Oregon State University, United States; Janean.Creighton@oregonstate.edu; jim.johnson@oregonstate.edu; Deanne.Carlson@oregonstate.edu*).

This investigation examines contemporary literature describing attributes of Oregon family forest owners with the objective of identifying potential educational interests of these owners, and evidence of their prior knowledge, interest, and concerns about topics at the intersection of small woodland owner interests and the interests of society: Intergenerational Transfer; Invasive Species; Climate Change; Riparian Management; and Management Plans. We used systematic evidence review as an analytical framework and content analysis as a methodology for data extraction to evaluate disparate sources of information to objectively inform a uniform construct representative of Oregon family forest owners. We identified 18 literature sources based on studies conducted between 2000 and present. Analysis of the literature for manifest expressions suggested varying degrees of landowner interest over the five program topics. However, a substantial amount of the extracted information came from un-interpreted findings that are poorly generalizable, both internally and externally. Although the landowner expressions extracted from the literature form a solid basis for directing further inquiry, interest alone is unlikely to adequately inform the development of theory-based educational programs. We suggest that future assessments of the educational needs of family forest owners be built on specific educational frameworks that would allow for more generalizable findings.

Assessment of the impact of Forestry Research Institute of Nigeria activities on neighboring communities. Julius, A., Onilude, Q., Akinyemi, O., Olayiwola, I., Oniroko, N., Eyinfunjowu, L., Solanke, I. (*Forestry Research Institute of Nigeria, Nigeria; talktobayo247@yahoo.com; omoonilu@yahoo.com; akinyemi77@yahoo.com; funbola2003@yahoo.com; chopperflows@yahoo.com; tessysplace1@gmail.com; solancy1983@hotmail.com*).

The main objective of this study was to assess the impact of Forestry Research Institute of Nigeria (FRIN) activities on the surrounding communities in the past 20 years. The assessment was carried out in 6 research outstations of FRIN and the 4 colleges of forestry spread across the 6 geopolitical zones of the Country. Two sets of structured questionnaire were designed to collect information on the impacts of colleges of Forestry and research Outstations on their neighboring communities. For each outstation and college, 4 communities were sampled, and 25 household heads in each community were interviewed. A total of 1000 questionnaires were distributed within the 6 geopolitical zones of Nigeria for the study. Results showed that FRIN activities in the sampled communities has translated to sustainable growth and development in the areas of environmental protection, forest conservation and management, education and training, plantation establishment, employment opportunities and a better healthcare delivery through forest products. It is suggested that research funding should be a government priority, and that support from international communities will go along way in further strengthening FRIN to deliver her research mandates at local, national and international levels.

Communication gaps regarding biodiversity in the mass media: experience from the Convention on Biological Diversity COP10 meeting and beyond. Kohsaka, R., Kohsaka, R. (*Kanazawa University, Japan; kohsaka@hotmail.com*; *tomiyoshi@staff.kanazawa-u.ac.jp*).

Communicating the importance of biodiversity and ecosystem services of forests is critical for policy makers and scientists. To date, scientists and policy makers have aimed to demonstrate the value of biodiversity in various channels, such as science-policy

report (CBD's Global Biodiversity Outlook), economic evaluations (e.g., The Economics of Ecosystems and Biodiversity (TEEB) initiative), designation of sites (protected areas, MAB reserves) or general education activities. Yet scientists, practitioners, policy makers are struggling with the challenge to communicate and demonstrate the value of biodiversity. The 10th CBD Conference of the Parties meeting (COP 10) held in Japan provides us with unique opportunity to explore the media strategies of various stakeholders and the discourses in mass media. The COP10 is a benchmarking conference for the process because the Parties agreed on Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) and post-2010 Target. We analyze the gap of newspaper articles between pre-COP10 and COP10 conference period. The issues relevant to ABS was largely absent in pre-COP10 but emerged as major news during the COP10, analyzing the trends and internal politics of media through detailed interviews.

Social mapping for the determination of environmental dynamics in rural contexts: the case of the Rio Grande basin, Department of Antioquia, Colombia. Lopez Gomez, C., Botero Fernandez, V., Ortega Molina, L. (*Universidad Nacional de Colombia, Colombia; cplopezg@unal.edu.co; vbotero@unal.edu.co; lfortega@unal.edu.co*)**.**

This work defines the dynamics of environmental change in the basin to the Rio Grande-Antioquia-Colombia, through the development of social baseline mapping. It was hypothesized that the development of social mapping produced by a community of its territory, allows us to reconstruct the process of change for the territory, generating a valid cartographic document, facilitating relationships between the community and public bodies for environmental management and local governance processes, and fill the information gap in rural settings which limits decisions on these. The study showed that the loss of the areas's native forests began over 30 years ago and that by 2012, the area's vegetation became dominated by grasses. However this transition from forest to pasture not apparent from available official data sources, but could be reconstructed by developing baseline social mapping. The work shows that where only limited information available for understanding dynamic environmental change, a larger more detailed picture can reconstructed by utilizing local knowledge, thereby increasing the level of knowledge of the territory, and possibilities for governance and decision making.

Forest as a place for health, recreation and learning – case studies. Marusakova, L., Sarvas, M. (*National Forest Centre, Slovakia; marusakova@nlcsk.org; sarvas@nlcsk.org*).

In this paper we discuss the variety of social benefits connected with forests and forestry. In central Europe countries, forestry is considered mostly in contex of productive aspects, but the general public is not aware of other benefits, like tourism, recreation, education, and rural development. The problem seems to be connected with the interruption of the contact and relationship among human being and nature and insufficient communication by those in the forestry sector with society. The study is focused on best practises examples of programmes dealing with forest related environmental education, woodland learning, ecotourism and forestry communications projects across the Slovak republic and neighbouring countries. The programmes highlight increasing knowledge about forests together with physical activities in woodland and strengthening personal responsibility for natural resources conservation. Public participation and involvement in programmes results in better understanding and perception of forest sector as well as benefits to society in spending more time outdoor in healthy environment.

Predicting wildland-urban interface homeowners' perceptions of risk and willingness to conduct defensible space activities. Olsen, C. (*Oregon State University, USA; christine.olsen@oregonstate.edu*), Kline, J., Ager, A. (*U.S. Forest Service, USA; jkline@fs.fed.us; aager@fs.fed.us*).

Two factors that influence forest policy in dry-land forests are: (1) the increased size and number of wildfires over the last decade; and (2) expansion of the wildland-urban interface (WUI) owing to amenity migration and growing suburban populations. These factors result in more human lives, properties and values at risk of fire. Notably, WUI homeowners can reduce fire hazard on their own land, by using non-flammable construction materials, pruning branches, or reducing trees. Commonly known as defensible space activities, these actions are believed to greatly improve the survivability of a home during a fire. However, many homeowners still do not act. In this study we examine factors that influence WUI homeowners' willingness to conduct these activities. We report on findings from a 2012 mail survey in central Oregon (USA) that asked WUI homeowners about their defensible space activities. In our study, we evaluated factors that are correlated with homeowners' self-reported mitigation measures, including objective and perceived wildfire experience and risk, as well as other social and spatial variables. Results help us understand what influences homeowners' willingness to conduct mitigation activities so that resources and policies can be aimed at those influencing factors, with the goal of getting more homes and lives protected.

Differences in biodiversity assessment strategies between experts and novices in ecology in logged forests. Pihel, J., Ode Sang, Å. (*Swedish University of Agricultural Sciences, Sweden; johan.pihel@slu.se; asa.sang@slu.se*), Nyström, M. (*Lund University, Sweden; marcus.nystrom@humlab.lu.se*), Hagerhall, C. (*Swedish Agricultural University, Sweden; caroline.hagerhall@slu.se*).

The study investigates the impact of expert knowledge on strategies when assessing biodiversity in photographs of recently cut forests. 13 experts and 17 novices viewed photographs on screen and were asked to place a square over the area that contained most species. After all images had been presented, the participants reported what strategies that they used. The strategies used as reported by the participants were coded into a common set of content based categories. These included categories also identified from previous research such as dead wood and standing trees. All squares for the each participant were screened for any of the content based categories which meant that a square could contain several categories. The present study discusses the implications of having expert design for biodiversity, and that the novices might not acknowledge the same areas as important. In connection to Fry et al. (2009) the aspect of different groups having varying strength in the connections between visual indicators and management of the site is something planners and managers of forests need to deal with if the goal is a truly multifunctional forestry.

Capacity building – training for forestry sector to support better cooperation with local population: Guyana case study. Poljanec, A. (*University of Ljubljana, Slovenia; ales.poljanec@bf.uni-lj.si*), Benn, S., Mohase, A. (*Guyana Forestry Commission, Guyana; 1simonebenn@gmail.com*; *a_mohase@yahoo.com*), Beguš, J. (*Slovenia Forest Service, Slovenia; jurij.begus@zgs.gov.si*).

In relation between forestry professionals and forest dependent communities, ways of participation and extension have the most important role. To improve such skills and knowledge, we designed the project "Capacity building – training for forestry sector to support better cooperation with local population", where the most important goal was to create trained group of selected forestry stuff in Guyana. In the first phase of the project the situation analysis were performed including stakeholder analysis, analysis of extension and participatory needs. The role of different stakeholders was analyzed using guided interviews, while the relations between stakeholders were analyzed using Vann diagram. The extension needs were analyzed using Delphi approach where in the first step writestorming was used to identify extension needs and in the second step extension needs were grouped and voting was performed to identify extension priorities. The participation needs were analyzed using H-form, guided interviews and expert estimations. In the second phase the initial curriculum of extension skills and participatory methods was modified according the situation analysis and the training for selected Guyana Forestry Commission and Forestry Training Centre staff was performed. In the paper content of the project, experiences and problems in organizing and implementation are discussed and evaluated.

Science in forest policy program and political discussion: the example of Bangladeshi forest policy program and print media discourse. Sadath, M. (*Khulna University, Bangladesh & University of Göttingen, Germany; mnsadath@yahoo.com*).

Forest issues are very important in Bangladesh and are widely discussed in the print media. The print media play an important role in the construction of the social, environmental and economic context of the Bangladeshi forest sector where forest policies are formulated and modified. As forest issues are mostly science driven problem, the information provided by the forest science in the media has greater importance in influencing public opinion and hence to policy directives. This paper explores the scientific communication in forest media discourses in the Bangladeshi print media as well as the presence of scientific research findings in Bangladeshi forest policy programs over last 12 years. It analyses the media discourse in the "The Daily Ittefaq", a reputed Bangladeshi print medium and Bangladeshi forest policy documents from 2001 to 2012. A quantitative, qualitative content analysis, followed by interviews of policy decision makers and scientists was chosen as methodology. The empirical findings reveal low presence of scientific communication in the print media, where only 17% of speaking actors are scientists. This study also reveals limited presence of scientific research findings in forest policy decision making process, where only 29% of examined policy decisions were driven by scientific research findings.

Exploring the science-stakeholder interface in climate change adaptation research within Swedish forestry. Swartling, Å.G. (*Stockholm Environment Institute & Stockholm Resilience Centre, Sweden; asa.swartling@sei-international.org*), Jönsson, A. (*Lund University, Sweden; anna_maria.jonsson@nateko.lu.se*).

Stakeholder engagement has gained increasing importance in research programmes over the past few years. Several scientific arguments for involving stakeholders in the research process have been put forward in the recent literature, including the value of providing a reality check and identifying social relevant research questions. However the communication between researchers and stakeholders in the sustainability science sphere is often impaired by linguistic barriers, different priorities and time constraints. We have studied the organizational aspects of the science-stakeholder interface in climate change adaptation research in the context of Swedish forestry. Our study indicated some difficulties in conducting fruitful science-practice dialogues on research on climate change impacts in the forestry domain. Researchers focusing on a multitude of ecosystem services and uncertainties associated with future projections may experience a conflict between producing general recommendations and providing support to a planning process carried out external to the research process, with negotiations among stakeholders on common goals and shared responsibilities. We conclude that researchers should take responsibility for this issue by reflecting upon which stakeholders are invited to the dialogue and whose perspectives are included in the research process.

Posters

Forest models dissemination and knowledge transfer on cork oak based ecosystems: bridging the gap between research and practice. Amaral Paulo, J., Faias, S., Palma, J., Tomé, M. (*Technical University of Lisbon, Portugal; joanaap@isa.utl.pt; soniapf@isa.utl.pt; joaopalma@isa.ulisboa.pt*; *magatome@isa.utl.pt*).

The objective of this work was to define a new strategy for the dissemination of the improved version of the SUBER growth and yield model released in the end of 2011. This strategy was supported in 3 pillars: on the Web; at the university; in the forest. The SUBER model is now included in the sIMfLOR platform, a user-friendly interface available for free download in the FcTools web-site (www.isa.utl.pt/cef/forchange/fctools). This site was specifically developed for the purpose of forest models dissemination, knowledge transfer from the research group and user's feedback collection. Other tools are also available, such as a cork growth simulator. At the university, technical education courses are being organized regarding the best use of existing forest models tools by private and public forest managers. Seminars for the presentation of research and project results are periodically organized including multidisciplinary programs. These events are made outside the university, in collaboration to forest owners associations and other organizations, with practical field trips 'in the forest' if needed. Inquiries made to participants and on the web site reveal an increase interest in the existing forest management tools and research results.

The Community Biomass Handbook and computer app. Becker, D. (*University of Minnesota, USA; drbecker@umn.edu*), Lowell, E. (*U.S. Forest Service, USA; elowell@fs.fed.us*), Bihn, D. (*Bihn Systems, USA; dan@danbihn.com*), Anderson, R. (*The Beck Group, USA; Roya@beckgroupconsulting.com*), Taff, S. (*University of Minnesota, USA; sjtaff@umn.edu*).

The Community Biomass Handbook is a multimedia electronic library to help community partners rapidly explore and initially evaluate a variety of thermal energy options without having to invest significant time, resources, or pursue costly feasibility studies. The Handbook showcases successful projects from around the country using text, photos, video interviews, diagrams,

and – most importantly – an interactive financial computer app. The Handbook connects forest planning with value chain and pre-feasibilitiy analysis in an interactive PDF, ebook, and conventional webpage format.

"Forest Culture" network in Austria: a new approach to put international agreements into practice for the benefit of local people. Johann, E. (*IUFRO Research Group 9.03, Austria; elisabet.johann@aon.at*).

Austrian's forests are the most characteristic element of the cultural landscape and render a number of extremely important economic, ecological and social services. Due to the long history of utilization the sustainable management of forests bas been an objective of forest policy for generations. People depended heavily on the products of the forest both in their personal lives and in the general economy. A high amount of traces of this traditional forest utilisation practises are still visible in the landscape and give evidence of forest management as well as of industrial growth. However, migration and socioeconomic development have deeply changed the relationship between society and forest resources, interrupting the transmission of traditional forest related knowledge between generations and reducing their role in representing the cultural identity of specific regions. The study intends to reveal the Austrian attempts to put international and European agreements such as *Forest Europe* and the *Unesco Convention on Immaterial Cultural Heritage* into action for the benefit of the local people. It addresses the establishment of the network Forest Culture in Austria, its targets and visions and introduces its stakeholders. The paper also puts attention on the efforts to raise awareness to this topic by specific educational programs.

Participatory approach potentials in adoption of agronomic, land and water management technologies in semi-arid areas of Tanzania. Kagosi, P. (*Tanzania Forestry Research Institute (TAFORI), Tanzania; pjkagosi@yahoo.com*).

The study was conducted to asses the potentials of participatory approach (PA) in enhancing adoption of improved technologies. The literature provides much general information on Participatory Approach (PA) in Tanzania, but there is insufficient scholarly work available on the contribution of PA in adoption of improved technologies. Specifically, this study determined technologies adoption rates in the study areas using a cross-sectional research design. Methodologies used for data collection includes focus group discussions, questionnaires survey, key informant Interviews and participant observation. Questionnaire data were collected from 240 randomly selected households. Data were analysed using the Statistical Package for Social Sciences and content analysis. The results show that PA improved knowledge and skills of beneficiaries as most of respondents from Participatory Irrigation Development Programme (PIDP) schemes (61.3%) adopted improved technologies than respondents in Non-PIDP schemes (25%). The results further revealed that farmers using PA adopted more improved agronomic technologies as 63.7% of respondents in PIDP adopted improved maize varieties vs 22.5% of non-PIDP respondents. Furthermore, 61.2% of respondents in PIDP schemes planted trees vs 24.4% in non-PIDP schemes. It was concluded that PA encourage a large proportion of farmers to adopt improved technologies as farmer's ideas have been incorporated.

Pedagogy of Place Institute. Kruger, L. (*U.S.Forest Service, USA; lindalaska2003@gmail.com*), Standley, M. (*University of Alaska Southeast, USA; mark.standley@uas.alaska.edu*).

Educators at the University of Alaska Southeast and an array of partners designed and implemented a three-day professional K-12 development program based on incorporating scientific, cultural and local knowledge in place-based learning. During the four day experiential event held July 17–19. 2013, Alaska teachers explored Southeast Alaska's Coastal Temperate Rainforest, including visiting an estuary, a beach and tidal area, a lake, a river, and a retreating glacier. The institute integrated the threads of STREAM – Science, Technology, Reading, Engineering, Art and Math and incorporated local Tlingit culture bearers as speakers and field trip co-leaders. Eighty teachers participated in technology and cultural workshops each morning and spent their afternoons applying what they learned to help them learn about a different field setting each day. The desired outcome is for teachers to transform insights, ideas and field experiences incorporating relevant STREAM curriculum and cultural knowledge into classroom activities. Discussions included Native uses of plants, animals and land, local effects of climate change, and different ways to experience, study and document the world we live in. For more information see: http://www.uas.alaska.edu/education/pec/stream/index.html.

Managing knowledge in a research organisation: the case of Kenya Forestry Research Institute. Mbiru, S. (*Kenya Forestry Research Institute, Kenya; sheilambiru@gmail.com*).

In today's global economy, knowledge is a strategic asset that gives organizations a competitive edge. This is especially true for research organizations where new knowledge must be generated, shared, applied and managed for maximum impact. Kenya Forestry Research Institute (KEFRI) creates knowledge by developing technologies that are making significant contributions to forestry development in Kenya. Although KEFRI manages its knowledge to some degree, there is no systematic, coordinated and integrated approach to drive the process. Thus, management of KEFRIs knowledge products and services is required to achieve wider dissemination to stakeholders and decision makers. To successfully implement knowledge management (KM) activities it is essential to have a knowledge management strategy (KMS) that is aligned with the organization's overall strategy. In recognition of the importance of managing knowledge, KEFRI is developing a KMS. This process requires a knowledge audit (KA), to review existing knowledge assets, flows and gaps. A survey design using probability and non-probability sampling techniques was used to select 11 research management team members, 333 employees and 222 stakeholders and a semi-structured questionnaire administered. Based on the findings of the knowledge audit, a knowledge management strategy will be developed to guide implementation and institutionalization of knowledge management in KEFRI.

Uneven-aged management in a mixed-conifer forest in northeast Oregon: a case study with an innovative educational approach. Oester, P., Fitzgerald, S., Parker, B., Hino, J. (*Oregon State University, USA; paul.t.oester@oregonstate.edu; stephen.fitzgerald@oregonstate.edu*; *bob.parker@oregonstate.edu; jeff.hino@oregonstate.edu*).

Little is known about the application of uneven-aged management methods, like Individual Tree Selection (ITS) for managing mixed-conifer forests in the northwest. Many family forestland owners and state and federal managers are interested in ITS

because it provides a continuous forest canopy, reduces reforestation costs, it's aesthetically pleasing and avoids clearcutting. However, there are many questions we don't know the answers to. The primary goals of this comprehensive educational program are to: 1) learn more about and document the "how to's" for implementing ITS in a typical mixed-conifer forest and how the stand, including regeneration, responds to periodic harvest entries; and 2) communicate what we learn through typical delivery systems such as tours and workshops, as well as a traditional PDF coupled with a separate interactive, online multimedia app. In 2005 we implemented an ITS case study, including establishing permanent plots in a 50-acre dry mixed-conifer forest on the Oberteuffer Research and Education Forest near Elgin, Oregon, which is a satellite research forest of Oregon State University. We will provide an overview of this project including lessons learned to date in the case study and an example of the twofold educational materials, a PDF and interactive, online multimedia app.

Pest scene investigators: a citizen science-based effort to improve forest health in Oregon. Oester, P., Shaw, D., Strong, N. (*Oregon State University, USA; paul.t.oester@oregonstate.edu; dave.shaw@oregonstate.edu; nicole.strong@oregonstate.edu*).

Forest health is one of the most challenging issues facing woodland owners in Oregon. Surveys consistently show that forest owners and managers' rate forest health issues as high priority. Evidence continues to mount that climate change will likely elevate pest risk and mortality. The Oregon State University Forestry and Natural Resources Extension Program recently embarked on an educational strategy for addressing these issues. The Pest Scene Investigator (PSI) program has three guiding objectives: 1) Promote mitigation practices that reduce risk of forest decline or catastrophic fire due to insect, disease and invasive species. Actions include development of a PSI training curriculum, volunteer coordination, annual trainings, and a management guide; 2) Demonstrate cost-effective and innovative methods and technologies for use in forest health mitigation; and 3) Provide a platform for on-going education and awareness for current PSI's as well as other landowners and technicians through email updates, website and an online OSI forum (Moodle). Our presentation will highlight these outreach products and share the results of an impact evaluation recently completed.

IUFRO and Global Forest Decimal Classification – status and future. Saarikko, J. (*Finnish Forest Research Institute, Finland; jarmo.saarikko@metla.fi*), Holder, B. (*FP Innovations, Canada; barbara.holder@fpinnovations.ca*).

The Global Forest Decimal Classification, an update of the earlier Forest Decimal Classification, was published in printed form in 2006 in IUFRO World Series nr. 19. It was prepared by an editorial team of experts from IUFRO WG 6.03.03. This paper will study the current implementation and usage of the classification. The paper will also discuss the future needs of editorial work, updates and maintenance as well as propose new means of online delivery and linkages to other related subject specific classifications and thesauri. Online availability of the classification would make its access easier and help in creating subject specific metadata and search interfaces to forest related online resources. The classification would continue to be an official subdivision of class 630 of the Universal Decimal Classification (UDC).

A role for research in supporting small-scale emerging tree growers in South Africa. Upfold, S. (*Institute for Commercial Forestry Research (ICFR), South Africa; sally.upfold@icfr.ukzn.ac.za*), Dlamini, N. (*Forestry South Africa, South Africa; norman@forestrysouthafrica.co.za*).

The South African Forest Industry contributes significantly to the country's economy. Tree growing is a rurally based activity, creating over 92 700 direct and indirect jobs. Historically, plantation forestry was dominated by large corporate firms and private commercial tree farmers. More recently, tree farming has become attractive to small scale emerging growers, driven by changing land ownership patterns, development of timber markets, and government support for small, micro and medium enterprises (SMMEs). To operate as sustainable, productive tree farmers, SMMEs require support in capacity building, skills development and access to technical knowledge. The role of forestry research in this process is twofold. Firstly, to exploit existing knowledge to develop useful, practical information, and provide training and support in using this knowledge. This includes all aspects of sustainable tree growing from planting through to harvesting and transport, as well as timber and non-timber products/processing, managing risk, and the business enterprise of tree growing. Research also needs to investigate and address gaps in our knowledge of appropriate technologies for these stakeholders. Currently there are a number of initiatives aimed at supporting and uplifting small growers, including field-based community projects, toolkits and technology transfer material. This paper explores these projects, highlighting the strengths and successes of each, as well as investigating proposed synergies and identifying knowledge gaps where new research is required.

Forest culture in the neotropics: What is it? Why is it needed? Villalobos, R., Sasseville, E. (*CATIE, Costa Rica; rvillalo@catie.ac.cr; emiliesasseville@gmail.com*), Duran, L. (*Cachapoal Model Forest, Chile; leonardo.duran@bmcachapoal.cl*), Carrera, F. (*CATIE, Costa Rica; fcarrera@catie.ac.cr*).

The tropical areas facing the most intense and constant deforestation in the last decades are located in Latin America, where forest land has been predominantly seen as useless, since it does not provide a significant contribution to the national, local or family economies, and economic development is clearly linked to the change of land uses for agriculture and livestock. In 2012 and 2013, GIZ, CATIE and the Ibero-American Model Forest Network (RIABM) have organized four events to analyze strategies to build and strengthen forest culture in Latin America. Three international workshops were held: in El Petén, Guatemala; in Tarapoto, Peru; and in Oaxaca, Mexico. There was also a study tour to Bavaria, Germany. Local leaders, technicians and officials directly involved into successful participatory forest development processes attended these events. Key issues to build forest culture and help mitigating deforestation were identified, such as education and evidence about the value local forest goods and services; markets for these goods and services; clarity in forest land tenure and governance; capacity building and technical advice for forest management; product processing and local trade by families and communities; and participation of national institutions as partners and guides of these processes, not as controllers.

A-38 How to make forest science available for all? Publishers', editors', and authors' challenges

Organizers: Pekka Nygren (Finnish Society of Forest Science) & Eeva Korpilahti (Finnish Forest Research Institute, Finland)

What future for research journals in forest and wood sciences? Dreyer, E. (*National Institute for Agricultural Research,* France (*Inra), France; dreyer@nancy.inra.fr*).

Science editing is changing very quickly with the emergence of new editorial procedures, new and often open-access journals. This is true also in the fields of forestry and forest and wood sciences, and the editor of "traditional" journals in this area feel very concerned by these changes. For instance, a recent survey showed that the journals from the ISI subject category "Forestry" published only about 20% of the papers dealing with forests and wood during the period 2002–2011. This shows the vitality of the research in this area, but also leads to the question of the specific aims and contribution of journals devoted to forests, which in general have a smaller impact factor than those in other subject areas like plant biology or ecology. A network of forest and wood sciences editors recently met to discuss this issue and came up with several suggestions about the actual contribution of our journals as well as some directions for evolution of their editorial policy. The presentation will convey some thoughts about potential changes in our editorial policy, and will be co-authored by editors from several forestry and forest and wood sciences journals.

Development of boundary organizations to span barriers between fire science and fire managers in the United States. Kocher, S. (*University of California Cooperative Extension, USA; sdkocher@ucanr.edu*), Wright, V. (*U.S. Forest Service, USA; vwright@fs.fed.us*), Toman, E. (*Ohio State University, USA; toman.10@osu.edu*), Trainor, S. (*University of Alaska, Fairbanks, United States; sarah.trainor@alaska.edu*).

Use of forest science, though critical for sound management of public and private forests, is often constrained by logistical, political, and social factors. Obstacles include communication barriers and differences in "culture" between scientists and managers. Managers may not be aware of relevant science or have tools to evaluate its quality and applicability. There may be too much information for managers to digest, interpret, and apply. In 2009, the U.S. Joint Fire Science Program developed a boundary organization to accelerate awareness, understanding, and use of wildland fire science by managers. The success of boundary organizations hinges on being scientifically credible and legitimate, and understanding the decision context and science user perspective, developing strong relationships, and providing information at relevant spatial and temporal scales. Needs assessment findings showed that though use of and regard for Internet-based fire science information is universally high, in-person knowledge exchange is preferred. Obstacles to fire science application include lack of time, resources, and access to the most relevant information as well as communication barriers between scientists and managers. These results suggest boundary spanning efforts need to organize and consolidate science through easily accessible websites and host in-person events that strengthen relationships between scientists and managers.

Progress in knowledge dissemination: combining fundamental and applied research journals. Moser, W. (*U.S. Forest Service, USA; moserk@safnet.org*), Walls, M. (*Society of American Foresters, USA; WallsM@safnet.org*).

Traditionally, fundamental and applied forest science research results have been disseminated via different pathways. The assumption has been that both authors and readers self-segregate into more theoretical or more-applied camps and are not interested in journals that seek to integrate these two themes. *Forest Science*, the scientific journal of the Society of American Foresters, recently merged with the three applied research journals of the Society: the *Southern Journal of Applied Forestry*, the *Western Journal of Applied Forestry*, and the *Northern Journal of Applied Forestry*. It is our view that both types of articles are issue-focused and could conceivably emanate from the same research. An important factor is to preserve the identity of each type of information stream while encouraging both readers and authors to think across the basic research-applied research divide. This presentation will discuss the genesis of this merger, the implementation, and early responses after almost a year of combined effort.

From paper to bits – how to make and keep 100 years of forest science available online? Nygren, P. (*Finnish Society of Forest Science, Finland; pekka.nygren@metla.fi*), Korpilahti, E. (*Finnish Forest Research Institute, Finland; eeva.korpilahti@metla.fi*).

Libraries around the world have provided a secure, distributed archive of printed literature for centuries. When science publishing goes on-line only mode, publishers must take also the libraries' archive keeping role. Melbourne Code on publishing new plant species gives a good advice for all scientific e-publishers on distributed archive: it requires that electronic species descriptions are deposited in several digital repositories in different geographic regions, preferably in different continents. Further, old valuable print-only literature may be forgotten because of the perceived "difficulty" – real or not – of searching library collections. Publishers need to take several actions for keeping science available for all users: i) digitise old print-only collections; ii) make them available on-line; iii) build a network of safe e-repositories with libraries; iv) keep both hardware and publishing formats of the archives up-to-date; and v) create a unified indexing system for searching old archives and new literature. Finnish Society of Forest Science has responded to these challenges by digitising all its forest science publications since 1913 and making them available on-line. Indexing and distributed archiving system are under work. In this contribution, we discuss our experiences within the wider context of changing science publishing environment.

Bringing forest science to the end-user: three key challenges. Stelzer, H. (*University of Missouri, USA; stelzerh@missouri.edu*), Sagor, E. (*University of Minnesota Extension, USA; esagor@umn.edu*), Smallidge, P. (*Cornell University Extension, United States; pjs23@cornell.edu*).

Foresters face three key challenges in delivering forest science to the end-user; be that a forest landowner, logger, or governmental official. Socrates identified three key facets of effective communication: the sender, the message, and the receiver. As the sender, the forester must be an effective manager, facilitator if you please, of all the information that is available to the end-user. He or she must separate science-based information from anecdotal experiences that become 'fact' by their mere presence on the Internet. The second challenge lies in delivering the message. Today's end-user is accustomed to receiving instant gratification and the 'easy' answer. Complex topics, such as climate change or bioenergy, are often relegated to 1,000 printed words or less, or 60-minute webinars. So, the forester must be able to package the message as succinctly and efficiently as possible. The last challenge facing the forester bringing science to the end-user is delivering the message to 'Boomers' and 'Millennials' alike. Today's audiences are a mix of at least three generations; each with their own preference for receiving information and equally important, how they process that information. All three challenges will be addressed in the presentation.

Implications of changing publication formats for public accessibility of developing country forest and agroforestry science. van Noordwijk, M., Hairiah, K. (*World Agroforestry Centre (ICRAF), Indonesia; m.vannoordwijk@cgiar.org; K.Hairiah@cgiar.org*), Namirembe, S. (*ICRAF, Kenya; S.Namirembe@cgiar.org*), Hairu, B. (*ICRAF, Indonesia; L.Beria@cgiar.org*), Tata, M. (*Forest Research and Development Agency, Indonesia; hl.tata@gmail.com*).

Progress in science, as measured in the number of peer-reviewed publications, is unevenly distributed over the nations, with the number of forest-related publications negatively correlated in space and time with forest cover in the first phases of national forest transitions. For scientists who are actively engaged in interdisciplinary action-oriented work, the threshold to meet the academic standards of disciplinary journals remains high, while the readership of these journals and publication media is restricted among the target groups in the countries of primary concern. Open access journals and a more direct link of popular and policy-oriented write-ups to scientific journals has increased accessibility to the intended readership, but the change from "reader pay" to "author pay" puts additional financial burdens on developing country scientists. The emergence of lower cost journals of more dubious reputation with low thresholds due to peer review indicates a shift towards "reader select" over "editor select" modes of publication which further increases accessibility, but adds to confusion on what credible, salient and legitimate science contributes to public debates.

Increasing access to forest science research while improving research impact: a perspective from *Tree Physiology*. Way, D. (*University of Western Ontario, Canada; dway4@uwo.ca*).

Making forest science accessible to researchers around the world and also to non-scientists requires moving beyond the traditional monthly paper editions of a journal and thinking outside of the research paper. The journal *Tree Physiology* has recently undertaken two initiatives to: 1) increase the impact of outstanding research publications; 2) make key research accessible to non-scientists and to scientists who do not have paid access to the journal; 3) reach out to the next generation of tree researchers. These include a monthly commentary section to highlight novel or particularly synthetic research papers and a Facebook page to publicize new papers and free content. As the editor responsible for running these initiatives, I will discuss both the successes and difficulties of using these approaches in publishing forest science.

Search engine optimisation – should we edit or not? Wennström, K. (*Taylor & Francis, Sweden; sofie.wennstrom@tandf.se*).

The scientific journal of today is almost entirely turned into a digital entity. Print subscription orders are constantly decreasing and the online usage of articles in full text increases exponentially. The modern search engines indexes more data than before, in Scandinavian Journal of Forest Research the entire abstract text is for example indexed in Google searches, to ensure the widest dissemination of the data presented. This gives a new dimension to the term selective editing, where there is potential for authors and editors to further ensure that their research is being picked up and read to a greater extent. It also creates a dilemma for Editors worldwide – how much should we interfere with the content of each paper? Is it safe to go ahead and add words to enhance searchability withouth changing the meaning of the text?

Theme B: Forest Biodiversity and Ecosystem Services

B-01 The future of ecosystem services from forests

Organizers: William Nikolakis & John Innes (University of British Columbia, Canada)

What is needed to make markets for forest ecosystem services a reality? Brand, D. (*New Forests, Pty Limited, Australia; dbrand@newforests.com.au*).

The concept that ecosystems provide real and potentially quantifiable benefits to human society has been accepted for at least 20 years. The Earth Summit in 1992 created an international negotiating framework related to climate change, biodiversity conservation, and sustainable development. However, the fundamental problem has been to change the price signals and economic market failures that lead to continuing pollution, loss of ecosystems, and depletion of natural resources like freshwater. There have been a number of attempts to introduce solutions to this problem via regulatory approaches, market-based systems and voluntary certification schemes. We review some of the these efforts, including markets for sulphur dioxide allowances, European Union carbon allowances, wetlands, stream and endangered species mitigation banks, water rights, voluntary certification schemes and commodity roundtables, and other forms of conservation finance. Finally, we consider how we ultimately achieve a form of end-game where both conservation functions and production functions have economic value, become stable in landscapes, and support a truly sustainable economy.

Biodiversity offsets: delivering additionality to the conservation woodlands in Italy? Chavarria Resendez, A., Gatto, P. (*University of Padova, Italy; ariadna.chavarria@gmail.com; paola.gatto@unipd.it*), Thompson, S. (*Oxford Brookes University, UK; sthompson@brookes.ac.uk*).

Woodland habitats are home to large numbers of species and provide multiple environmental functions. In 2012 the European Union (EU) launched the strategy Prioritized Action Frameworks to find co-finance sources that ensure the conservation of Natura 2000 sites. Contemporaneously, the EU Biodiversity Strategy 2020 and the No Net Loss strategy were established to commit the Member States to implement actions that halve the current rate of biodiversity loss by 2015. Thus, the objective of this study is to analyze the potential of biodiversity offsets, planned to compensate the residual environmental impacts of development projects, to enhance the biodiversity conservation of protected woodlands in Italy. The construction of the highway Pedemontana Veneta has been taken as a case study to develop a biodiversity offsetting proposal that equitably compensates for the residual impacts. A methodology approach was designed to identify the more suitable woodlands that embrace the offsetting to reach the goal of no net loss, and preferably, deliver additionality to such areas by having a net gain of the natural resources and services. The results of this study will promote the creation of a more effective compensation policy in Italy, whilst boosting the conservation of prioritized natural sites and their networking areas.

Current and future provision of ecosystem services in European mountain forests. Lexer, M. (*University of Natural Resources and Life Sciences, Austria; mj.lexer@boku.ac.at*), Bugmann, H. (*ETH Zurich, Switzerland; harald.bugmann@env.ethz.ch*), Cordonnier, T. (*National Research Institute of Science and Technology for Environment and Agriculture, France; thomas.cordonnier@irstea.fr*), Knoke, T. (*Weihenstephan-Triesdorf University of Applied Sciences, Germany; knoke@forst.wzw.tum.de*), Lamas, T. (*Swedish University of Agricultural Sciences, Sweden; tomas.lamas@slu.se*), Boncina, A. (*University of Ljubljana, Slovenia; Andrej.Boncina@bf.uni-lj.si*), Sarvasova, Z. (*National Forest Centre, Slovakia; sarvasova@nlcsk.org*), Zlatanov, T. (*Forest Research Institute, Bulgaria; tmzlatanov@gmail.com*), Pardos, M. (*Instituto Nacional de Investigacion y Technologia Agraria y Alimentaria, Spain; pardos@inia.es*), Wolfslehner, B. (*European Forest Institute (EFICEEC), Austria; bernhard.wolfslehner@efi.int*), Cienciala, E. (*Institute for Forest Ecosystem Research, Czech Republic;* e*mil.cienciala@ifer.cz*), Leber, D. (*Geoexpert Research and Planning GmbH, Austria*; *leber@geoexpert.at),* Kourakli, P. (*Stichting BirdLife Europe, Greece;* p*kourakly@ornithologiki.gr*).

Mountain forests provide a range of ecosystem services (ES). Multiple functions, contrasting interests of owners, and local and regional stakeholders as well as national and international policies and other exogenous drivers such as climate change make the design of forest management strategies for portfolios of ES a complex task. Not much quantitative information is available about the inherent trade-offs among different ES and how these may be affected by future developments such as climate and land-use changes. The Advanced Multifunctional Forest Management in European Mountain Ranges initiative (ARANGE), funded by the Framework Programme of the European Union, has set out to map current forest management approaches in seven case study regions in major European mountain ranges and to assess current and potential future provisioning of ES by means of model-based scenario analysis. Trade-off relations among ES and vulnerability of ES towards changes in climatic conditions and management practices as driven by socioeconomic developments are presented. Furthermore, the capacity to improve the provisioning of portfolios of ES and to respond to external pressures via alternative management strategies is highlighted. The contribution provides a synthesis of current and desirable future management practices across major European mountain ranges and recommendations for policy and forest management.

The future and legitimacy of forest ecosystem services schemes for indigenous peoples: insights from Clayoquot Sound, British Columbia. Nikolakis, W., Nelson, H. (*University of British Columbia, Canada; william.nikolakis@ubc.ca; harry.nelson@ubc.ca*).

Are forest ecosystem services considered legitimate schemes by indigenous peoples? Literature is inconclusive on this question, but it is documented that indigenous peoples find forest ecosystem services to be consistent with their values. We use a novel choice experiment to understand the preferences of indigenous Canadians (First Nations) to different land management scenarios, including industrial development (mining and industrial forestry), tourism, and conservation and restoration (or none). A range of attributes such as income to the Nation, jobs, land access, and contract duration distinguish the three scenarios. We present results

from the experiment which captures the effect of collective versus individual decision making on the acceptability of forest ecosystem services, and we also show in this context, that while payment for ecosystem services (PES) schemes can be consistent with the goals of indigenous peoples in this region, the legitimacy of these schemes is contested. Surprisingly, this emerges not from risks of commodification but instead because of the control these schemes may give to outsiders over land and resource use decisions. Hence, the legitimacy of schemes is influenced by the degree of control provided to outsiders over land claimed by indigenous peoples.

Direct and functional economic value marginal effects of tropical forest conversion to cacao agroforestry systems. Obeng, E. (*Forestry Research Institute of Ghana; amadanso@yahoo.co.uk*), Aguilar, F. (*University of Missouri-Columbia, USA; aguilarf@missouri.edu*).

This presentation discusses marginal changes in direct (i.e., market) and ecosystem functional values of transitioning from natural forests to cacao land use systems (traditional lower-density agroforestry to high-density hybrid cacao monoculture). Marginal estimation addresses the extent to which natural forest direct and functional values are lost in a transition to alternative land uses. As expected, forest conversion may lead to up-front and short-term increases in direct economic gains that drive deforestation. Negative marginal changes were observed for above- and belowground carbon sequestration potential in the two alternative cacao land use systems over the baseline. The extent of marginal losses in carbon storage was comparatively higher for the monoculture system than the cacao agroforestry systems and resulted in significant loss of functional values. A positive marginal change for mean species richness in soil and litter and some essential chemical and physical soil properties (including calcium, magnesium, sand, and silt) was found in cacao agroforestry systems compared with a natural forest. The balance of negative and positive marginal changes in direct and functional values highlights the long-term benefits of tropical forest conservation but also the potential of traditional cacao agroforestry systems to provide ecosystem services closer to a natural forest state.

Institutions and natural resource management: exploring payments for ecosystem services (PES) in the context of decentralised native tree planting in Lebanon. Sarkissian, A., Brook, R., Hockley, N. (*Bangor University, UK; arbi.sarkissian27@gmail.com; r.m.brook@bangor.ac.uk; neal.hockley@univ.bangor.ac.uk*), Talhouk, S. (*American University of Beirut, Lebanon; ntsalma@aub.edu.lb*).

Deforestation threatens biodiversity and diminishes ecosystem services, which has stimulated efforts for increasing forest protection, restoration, and management globally. While large-scale reforestation efforts are important in restoring watersheds and sequestering carbon, enhancing forest biodiversity remains a major challenge. Most landowners are often reluctant to voluntarily plant trees that have little market use or value largely due to high opportunity costs. Through the conceptual framework of payments for ecosystem services (PES), this study aimed to test various hypothetical PES designs to determine the willingness of potential ecosystem service suppliers to accept payments that are affordable enough for potential buyers for encouraging the establishment of diverse native trees and shrubs on private lands. Designing cost-effective PES schemes is essential to encourage new markets for ecosystem services and provide decentralised natural resource management opportunities to benefit landowners who provision public goods, e.g., biodiversity. An important aspect of this study was to estimate the relative trade-offs between diversity (e.g., number of species) and production (e.g., area and numbers of trees established) through determining landowner preferences to reforestation schemes. These insights will aid policy efforts in tailoring cost-effective designs for broadening participation, thus enabling both reforestation and biodiversity conservation efforts to be achieved simultaneously.

Integrating ecosystem services into U.S. Forest Service programs and operations. Smith, N., Deal, R., Weidner, E. (*U.S. Forest Service, USA; nmsmith@fs.fed.us; rdeal@fs.fed.us; eweidner@fs.fed.us*).

The ecosystem services concept aligns closely with the U.S. Forest Service (USFS) mission to "sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations." USFS employees are addressing ecosystem services in forest planning, management, and research to consider and sustain the broad suite of ecological, social, and economic goods and services that forests provide to people. The USFS is also encouraging landscape-scale approaches to forest management in partnership with adjacent landowners, land managers, and non-governmental organizations. This effort includes contributing to the development of markets, valuation research, and payment incentives for private forest conservation and restoration. We describe the objectives of the USFS National Ecosystem Services Strategy Team (NESST) whose purpose is to advance this work and develop cohesive ecosystem services strategy and policy for USFS programs and operations. A primary objective is to develop effective communication about ecosystem services within the USFS as well as with stakeholders. The team is also identifying research tools and capacity needed to actively apply ecosystem services and biodiversity considerations to land management and decision-making, such as methodologies for determining benefits provided by a landscape, and the potential impacts of management actions on those values.

Future payment for forest environmental services: lessons learnt from Viet Nam. Vu Tan, P. (*Vietnamese Academy of Forest Sciences, Viet Nam; phuong.vt@vafs.gov.vn*), Pham Thu, T. (*Center for International Forestry Research, Viet Nam; brissiesugar@gmail.com*), Bennet, K. (*U.S. Forest Service, USA; kabennett@fs.fed.us*).

Although forest environmental services play important roles in environmental and social sustainability, their actual values are often underestimated and there is often limited empirical evidence to illustrate how these values could be acknowledged and protected in forestry policies. Payment for environmental services (PES) offers a new approach in mainstreaming these values in broader forestry sector. Using Viet Nam as a case study, we discuss how PES could improve environmental and social outcomes as well as the challenges for PES policies to deliver effective, efficient, and equitable outcomes. Viet Nam has been implementing a national policy on payment for forest environmental services (PFES) since 2008 that aims to improve the income of local people, increase forestry sector's contribution to the national economy, reduce the state's budget for forest management, and improve environmental conditions. This research provides a comprehensive analysis of the PFES and of its progress toward achieving its goals. For PFES to have outcomes that are effective, efficient, and equitable, however, policy makers need to work toward developing a functional monitoring and evaluation system, with an accessible grievance mechanism, to ensure transparency

and accountability in the distribution of PFES revenues from central to local levels. PFES could also benefit by being part of a more holistic program, working with complementary conservation and socioeconomic development programs.

Designing payments for environmental services programmes. Wunder, S. (*Center for International Forestry Research, Brazil; swunder@cgiar.org*).

Payments for environmental services (PES) are an integrated financial and direct incentive mechanism. Among the full set of services listed by the Millennium Ecosystem Assessment, PES is relevant to the strategic subspectrum of regulating services that depend upon users' willingness-to-pay exceeding providers' willingness-to-accept compensation. However, PES are also a demanding tool, which can only be applied if certain preconditions are met (or can be created). First, spatial targeting of high PES values is preferable in heterogeneous landscapes. Second, targeting of high threat/leverage areas is also key, so as to avoid selection biases that result from voluntary participation. Third, differential payment rates are often required to customize PES to different provision costs. Finally, PES programmes cannot work effectively without sufficient payments, a defining feature of this tool. There is often scope to improve PES design and implementation, although political obstacles may also cause public-sector PES programmes to deviate from first-best design principles.

B-02 Urban forest diversity and ecosystem services

Organizers: David Nowak (U.S. Forest Service) & Wesley Kocher (International Society of Arboriculture, USA)

Urban forest tree species diversity and its impact on air pollution removal capacity. Abdollahi, K, Ning, Z. (*Southern University, USA; kamrana664@cs.com; zhu_ning@subr.edu*).

Through pollution removal and other tree functions, urban trees can help improve air quality in cities, and consequently can help improve human health. Four controlled environmental studies were conducted for the quantification of 20 urban forest tree species capacity for removing ozone, sulfur dioxide, nitrogen dioxide, and particulate matter pollutants. The results indicated significant variation in air pollution removal capacity and physiological responses of the urban tree species. The results reveal the importance of urban forest tree species diversity in achieving air quality improvement.

Effects of residential development on forest attributes. Eskelson, B. (*Oregon State University, USA; bianca.eskelson@oregonstate.edu*), Azuma, D. (*U.S. Forest Service, USA; dazuma@fs.fed.us*).

Forested communities provide ecosystem services (e.g., wildlife habitat, wood and wood products, carbon sequestration) that may be at risk as residential development occurs with increasing human population. Little work has been done to show the effects of residential development on forest attributes. We used Forest Inventory and Analysis (FIA) plot data from Oregon and Washington in combination with building density estimates from photo-interpreted points to show how residential development is associated with coarse woody debris volume, snag volume, large tree basal area, the proportion of FIA subplots with introduced species, and other forest attributes. Our results indicate that building density and minimum distance to a point with a building are significant development metrics when explaining the variation in the forest attributes that we examined. The impact of building density and minimum distance on selected forest attributes are presented. For some forest attributes the results differed on public and private lands. For example, while snag and large tree volume increased with minimum distance to a point with a building on public lands it remained the same on private lands. Our work is one of the first attempts to quantify the impact of residential development on forest attributes.

Failures of urban forest diversification. Loeb, R. (*Pennsylvania State University, USA; rxl5@psu.edu*).

To provide ecosystem services the urban forest must survive over the long term. Building species diversity in the urban forest is favored to avoid losses related to diseases and pests afflicting dominant species. How to evaluate a species' ability to grow in rigorous urban conditions was understood by early urban forest visionaries such as Frederick Law Olmsted, Charles Sprague Sargent, and Liberty Hyde Bailey. However, attempts to build species diversity have faced failures. For example, <40% of the 1 110 species of trees and shrubs planted in Central Park, New York, USA, and Fairmount Park, Philadelphia, USA, in 1880 survived to 1970, despite repeated plantings to reestablish lost species over the intervening decades. The losses were spread over both native and non-native species. A detriment of increasing urban forest diversity is invasive species introductions. Comparing urban east coast American floras from 1818 to 2011 revealed 98 invasive species introductions which have spread through the region. More recent challenges to diversification efforts are related to urban forest naturalization, permitting losses to fire, deer browsing, and beaver damage. Increasing species diversity in city streets and green spaces must first consider past successes and failures, threats to regional forests, and potential wildlife and fire damage to assure the long-term success of new species for improving ecosystem services.

Relative abilities of six urban tree species in mitigating elevated CO_2. Ning, Z., Abdollahi, K. (*Southern University, USA; zhu_ning@subr.edu; kamrana664@cs.com*).

Urban trees can affect the factors underlying global warming in two ways, by directly sequestering CO_2 and storing carbon, both in the trees themselves and in urban soil, and by reducing the energy needs for both cooling and heating around buildings. The purpose of this study was to quantify the relative ability of selected urban trees in mitigating elevated CO_2. Six commonly used urban tree species were tested under seven elevated CO_2 treatments. Results showed that net photosynthesis (CO_2 sequestration) of all species increased in elevated CO_2 conditions, with peak rates at 500 and 600 ppm. Most trees responded to increases in the CO_2 level by displaying reduced stomatal conductance and transpiration rates. This water savings can result in greater soil moisture content in CO_2-enriched ecosystems.

Changes in urban forest species diversity and its impact on ecosystem services in the United States. Nowak, D. (*U.S. Forest Service, USA; dnowak1@fs.fed.us*).

Urban forest monitoring data in the United States is revealing how urban forest diversity and structure are changing in recent years. The changes in diversity and structure will impact the ecosystem services and values derived from the urban forest. Urban forest structure and ecosystem services in several cities in the United States have been assessed based on random sampling of field plots, photo-interpretation and the i-Tree Eco model (www.itreetools.org). In addition, some cities have long-term monitoring data based on resampling of permanent field plots. This presentation will overview ecosystem services derived from urban trees and forests, and the magnitude of these services and values at the national scale. The presentation will then discuss species diversity at the city scale and how it varies across the United States. Finally data will be presented on urban forest change in the United States and its implication on urban forest diversity and ecosystem services. While urban forests in the United States have a relatively high species richness and diversity, invasive species are affecting the urban forest diversity in some cities and the magnitude of the urban forest resource has declined in recent years.

Can urban sites support increased species diversity? Watson, G., Hewitt, A., Dwyer, J., Bonnewell, V. (*The Morton Arboretum, USA; gwatson@mortonarb.org; AHewitt@mortonarb.org; jdwyer@mortonarb.org; wbonnewell@mortonarb.org*).

Diversity is often lacking in the urban forest and species composition has a significant influence on the benefits provided. Fewer than 10 species can account for 50%, or more, of the urban tree population. These overplanted species tend to be hardy and capable of surviving on difficult urban sites. But urban areas can also be repositories for a wide range of species, though most are planted in very small numbers because site quality is limiting. A 2010 i-Tree Eco assessment of the Chicago metropolitan region showed that the urban forest was in a transitional state where older pre-urban trees were reaching the end of their lifespans, hardy planted species were increasingly being lost to introduced pests and pathogens, and smaller, lower-quality invasive and opportunistic species were the most widespread. By comparing the species characteristics and current size distribution, we can predict change in the species composition and structure of the forest over time. Sites with lesser quality urban soils that currently support hardy trees will have to be improved to support a diverse and sustainable urban forest of more sensitive species that can maintain or increase the level of ecosystem services provided.

Cultural and social ecosystem services of urban trees and forests. Wolf, K. (*University of Washington, USA; kwolf@u.washington.edu*).

The research addressing ecosystem services (ES) has expanded substantially since the release of the Millennium Ecosystem Assessment. There are two notable patterns as one reads the scientific literature: less attention to cultural services and a focus on rural and wildland landscapes as compared to urban ecosystems. This presentation, as part of a panel session concerning urban forestry, will consider a more complete array of nature-based benefits and functions that should be included in an expanded treatment of cultural ES. Nearly 40 years of research across social science disciplines (such as psychology, sociology, anthropology, and public health) provides evidence of extensive health and well-being benefits associated with the human experience of nature in cities. This knowledge is profoundly important, as benefits include stress reduction, healing and therapy, better learning and work productivity, and improved social dynamics in communities. All such findings have broad implications, from support of individuals, to community cohesion, to economic costs and benefits. A framework of cultural and social benefits will be presented, based on an extended literature review and synthesis (accessed at: www.greenhealth.washington.edu). The role of landscape diversity in health promotion will be addressed. Preliminary economic valuations of human health and well-being services will also be introduced.

Diversity of urban tree species over the globe and their links to ecosystem services. Yang, J. (*Tsinghua University, China; larix001@gmail.com*).

Studies on urban floras in Europe and North America show that urban floras are increasingly homogenized. In order to test this theory and to explore the potential impacts of the trend of homogenization on ecosystem services, a meta-analysis was carried out to analyze diversities of tree and shrub species in cities over the globe. From the literature, a list of 3 623 tree and shrub species reported from 338 cities in 63 countries has been compiled. The result shows that species like *Acer platanoides*, *Robinia pseudoacacia*, *Gleditsia traiacanthos*, and *Ailanthus altissima* are distributed widely. The species compositions of urban trees display strong similarities in cities in same ecozones. Many cities now have a high percentage of exotic species due to the homogenization process. These species offer a multitude of ecosystem services. On the top of the list are aesthetic values and microclimate regulation. At the same time, the homogenization also causes disservices. Species like *A. platanoides* and *A. altissima* are declared as invasive species in surrounding natural forests. Species from widely distributed genera such as *Populus* spp. and *Acer* spp. are sources of allergic pollens. The meta-analysis does show a homogenization trend but there are still uncertainties.

B-03 Providing ecosystem services under climate change: Community of practice of forest decision support systems

Organizers: Harald Vacik (University of Natural Resources and Life Sciences, Austria), Jose Borges & Jordi Garcia-Gonzalo (Technical University of Lisbon, Portugal) & Lujsk-Ola Eriksson (Swedish University of Agricultural Sciences)

Supporting participatory land use planning processes and decisions: the GISCAME platform. Fürst, C. (*University of Bonn, Germany; cfuerst@uni-bonn.de*), Frank, S. (*Dresden University of Technology, Germany; susanne.frank@tu-dresden.de*), Pietzsch, K. (*PiSolution GmbH, Germany; kp@pisolution.de*), Pietzsch, F. (*PiSolution GmbH, Germany; fp@pisolution.de*).

The aim of decision support tools is to identify optimal land use strategies for combinations of biogeophysical conditions and socioeconomic constraints. Challenges include 1) obtaining information on relevant rules and constraints and 2) reflecting

interactions between participants that modify them. Scenario simulation approaches supporting what-if constellations and negotiation on trade-off acceptance limits help to solve these problems. The software GISCAME was developed to support participatory decision processes that involve interactions between various stakeholders. GISCAME combines GIS routines for data handling with a cellular automaton for scenario building and a hierarchical multicriteria evaluation scheme. The platform offers scenario instruments such as simple mouse-click routines for inexperienced users, routines to define attribute and proximity dependent transition probabilities for experienced users, and expert-oriented rule configuration kits for attribute dependent or legally defined scenario constraints. Qualitative feed-back on ecosystem services balance, their temporal variability, and risks such as water erosion or mass movement is provided. This is complemented by assessing the impact of the spatial constellation of land uses for ecological and aesthetical land system value. We demonstrate a case from an integrated rural development on how to use the support tool to sustain, and increase temporally, variable lignocellulosic resources combined with a trade-offs analysis.

Architecture of a decision support system to address climate change (SADfLOR). Garcia-Gonzalo, J., Borges, J. (*Technical University of Lisbon, Portugal; jordigarcia@isa.utl.pt; joseborges@isa.utl.pt*).

The competition for forest resources is prone to increase in the context of global change (e.g., climate change, prices, and stakeholders' preferences). This tendency points out the urgency of developing new tools that may address risk and uncertainty. This research addresses the need to develop decision tools to address climate change in forest planning. In this research, we discuss a stakeholders' engagement plan and a participatory planning approach to involve the stakeholders in the design and identification of components for a decision support toolbox/platform (SADfLOR). The proposed approach was tested in Chamusca County, located in central Portugal, where different stakeholders are involved in planning processes (e.g., industrial owners, non-industrial private forestland owners, forest service providers). Based on this methodology, we developed a decision support system for addressing climate change on eucalypt plantations (SADfLOR v ecc 1.0). The system was also applied to Chamusca County to analyse ways to adapt management plans to future climate changes. Results demonstrate that the design of optimal management plans should take into account climate change.

Ecosystem services and climate change: a decision support process for a community forest in the Austrian Alps. Irauschek, F., Maroschek, M., Rammer, W., Lexer, M. (*University of Natural Resources and Life Science, Austria; florian.irauschek@boku.ac.at; michaek.maroschek@boku.ac.at; werner.rammer@boku.ac.at; mj.lexer@boku.ac.at*).

Various stakeholder demands for timber production, protection against gravitational natural hazards, nature conservation, wildlife management, and hunting, as well as tourism, challenge the development of forest management strategies. Additionally, changing climatic and socioeconomic conditions affect mountain forests and the provision of forest ecosystem services and impose complex decision making problems. For a large community-based forest holding in the eastern Alps in Austria, we demonstrate a decision support process for the development of adaptive management options at strategic and operational levels. Based on a generalized decision process, a comprehensive set of modelling tools was employed to assess the vulnerability of ecosystem services towards climate change under current management practices and to design and evaluate alternative adaptive strategies. Among others, a hybrid forest ecosystem model including bark beetle, wind and browsing disturbances, GIS-based assessment tools for protection forest functionality, and bird habitat quality and visualization tools were used to analyse and communicate alternatives. Interaction with internal and external stakeholders informed the modelling and assessment process. Results indicate increasing disturbance intensity and the need to adapt forest management. We highlight the assessment and decision making process and provide generalized recommendations for practical mountain forest management in the eastern Alps.

Studying trade-offs between biodiversity and ecosystem services: an integrated modeling approach based on uneven-aged mountain forests. Lafond, V., Cordonnier, T., Courbaud, B. (*National Research Institute of Science and Technology for Environment and Agriculture, France; valentine.lafond@irstea.fr; thomas.cordonnier@irstea.fr; Benoit.Courbaud@irstea.fr*).

Multifunctionality of Central European mountain forests have long been acknowledged, as they host numerous emblematic species, supply timber production, and have an important protection role against natural hazards, as well as aesthetic and recreational functions. Though these forests have a long tradition of selection silvicultural systems, considered favorable to multifunctionality, explicit consideration of ecosystem services provision within management planning is a recent issue and requires a better understanding of their response to silvicultural practices. Decision support systems are thus of great interest, though they often rely on the comparison of contrasted management practices and rarely on small adjustments within a given silvicultural system. This contribution aims at presenting a methodological framework designed to study the impacts of variations of management practices on biodiversity, ecosystem services provisions, and trade-offs. We conducted a simulation study coupling an uneven-aged management algorithm with Samsara2, an individual based and spatially explicit forest simulation model designed for spruce-fir uneven-aged mountain forests. Sensitivity analysis enabled influencing factors to be detected and response surfaces of biodiversity and production indicators to be established. Trade-offs between indicators were then identified and studied thanks to Pareto frontier techniques, and interesting management prescriptions were discussed with forest managers through a participatory approach.

Long-term forest planning under risk and uncertainty: can robust linear programming help? Mäkinen, A., Rasinmäki, J. (*Iptim Inc., Finland; antti.makinen@iptim.com; jussi.rasinmaki@iptim.com*).

Optimization methods are used in strategic forest planning to create plans that enable the best utility for the decision makers. The applied optimization techniques depend on the type and scale of the forest planning task, but it is common that the time horizon is quite long. Therefore the accurate realization of the plan is under considerable uncertainty; the outcome is affected among other things by errors in input data, natural variation in forest growth, natural hazards, and fluctuation in timber prices. However, accounting for the uncertainties in planning is not a common practice because the methods are complex and the information about the uncertainties is not always available. We present a case study on whether these hurdles could be mitigated to such a degree that the uncertainty evaluation could be a routine part in creating a strategic forest management plan. We will focus on

robust optimization as a method for accounting for the uncertainties, scenario definition for different uncertainty and risk factors, and the implementation of these in decision support software, Iptim, to make the combined approach usable for a forest planner. The focus of the case study is on sustainable timber production over a long time horizon, under economic objectives.

Design features behind the success of the Ecosystem Management Decision Support system. Reynolds, K. (*U.S. Forest Service, USA; kreynolds@fs.fed.us*).

The Ecosystem Management Decision Support (EMDS) system is an application framework for designing and implementing knowledge-based decision support systems for environmental analysis and planning at any geographic scale(s). The system integrates a state-of-the-art geographic information system, as well as knowledge-based reasoning and decision modeling technologies, to provide decision support for a substantial portion of the adaptive management process of ecosystem management. It integrates a logic engine to perform landscape evaluations, and a decision engine for developing management priorities. The logic component 1) reasons about large, abstract, multi-faceted ecosystem management problems, 2) performs useful evaluations with incomplete information, 3) evaluates the influence of missing information, and 4) determines priorities for missing information. The planning component determines priorities for management activities, taking into account not only ecosystem condition, but also criteria that account for logistical concerns of potential management actions. Both components include intuitive diagnostic features that facilitate communicating modeling results to a broad audience. Seventeen years after its initial release, EMDS remains popular in the natural resource community, perhaps because it provides a very general design framework suitable for many questions and spatial scales. This and other features of the system design that have figured in its success will be highlighted in the presentation.

Community of practice of forest management decision support systems and lessons learned for development and application. Vacik, H. (*University of Natural Resources and Life Sciences, Austria; harald.vacik@boku.ac.at*), Garcia-Gonzalo, J. (*Technical University of Lisbon, Portugal; jordigarcia@isa.utl.pt*), Gordon, S. (*Portland State University, USA; sean.gordon@pdx.edu*).

The motivation for the community of practice (CoP) on forest management decision support systems (FMDSS) came from the European Union-funded COST Action FORSYS (FP0804), which convened a network of more than 120 experts from 26 countries in Africa, America, Asia, and Europe. As part of the networking activities, participants built an online information repository to share information on FMDSS software and their application (including 57 software systems, 26 country reports, 30 case studies, and a survey among the CoP experts). Lessons learned were synthesized from these sources following a standardized format and common structure that could accommodate the different sources and was sufficiently detailed to be actionable. This contribution will explore how FMDSS are used for a sustained provision of ecosystem services under climate change and present a general framework for the demands on FMDSS supporting this complex task (e.g., methods for uncertainty and risk evaluation, climate sensitive growth models including disturbances). Based on the information compiled, we identified climate change and ecosystem services as somewhat common in different data sources but rarely used explicitly. We will draw our conclusions on decision support systems development and application based on the framework presented.

Posters

Evaluating future wood availability in Europe: methods and tools. Barreiro, S. (*Technical University of Lisbon, Portugal; smb@isa.utl.pt*), Schelhaas, M. (*Wageningen University and Research Centre, Netherlands; MartJan.Schelhaas@wur.nl*), Antón-Fernández, C. (*Norwegian Forest and Landscape Institute, Norway; caf@skogoglandskap.no*), Colin, A. (*AgroParisTechCentre de Nancy, France; Antoine.Colin@ign.fr*), Kandler, G. (*Forest Research Institute of Baden-Wurttemberg, Germany; gerald.kaendler@forst.bwl.de*), Schadauer, K. (*Bundesamt und Forschungszentrum fur Wald, Austria; klemens.schadauer@bfw.gv.at*).

Sustainable wood availability in Europe is highly relevant to define global change mitigation strategies at national and European levels and to support the proposal of an increased use of renewable energy sources. Future scenarios at the European Union-level highlight a deficit of wood supply compared to wood consumption. UseWood COST Action (FP1001) aims at improving information on the methodologies used at the European level for assessing the potential sustainable wood supply based on National Forest Inventories' data. To reduce uncertainties and better evaluate future wood supply forecasts, countries were asked to describe the methodologies and/or tools currently used to assist management that allow national evaluations of future wood availability. A total of 18 European country reports were received giving a fair characterization of the methodologies currently in use in Europe. A preliminary analysis shows that half the countries utilize forest simulation tools based on National Forest Inventory (NFI) data, mostly supply-driven simulators, whereas most eastern countries have more or less developed methodologies based on Standwise Forest Inventory (SFI). The remaining countries are either using tools developed for specific areas of their countries or nation-wide applicable tools that are not NFI based.

The system of silviculture for conservation and development (SICODESI): lessons from a successful case of forest management in Jalisco, México. Dominguez Hernandez, F. (*Benemérita Universidad Autónoma de Puebla, Mexico; forestal_umar@hotmail.com*).

The Mexican Forestry Law of 1986 mandated a policy of integrated forest management. The Sistema de Conservación y Desarrollo Silvícola (SICODESI) is a technology developed by the University of Helsinki at the request of the Mexican government to automate the concept of integrated forest management. The software was expected to empower forest owners to take over forest planning and decision making processes that before were the responsibility of professional foresters. SICODESI has been in practice for >20 years now. This is a chronicle of the SICODESI experience, assessed from its own stated purposes, and also from an abstract conception of forest management. Results confirm that SICODESI was politically and biologically successful thanks to a viable silvicultural regime, and a legal operation that produced an even flow of removals, while increasing timber stocking and forest health, while sustaining reasonable economic benefits for the forest owner. Policy goals failed because the forest owner remained disengaged, uninvolved, and ill informed; key decisions remained in the hands of professionals and

regulatory agencies. Satisfactory benefits accrued to the owner, and good expectations held by forest authority and the public provide credibility to SICODESI as a promising option for future Mexican forest management.

Spatial aspects of biodiversity as a part of the harvest scheduling decision process. Kašpar, J., Marusak, R., Vopenka, P., Hlavaty, R. (*Czech University of Life Sciences, Czech Republic; kasparj@fld.czu.cz; marusak@fld.czu.cz; vopenka@fld.czu.cz; hlavaty@pef.czu.cz*).

Over the last decade, the influence of non-wood productive functions, such as environmental services, has been increasingly expanding. We can expect that the impact of these functions will continue to grow due to mitigation of climate change impacts. As a result, foresters have to seek tools for solving complex ecosystem management problems that include social, environmental, and timber-production functions. The real forest management problems are multi-objective, meaning they include more than one objective, and several different restrictions and constraints as well, such as configuration of patches, their size and distribution, shape, adjacency or green-up delay, connectivity, proximity or core area, and many others. These problems can be solved by special exact mathematical methods such as multi-objective programming and by tools of geographic information systems (GIS). The use of multi-objective programming in forestry brings many risks. Determination of objective weights can be one of the many problems. Another problem is that each objective takes vastly different values in real environmental situations in most cases. This work presents possible solutions of the example of spatial harvest scheduling with regard to biodiversity aspects.

DSS Optimal: a case study from the Czech Republic. Marusak, R., Kašpar, J., Vopenka, P. (*Czech University of Life Sciences, Czech Republic; marusak@fld.czu.cz; kasparj@fld.czu.cz; vopenka@fld.czu.cz*).

Forest managers have traditionally planned harvests using expert knowledge, including the spatial distribution of harvest units. The amount of timber to be harvested has then been regulated by market demand. In addition to expert knowledge, there is a set of rules, which can be automated. Computerized harvest planning will lead not only to saving time for forest managers, but it will also enable them to explore various scenarios in a matter of minutes. We introduce Optimal: a GIS tool for spatial and temporal decision of harvest scheduling. Using Optimal, forest managers can create harvest units by cutting polygons of forest stands in a digital map. After the harvest units are created by the user, the adjacency matrix is automatically produced and passed to the solver module. The solver performs calculations using integer programming and then returns the spatial distribution of harvest units for each harvest period. Users can set the number of parameters and criteria according to desired ecosystem services to create different scenarios. Optimal is a decision support system (DSS) designed for and applied to clear cutting and shelterwood silvicultural systems with respect to environmental and economic constraints.

Balancing biomass and biodiversity in protected areas, the Triglav National Park case study. Pisek, R., Beguš, J. (*Slovenia Forest Service, Slovenia; rok.pisek@zgs.si; jurij.begus@zgs.gov.si*), Poljanec, A. (*University of Ljubljana, Slovenia; ales.poljanec@bf.uni-lj.si*), Grum, A. (*Slovenia Forest Service, Slovenia; andrej.grum@zgs.si*).

In Central Europe, national parks are mainly designed as protected areas where the traditional use of forests is allowed. Sustainable forest management also provides wood for biomass heating, which is in line with the aim of nature protection and a low-carbon society. To properly manage the resources, we need appropriate GIS tools. In our research, Slovenian Wood Energy Information System (SWEIS) from Slovenia Forest Service (SFS) was used to evaluate four different scenarios in Triglav National Park from biomass and energy and biodiversity views. First, we assessed available forest biomass according to current cut of biomass (Scenario 1), allowable cut according to forest management plans (Scenario 2), reduced cut due to pursuing the objectives of nature conservation (Scenario 3), and increased use of forests with higher cut (Scenario 4). In the second step, we assessed present and possible future local biomass demands. In the paper, an improved and tested existing high quality decision support SWEIS for a special protected area with high conservation value will be presented; comparisons between different scenarios will be evaluated and the balance between conservation and economic objectives in the field of biomass will be discussed.

B-04 Long-term forest research on forest ecosystem management

Organizers: Hosang Kang (Seoul National University, Republic of Korea), Xingguo Han (Institute of Applied Ecology, Chinese Academy of Sciences) & Björn Hånell (Swedish University of Agricultural Sciences)

Vegetation and soil interactions during an 80-year succession in forest stands in the Moricsala Island Nature Reserve, Latvia. Brumelis, G., Kokarevica, I., Rolava, A., Cepuritis, E. (*University of Latvia, Latvia; guntis.brumelis@lu.lv; anonima2@inbox.lv; arta.rolava@gmail.com; e.cepuritis@gmail.com*).

The aim of the study was to determine changes in tree species composition and vegetation, in relation to soil factors, in permanent plots that had been described in 1929 in the Moricsala Island Nature Reserve, located in the boreonemoral forest zone. Prior to establishment of the nature reserve in 1912, part of the area had been used for hay collection and as pasture. The reserve is dominated by *Quercus robur* and *Tilia cordata* woodland. Description of forest structure and vegetation was conducted precisely as had been done earlier by J. Grožinskis. In 50 m × 50 m plots, DBH was measured for all trees (>10 cm), saplings were counted in 2 m × 2 m subplots, and cover of species was estimated in 1 m × 1 m subplots. In the earlier study, an accurate description of soil profiles was made; in the present study, additional soil parameters (texture, depth to free carbonates, pH, C, N, and base cation concentrations) were determined. The main factors driving vegetation change were parent material, depth to free carbonates, dominant canopy species, and shading. Comparisons with historical data indicated an increase in the depth of the organic horizon. The proportion of species typical of open habitats decreased, with replacement by species typical of nemoral forest plant communities.

Variable retention harvesting and sustainable forest management in the boreal forest of Canada: lessons learned from the EMEND experiment. Pinzon Cortes, J., Spence, J. (*University of Alberta, Canada; jpinzon@ualberta.ca; john.spence@ualberta.ca*), Bourassa, S., Langor, D. (*Canadian Forest Service, Canada; sb22@ualberta.ca; david.langor@nrcan-rncan.gc.ca*).

Biodiversity conservation has been recognized as one of the cornerstones for sustainable forest management. In addition to the maintenance of healthier systems, it is fundamental for the recovery of managed forests after industrial harvesting. In this study we summarized responses of ground-dwelling arthropod (spiders and carabid beetles) assemblages during the first 10 years after the application of various variable retention harvest prescriptions as part of the large scale Ecosystem-Based Management Emulating Natural Disturbances (EMEND) experiment in the mixed wood boreal forest of western Canada. Data for these groups were collected 2, 5, and 10 years post-harvest in addition to environmental variables that assessed post-disturbance changes in the forest. Results suggest that, compared to clear-cutting, variable retention harvesting not only reduced the adverse effects of current practices, preserving habitat features that allow the survival of species sensitive to disturbance and retains landscape heterogeneity, but in addition enhanced forest recovery. Results from the EMEND project have prompted some forest companies in Canada to apply variable retention harvest practices on a large scale as an alternative to conventional clear-cutting in an effort to achieve more sustainable forest management.

A study on long term monitoring of major planting trees in Korea. Seo, Y., Choi, J., Lee, D., Kim, Y. (*Kangwon National University, Republic of Korea; ywseo@kangwon.ac.kr; jungkeechoi@kangwon.ac.kr; lds9940@naver.com; yeong@kangwon.ac.kr*).

The study was conducted to investigate the changes in stand structure of major coniferous planting trees (*Pinus koraiensis*, *Pinus densiflora*, *Larix kaempfri*) by thinning intensities in Korea. For the study, permanent monitoring plots were installed for each species by age class. The study areas were selected at East Region for *Pinus densiflora* and at Northern Region for *Pinus koraiensis* in 2012 and at East Northern and Southern Region for *Larix kaempferi* in 2013. Three rectangular plots for no thinning, low intensity thinning and high intensity thinning were established in each study area with the size of 20 m × 20 m, 25 m × 25 m, and 30 m × 30 m, respectively. DBH, height, tree quality, and tree coordinates were collected from each plot. We removed 20 and 40% of total basal area from low intensity thinning and high intensity thinning plots, respectively. The installed plots will be measured by every 3 years to monitor the changes in stand structure after thinning. It is expected that the study will play a key role in the long-term monitoring for tree growth, wood production, and utility according to thinning intensity.

Forest observational studies network for growth modelling and long-term ecological monitoring. Tewari, V. (*Institute of Wood Science and Technology, India; vptewari@yahoo.com*).

Forest resource information, gathered in forest inventories at local, national, and global levels, is required for planning and policy decisions, whereas forest research plot networks provide essential data for studying forest ecosystems. In this contribution, a distinction is made between two types of field studies, manipulated experiments and observational studies. A manipulated experiment deliberately imposes treatments on experimental plots with the aim of observing a particular response. In contrast, a comparative observational study (also known as a quasi-experiment) involves collecting and analyzing data from different site conditions but without actively pre-defining these conditions. According to the time scale, a distinction is made between cross-sectional studies typically involving few observations on a large number of individuals, longitudinal studies where few individuals are typically measured many times, and interval studies representing a practical compromise between the two types of studies. Forest observational studies provide the empirical basis for the study of ecosystem structure and dynamics, including tree growth, recruitment, and mortality. This paper presents the history and current state of long-term forest research plots in India, including details of locations and re-measurements. A methodology is presented for plot enumeration and analysis of forest structure and diversity in line with current approaches in forest ecological research.

Shelterwood method in hemiboreal conditions as an alternative to clearcutting for more efficient ecosystem services management. Tullus, H. (*Estonian University of Life Sciences, Estonia; hardi.tullus@emu.ee*), Tullus, A. (*University of Tartu, Estonia; arvo.tullus@ut.ee*), Tullus, T., Rosenvald, R. (*Estonian University of Life Sciences, Estonia; tea.tullus@emu.ee; raul.rosenvald@emu.ee*), Karoles, K. *(Estonian Environmental Agency, Estonia; kalle.karoles@envir.ee*), Lutter, R. (*Estonian University of Life Sciences, Estonia; reimo.lutter@emu.ee*), Kõresaar, P. (*State Forest Management Centre, Estonia; priit.koresaar@rmk.ee*), Aasamets, P. (*Estonian University of Life Sciences, Estonia; pille.aasamets@emu.ee*).

In the hemiboreal forest zone, clearcutting systems have been traditionally used for forest management. Modern attitudes about biodiversity conservation, aesthetic value of landscapes, and ecosystem services require the use of alternatives to clearcutting. Wider use of the shelterwood method and principles of continuous forestry are one option for this. Sixty shelterwood cutting research areas have been recently established in Estonia. Research and monitoring focuses on natural regeneration of different tree species, diversity and dynamics of understorey vegetation (vascular plants, bryophytes, lichens), and the impact of root and light competition on the emergence and development of new trees under the shelter of the older forest generation. Also public opinion towards the use of different silvicultural methods is clarified and economics of clearcutting and shelterwood systems are compared. Although clearcutting provides a better economic outcome, the results of the study encourages wider use of shelterwood method for close-to-nature management of boreal forests and the use of their ecosystem services. The success of regeneration under the shelter of remaining trees was more dependent on root than light competition in boreal and hemiboreal areas. Thus, the first cut of the shelterwood system should be quite intense to decrease this negative effect.

Use of bioindicators for protected area management and ecological monitoring in the western Himalayan landscape, Uttarakhand, India. Uniyal, V., Sanyal, A., Bhardwaj, M., Quasin, S. (*Wildlife Institute of India, India; uniyalvp@wii.gov.in; abeshsanyal@gmail.com; bhardwmanish@gmail.com; shazia.quasin@gmail.com*).

In Himalaya**,** protected areas represent one of the most significant natural resource use allocations on the planet. The importance of protected areas is reflected in their widely accepted role as indicators for global targets and environmental assessments. A regional approach to protected areas planning and management is necessary to accommodate critical large-scale spatial and

temporal components such as the representation of natural landscapes and population viability of indicator species and other trans-boundary phenomena. In the western Himalayan landscape of Uttarakhand, protected areas are rich in biodiversity and natural resources. This study was conducted using bioindicators (insects and spiders) to assess the impact on natural resources of early warning change and long-term ecological monitoring of biodiversity. Indicator species and ecosystems warrant special consideration because they are functionally important and sensitive to changes in habitat quality, quantity, and configuration. They are communication tools between environments and people. Bioindicators can thus help to safeguard natural resources and protected areas of cultural importance that local communities and indigenous peoples depend on.

A preliminary analysis of long-term dynamics of Venezuelan tropical forests: evidence from field-based plots. Vilanova, E. (*University of Washington, USA; vilanova@uw.edu*), Ramirez-Angulo, H., Torres-Lezama, A. (*University of the Andes, Venezuela; rhirma@ula.ve; torres@ula.ve*).

Long term-monitoring represents a key tool for analysis and comprehension of spatial and temporal dynamics of forests. Consistent monitoring of Venezuelan forests has occurred since the 1960s, assessing key elements including growth and productivity of several types of forests. We present a preliminary synthesis of results obtained after >40 years of long-term monitoring, analyzing tree species diversity, growth, and aboveground biomass dynamics. Lowland moist tropical forests in southern Venezuela (Guayana) have the highest tree species richness (>200 species/ha) compared with other forest formations. Cloud forests in the western Andes have the greatest aboveground biomass (390 ± 10 Mg/ha), whereas deciduous seasonal forests in western plains have the most dynamic forest communities with high tree mortality and recruitment. Coarse wood productivity values for all sites are similar to those for many tropical forests (2–6 Mg/ha/year) with a consistent increase over the last 20 years, a pattern previously observed in the Amazon region. Species composition has also changed over time, especially in forests subject to periodic droughts. Yet, great uncertainty remains on how these forests will respond to major disturbances factors such as increased droughts and anthropocentric forest degradation.

B-05 The benefits of introducing the ecosystem service concept in forest management and planning at different spatial scales

Organizers: Sandra Luque (IRSTEA, France) & Christine Fürst (ZEF Uni Bonn, Germany)

Perceived benefits from boreal forest landscapes: the importance of historical legacies for interpretation of ecosystem services. Angelstam, P., Elbakidze, M., Axelsson, R. (*Swedish University of Agricultural Sciences, Sweden; per.angelstam@slu.se*; *marine.elbakidze@slu.se; robert.axelsson@slu.se*).

The emergence of policies about sustainable use of forests and landscape values, as well as global economic change, has expanded the desired range of ecosystem services in the boreal biome. Focusing on boreal regions with different landscapes histories in northwest Russia, Sweden, Norway, and Scotland, we compared the perceived profiles of ecosystem services in one case study landscape in each country. Using focus group discussions and interviews with stakeholders we mapped the current use and future scenarios of desired benefits from ecosystems. Linked to the duration of forest landscape history, we observed a steep gradient from modernistic focus on mainly provisioning ecosystem services in terms of material goods and industrial jobs, to a post-modernistic focus based on cultural ecosystem services in terms of non-material values for service jobs. Thus, implementation of sustainable forest management policy requires regionally adapted solutions. To support place- and evidence-based solutions we propose an integrated approach to research and learning towards sustainable use of ecosystem services. This involves iterated research, collaboration among academic and non-academic stakeholders, and communication with and dissemination to society at large. To further research and learning, there is a need to improve the availability and use of data about all sustainability criteria at multiple spatial scales and over time.

Integrating ecosystem services and forest ecological networks into state planning at multiple scales: the experience from Colombia. Armenteras, D., Rodriguez, N. (*National University of Colombia, Colombia; darmenterasp@unal.edu.co; neraso2000@gmail.com*), Cediel, M. (*Ministry of the Environment, Housing and Territorial Development, Colombia; MCediel@minambiente.gov.co*), Molina, E., Gonzalez, T. (*National University of Colombia, Colombia; edumolgo@gmail.com; tmgonzalezd@unal.edu.co*).

Here we present the experience of integrating an ecological dimension, with emphasis on forests, biodiversity (BD), and ecosystem services (ES), with a management dimension for an environmental planning tool in Colombia. The first dimension ensures the functioning of ecological processes, ecological integrity, and connectivity, and the second one includes aspects of interagency coordination and public participation in this tropical country. The interactions between these dimensions of work have generated and will continue to create different patterns of landscape use, and accordingly various land management strategies in the country, balancing the supply of natural resources, the needs of society, and the dominant political and economic policies. Meanwhile, society demands the provision of commodities, through regulation that supports ES, but at the same time demands the protection of BD, with policy, management, and conservation planning at all levels. We present the development of a national planning tool based on forest ecological networks as one of the strategies to support environmental land planning at multiple scales. Different elements that comprise a specific role in forest ecological networks can be used for BD and ES conservation and for preserving ecological integrity and connectivity and thus the welfare of the population in a complex tropical landscape.

Forest management for ecological restoration and conservation of ecosystem services around Mexico City: an applied, ongoing case study. Avila-Akerberg, V. (*Instituto de Ciencias Agropecuarias y Rurales, Mexico; vicaviak@gmail.com*), Hernández-Sánchez, P., González-Martínez, T. Almeida-Leñero, L. (*Universidad Nacional Autónoma de México, Mexico; amabel18@yahoo.com; tanyamgm@gmail.com; lucia0950@yahoo.com*), Endara-Agramont, Á., Nava-Bernal, G. (*Universidad Autónoma del Estado de México, Mexico; arendaraa@uaemex.mx; gnavab@uaemex.mx*), Del Ángel-Muñoz, M., García, X.,

Gómez-Álvarez, E., Ortíz-Fernández, R. (*Universidad Nacional Autónoma de México, Mexico; delangel@ciencias.unam.mx; xarhini9@hotmail.com; eileenfatima.92@comunidad.unam.mx; raquelof@ciencias.unam.mx*).

Mexico City possesses half of its territory in conservation areas covered with temperate forests, agricultural lands, and human settlements. These areas provide ecosystem services and goods that are fundamental to the city's functioning, mainly related to clean air, carbon storage and sequestration, water provision and infiltration, recreational spaces, and biodiversity conservation. With a population of more than 21 million inhabitants in Mexico City, its surrounding forested lands face enormous pressure from air pollution, water over-exploitation, and land use changes. We present an integrated proposal towards ecological restoration and conservation of a forested catchment of about 38 000 ha northwest of Mexico City, with a focus on ecosystem services and participatory management. The project involves water and soil conservation works, cropland enrichment through agroforestry, reforestation with native trees, improvement of a tree nursery, and communication materials development such as signs, flora and fauna field guides, and a documentary film aimed at raising people's awareness and participation. For a megacity like the Mexican capital, ensuring ecosystem services such as clean air and water is of crucial importance. However, conservation lines of action must consider people`s social capital improvement at all times, as well as an appreciation of nature's intrinsic value.

Trade-offs and synergies between ecosystem services in Nordic forests: what does this mean for forest management decisions? Filyushkina, A. (*University of Copenhagen, Denmark; anfi@ifro.ku.dk*).

The need for integration of various ecosystem services into forest management decisions has been widely acknowledged. However, due to the complexity of interactions between different ecosystem services, the trade-offs and synergies are not fully understood. This is the basis for valuing the multifunctionality of ecosystems for human well-being. The objective of this study was to provide insights into trade-offs and synergies between different ecosystem services in Nordic forests. The potential implications for forest management decisions are discussed. Data were collected from a systematic review of previous studies and a Delphi survey involving experts on ecosystem services. Ecosystem services such as carbon sequestration, recreation and aesthetics, biodiversity, and timber production were assessed against a set of forest stand attributes, which represent changes created by forest management activities in planted forests. The results showed the presence of functional forms that demonstrate synergies and trade-offs between different ecosystem services. The findings revealed the scope for integrative assessments of ecosystem services and their interdependence with forest management decisions.

Forest management at the landscape level: an integrated approach. Frank, S., Fürst, C. (*University of Bonn, Germany; Susanne.Frank@uni-bonn.de; cfuerst@uni-bonn.de*), Pietzsch, K. (*PiSolution GmbH, Germany; kp@pisolution.de*).

Integrated forest management is confronted with the challenge that the contribution of forests to economic and ecological planning targets must be assessed in the context of other land uses, such as urban or agricultural areas. Planners and decision makers have to balance interests of different land use sectors, and between private economic interests and public demands. Decision support systems have been developed to analyze the effects of changes in the land use pattern and management strategies. Often, temporal dynamics in changing landscapes are not considered in such integrated assessment approaches. With a focus on forest management, we present an approach that facilitates the appraisal of forest growth and yield in 5-year steps. Output parameters for the assessment of alternative management strategies are, for example, the harvestable stem volume, the fuel value of a landscape, or main assortments. Planners can investigate the effect of forest management strategies in a landscape 1) on the provision of lignocellulosic resources from agriculture, forestry, and urban areas and 2) on several ecosystem services. Together with foresters, forest managers, and regional planners we develop integrated forest management strategies which contribute to an efficient resource management.

From forest functions to forest ecosystem services (ES): benefits from introducing the ES concept. Fürst, C. (*University of Bonn, Germany; cfuerst@uni-bonn.de*).

The concept of ecosystem services (ES) has most recently and with increasing success been introduced to land use planning (ESP WG 9 ES in Planning, Management and Restoration). In forestry, however, this concept is still separate from the much more long standing and well approved multifunctionality approach, which attempts in a very similar manner to balance economic considerations against societal and ecological aspects in planning. From a forest management planning perspective, the introduction of the ES concept is therefore not necessarily required. Considering the increasing public participation interest in natural resources use and design of landscapes, the use of the ES concept might, however, be recommended. By means of a case study, we demonstrate how to assess in a participatory manner forest management strategies with a number of case-study-specific ecosystem services and how the outcomes can be introduced in territorial planning. Our conclusion is that embedding the forest multifunctionality concept into and co-evolution with the ES concept in integrated land use planning will be beneficial to support stakeholder communication, to increase acceptance of forest management requirements, and finally to enhance the perception and understanding of the role and contribution of forests to human well-being.

Spatial modeling of ecological-economic tradeoffs: bioenergy production and biodiversity conservation in the Alps. Fuss, S. (*Mercator Research Institute on Global Commons and Climate Change, Germany; fuss@mcc-berlin.net*), Kraxner, F., Leduc, S., Forsell, N. (*International Institute for Applied Systems Analysis, Austria; kraxner@iiasa.ac.at; leduc@iiasa.ac.at; forsell@iiasa.ac.at*).

Renewable energy is considered a cornerstone of the European Union (EU) climate change mitigation policy and at the same time is gaining importance in response to moves by Germany, Switzerland, and partially also Italy to distance themselves from nuclear power solutions. According to the Alpine Convention's Energy Protocol, the Alpine region will make a long-term contribution to meeting Europe's energy needs. However, other ecosystems services and most notably biodiversity often compete with renewable energy and especially bioenergy/forest management for productive sites and thus there are important tradeoffs to be analyzed and understood to maintain ecosystem functions and services. The study presented used a spatial optimization model to determine the cost-optimal location of bioenergy plants for the production of centralized heating/cooling, electricity, and biofuels under sustainability criteria at different scales (the Alps versus selected Alpine pilot regions, where higher-resolution data are available).

In addition, the analysis did not intend to assign a monetary value to biodiversity and other ecosystems functions, but progressively excluded areas from the optimization process according to a ranking of the ecosystem services they provided, thereby tracing out the marginal costs of protecting those areas.

Payment for environmental services aims to combat desertification in Irauçuba, Ceará, Brazil. González Carantón, M. *(Federal University of Paraná, Brazil; marcocaranton@gmail.com*).

According to the Brazilian Institute of the Environment, Irauçuba (city located in the Brazilian northeast) is classified as one of the cores of intense desertification, being one of the most arid areas of the world. Therefore, there are problems of overuse or improper use of natural resources such as overgrazing, expansion of monocultures, and the cutting and burning of trees for timber. The frame of payments for environmental services (PES) represents an approach focused on generating positive environmental externalities through socioeconomic incentives for custodians of ecosystem resources. In order to propose management tools that seek to solve the problems mentioned before, this paper presents a model of local public management on PES by means of the participation of communities. The study showed important results. First it analyzed the social and environmental impacts of desertification. Then it determined the social and ecological values of environmental services to establish public frames for PES. The valuation gave priority to a dignified and productive livelihood from the arid and semiarid areas. Furthermore, the study proposed an innovative way to change land use by improving forest vegetation. Finally the study suggests important policy-oriented recommendations to combat the social implications of desertification.

Incentive payments for plant biodiversity conservation in forests: dynamic and spatial analysis. Hily, E., Garcia, S., Stenger, A. *(National Institute for Agricultural Research (INRA), France; emeline.hily@gmail.com; serge.garcia@nancy.inra.fr; anne.stenger@nancy.inra.fr*).

Global warming leading to a north-south migration of species casts doubt on current static approaches for biodiversity conservation such as natural protected areas. The aim of this research is to define economically efficient incentive payments allowing vegetal biodiversity conservation in forests in a context of global warming and privately owned land. A regulator aims at maximising ecological benefits (linked to the conservation of a target plant species in its initial natural range as well as in its future northern natural range) under compatible participation and incentive constraints of different forest owners in order to minimize information rents. Thus, definition of payments considers heterogeneity of private ownerships as well as forests and species, triggering spatial heterogeneity of conservation costs. In order to guarantee dynamic effectiveness, payments are adapted to the temporal evolution of forests and species due to global warming, triggering temporal heterogeneity of conservation costs. Defining economically and ecologically efficient incentives requires working at several scales; we model owner decisions whether to participate with biodiversity conservation at the single forest property level and define and differentiate incentive payments at the local and regional scale.

The potential of payment for watershed protection in Ndaka-ini Dam, Murang'a County, Kenya. Kagombe, J. (*Kenya Forestry Research Institute, Kenya; jokagombe@yahoo.com*), Kungu, J. (*Kenyatta University, Kenya; kungujames@gmail.com*).

Payment for environmental services (PES) links suppliers and consumers of goods and services from a natural resource in a way that both parties contribute to improved delivery. The study evaluated the feasibility of PES, in particular hydrological services, at Ndaka-ini Dam, the biggest water reservoir for Nairobi city and its environs. The major objective of the study was to determine whether water suppliers and users would participate in watershed protection through PES. This study identified 1) changes in land use and their effects on water quality and quantity, 2) factors that influenced willingness of water users to pay for environmental services, 3) environmental services farmers were willing to accept, 4) and economic incentives buyers were willing to provide. Results showed that land use affected water quality with Nairobi Water Company incurring heavy costs for treatment. Farmers upstream were willing to adopt environmentally friendly conservation practices in return for incentives, while users were willing to provide incentives, though much lower than farmer expectations. However, mechanisms to plough back incentives need to be strengthened. This study gives guidelines for the better adoption of PES as an innovative financing mechanism for better management and conservation of catchments areas.

Ecosystem services in urban forest areas: balancing carbon storage and biodiversity. Lafortezza, R., Pesola, L., Elia, M., Colangelo, G., Sanesi, G. (*University of Bari, Italy; raffaele.lafortezza@uniba.it; lucia.pesola@uniba.it; mario.elia@uniba.it; giuseppe.colangelo@uniba.it; giovanni.sanesi@uniba.it*).

The Millennium Ecosystem Assessment (MEA) contains compelling arguments that human well-being largely depends on the services provided by ecosystems and that, in some cases, these services have become so compromised that we can expect negative feedbacks to people. However, in some cases, actions and strategies to enhance the supply of ecosystem services, mainly those focusing on reducing carbon emissions, have led to declines in other services. The MEA approach is based on the notion that resource management involves trade-offs among ecosystem services and that quantitative and scientifically based assessment of the trade-offs is essential for sound decision-making. Consequently, there is now considerable interest in establishing new approaches to quantify the trade-offs between ecosystems services, particularly in relation to biodiversity. The approaches must also account for the varying spatial and temporal scales over which management decisions affect ecosystem services. In this paper, we investigate ecosystem services in urban forest areas by analyzing the relationship between carbon storage in biomass and the amount and patterns of biodiversity at different spatial and temporal scales. By understanding this relationship, we should be better able to incorporate ecosystem services into urban areas thus informing land-use and management decisions and to maximize the net benefits that ecosystems deliver to urban society.

Spatial-temporal analysis of forest ecosystem services in southern Chile. Locher Krause, K. (*Helmholtz Centre for Environmental Research-UFZ, Germany; karlalocher@gmail.com*), Lautenbach, S. (*University of Bonn and Helmholtz Centre for Environmental Research-UFZ, Germany; sven.lautenbach@uni-bonn.de*), Volk, M. *(Helmholtz Centre for Environmental Research-UFZ, Germany; martin.volk@ufz.de*), Waske, B. (*Free University Berlin, Germany; bwaske@uni-bonn.de*).

Globally, forest ecosystems have faced an important process of transformation during the last decades. This transformation has led to a decrease of primary and secondary forest, in terms of their spatial extent and quality, as well as their ability to support ecosystem functions and services. Remote sensing methods can play an important role to identify the transformation of these ecosystems and their driving forces. A time-series analysis of Landsat data (1985–2013) was used to identify the trajectories of forest ecosystems in the south of Chile at a regional scale. Changes were analyzed in the context of the ecosystem service framework. Provisioning (crop production, livestock production), regulating (carbon storage, soil retention, surface water quality), and cultural (forest recreation) ecosystem services were analyzed, taking in account sets of services that appear together. The results show a decrease of primary forest as well as grassland and arable land while exotic forest plantations increased in the entire study area. The impacts of these changes on the selected ecosystem services were assessed together with a tradeoff analysis. This has implications for suitable management and territorial planning in this area which are discussed as well.

Operationalization of the concepts of ecosystem services and natural capital: forest ecosystem functioning and trade-offs. Luque, S. *(National Research Institute of Science and Technology for Environment and Agriculture, France; sandra.luque@irstea.fr*).

The concept of ecosystem services (ES) provides a powerful way of examining the interaction between ecosystems and human well-being, which are at the heart of landscape ecology science. Despite improved understanding of the potential of landscapes and their land use systems to provide human well-being and socioeconomic benefits, further conceptual and empirical work is needed to translate the concepts into operational frameworks for integrating ES into management and decision-making. The basic ecosystem service/natural capital framework links the ecological system (biophysical structure and function) to the social system (benefits and values) and helps explore the multidimensional role that geographical location can have in operationalizing the concept. We will present a range of spatially explicit methods of varying complexity to gain understanding on forest ecosystem functioning and trade-offs in different geographical contexts within the framework of the European Union project OpenNess (http://www.openness-project.eu/).

Exploring the relationship between tree species diversity and forest ecosystem services in the face of climate change. Perez, S., Rammer, W., Seidl, R., Lexer, M. (*University of Natural Resources and Life Sciences, Austria; susana.perez@boku.ac.at*; *werner.rammer@boku.ac.at; rupert.seidl@boku.ac.at; mj.lexer@boku.ac.at*).

The loss of biodiversity in forest ecosystems has motivated ecological research that links biodiversity, ecosystem functioning, and the provisioning of ecosystem services (ES). Interest in this topic has been amplified by expected climate changes. However, current scientific knowledge of how tree species diversity impacts essential ES is still scant. Furthermore, the potential effects of climate change on this relationship remain unknown. This contribution presents a simulation experiment investigating tree diversity, biomass productivity, carbon sequestration, and water cycles under current climate and transient climate-change scenarios. The process-based forest patch model PICUS v1.6 is employed in the Hainich National Park (Germany) and in Râșca, a submontane region in Romania. Preliminary results confirm a positive correlation of tree diversity and biomass productivity which saturates at higher diversity levels. Increasing species diversity seems to increase water consumption as well and consequently lowers groundwater recharge. Studying transient ES provisioning under climate change scenarios indicated the importance of species traits (e.g., regeneration mode, growth pattern) for maintaining ES. Habitat structure (i.e., related to bird species requirements) could be better maintained at higher diversity levels. The findings imply that the relevance of species diversity may vary depending on the required ES portfolio and site conditions.

Landscape sustainability in Sweden, Canada, and Chile in an ecosystem services context. Svensson, J. (*Swedish University of Agricultural Sciences, Sweden; johan.svensson@slu.se*), Johnston, M. (*Saskatchewan Research Council, Canada; johnston@src.sk.ca*), Sandström, P. (*Swedish University of Agricultural Sciences, Sweden; per.sandstrom@slu.se*), Alvarado, W. (*Araucarias Alto Malleco Model Forest, Chile; wservet@hotmail.com*).

Context and matrix have received increasing importance in understanding and empowering local socioecological sustainability in rural communities. The ecosystem services approach, in particular, has provided innovative tools and possibilities to weigh, compare, and balance various services and goods that are made available in different habitats and land cover types in a landscape continuum. This study includes large-landscape case studies in Sweden, Canada, and Chile (the Vilhelmina, Prince Albert, and Araucarias del Alto Malleco Model Forests). Despite different premises, the case studies share fundamental aspects of rural community sustainability problems and solutions, e.g., marginalized indigenous peoples, dependence of natural resources, and the importance of small-scale and site-specific livelihood and manufacturing of natural resources. In addition, the study sites represent a comprehensive gradient of duration and degree of land-use impact and, hence, the need for landscape restoration. In an ecosystem services context these case studies allow for multifunctional, scale-independent and spatially explicit assessments of good and services from alpine, agricultural, and forest habitats. Opportunities and barriers for sustainability, from various perspectives, are explored using large-landscape modeling, planning, and scenario analyses.

B-06 Research and management implications of the economics of ecosystem services

Organizers: Donald Hodges (University of Tennessee, USA), Donald Grebner (Mississippi State University, USA) & Runsheng Yin (Michigan State University, USA)

An investigation of nationality and distance dependence for biodiversity transnational coordination. Bakhtiari, F., Bredahl Jacobsen, J., Jellesmark Thorsen, B., Strange, N. (*University of Copenhagen, Denmark; fba@ifro.ku.dk; jbj@ifro.ku.dk; bjt@ifro.ku.dk; nst@ifro.ku.dk*), Boman, M. (*University of the West Indies at St. Augustine, Trinidad and Tobago; mattias.boman@sta.uwi.edu*), Gibbons, J. (*Bangor University, UK; j.gibbons@bangor.ac.uk*).

According to conservation management models, increasing international collaboration could increase biodiversity protection and cost-effectiveness. The underlying assumption of internationally coordinated biodiversity is that biodiversity is a public good in the countries affected by conservation policies, and the value of biodiversity protection is independent of geographical and political jurisdiction. If this is not the case, the internationally coordinated policies may have different welfare economic consequences compared to national ones. Thus, the main objective of the current paper is to investigate the dependency of distance and nationality on willingness-to-pay (WTP) for biodiversity conservation. Using a choice experiment, the individual's marginal utility for biodiversity protection was estimated in three comparable study locations in Denmark and southern Sweden, with the location as an explicit attribute. We explored the extent to which the marginal WTP in the two neighbouring countries, with similar biodiversity levels, is affected by both nationality and distance from the location. The results show the marginal rate of substitution of both nationality and distance from the policy location are significant. This suggests that WTP of respondents for biodiversity protection as a public good, both material and non-material values, depends on nationality and distance scales.

Walking the land: building an ecosystem approach in the Highlands and Islands by connecting cultural drivers with woodland expansion interests. Bowditch, E. (*University of the Highlands and Islands, UK; euan.bowditch.ic@uhi.ac.uk*).

The Highlands and Islands of Scotland are steeped in a history of land use conflict. Traditional private sporting estates dominate the landscape, which prioritise management for hunting and tourism. There is little impetus for woodland to become an important consideration for the majority of landowners due to poor past decision-making, perceived management issues, and a lack of commercial value for current stagnating stands. Scotland's woodland expansion strategies and push for domestic renewable energy sources has refocused the potential role of woodlands but landowner engagement remains a difficult barrier. An inductive approach is taken to explore the cultural drivers behind decision-making by working in the field with individual landowners and managers within three contiguous private estates, over four diverse case-study areas. Using resilience theory and a landscape approach, the study combines qualitative interview data (Dictaphone & GPS), spatial mapping (mobile mapping app), economic options (forest energy tool), and clustered land use collaboration workshops, enabling the researcher to build a detailed picture of a woodland's future within a traditional sporting landscape and how an ecosystem approach might begin to reconcile clashing land uses.

Public management model in payment for environmental services in the Sabiaguaba Dunes Natural Park, Fortaleza, Brazil. González Carantón, M. *(Federal University of Paraná, Brazil; marcocaranton@gmail.com*).

Wetlands are fragile ecosystems that are essential to maintain services and livelihoods of traditional communities. They are seriously threatened by development. Mangroves of the Sabiaguaba Dunes Natural Park, in Fortaleza, Brazil, are no exception. The direct and indirect dumping of industrial and domestic waste in the hydric resources, mismanagement of waste, and increasing urban invasion have caused serious impacts. Aware of the problem addressed, the proposed method aimed to restore this ecosystem through compensation to local residents. While giving ecosystem custodians empowerment, the proposal implemented a relevant conservation practice through the compensation of socioenvironmental benefits. The methodology included a socioecological qualitative valuation for wetland ecosystem services (water provision, food, protection, and regulation) and cost analysis (opportunity, implementation, and maintenance). The results show a clear improvement in the socioeconomic conditions of local communities, exceeding their actual rent and providing solutions to structural problems (collected through surveys). Moreover, the study emphasized the formation of a common fund to finance the program. In conclusion, the proposal helped the systematization of environmental and social guidelines, aiming to continue the flow and ties among ecosystems services, the local community, and the extractive industries within the territory.

Bio-econometric analysis of the efficiency of payments for biodiversity conservation: a case study of Natura 2000 forest contracts in France. Hily, E., Garcia, S., Stenger, A., Tu, G. *(National Institute for Agricultural Research (INRA), France; emeline.hily@gmail.com; serge.garcia@nancy.inra.fr; anne.stenger@nancy.inra.fr; gengyang.tu@nancy.inra.fr*).

Biodiversity conservation literature underlines the need for efficient instruments in economic and ecological terms. As a great part of biodiversity is found on private land, conservation tools have to give the right incentives. In this research, we empirically assessed the efficiency of payments for Natura 2000 forest contracts in France, a payment-for-ecosystem-services-like scheme, aiming at biodiversity conservation. The contribution of this paper consists of a bio-econometric analysis of private and public contracts based on the study of biodiversity provision costs. Through the development of a biodiversity indicator, we estimate a cost function for biodiversity provision. We assess the efficiency of contracts in terms of ecological benefits and cost-efficiency. Our results show that payments for Natura 2000 contracts are inadequately defined. Payments do not consider opportunity costs, impeding satisfactory participation, especially for private forest owners who are the most cost-efficient biodiversity producers. We showed that the cost-elasticity term for biodiversity provision is significantly lower than 1. Despite being less cost-effective biodiversity producers, public stakeholders are able to bear higher opportunity costs than private owners and provide greater ecological benefits. We conclude that payments for Natura 2000 forest contracts should be redesigned to make them give the right economic incentives.

Economic value of the recreation role of a selected urban forest in Slovenia's capital: new information supporting sustainability in forest management planning. Japelj, A. (*Slovenian Forestry Institute, Slovenia; anze.japelj@gozdis.si*), Mavsar, R. (*European Forest Institute, Finland; robert.mavsar@efi.int*), Kovač, M. (*Slovenian Forestry Institute, Slovenia; marko.kovac@gozdis.si*), Hodges, D. (*University of Tennessee, USA; dhodges2@utk.edu*).

For forests to provide ecosystem services they should be managed sustainably, meaning ecological, social, and economic aspects of society's needs must be accounted for. To lay ground for this, a multifaceted approach should be taken to obtain people's preferences for different services. Determining preferences for services that do not have a market price comparable to economic services can be achieved by various techniques. Discrete choice method is one such tool. It was employed in a study of the recreation role of an urban forest within the Slovenia's capital. The survey approach consisted of 262 face-to-face and web-based questionnaires. The central part consisted of nine choice sets, combinations of levels of four attributes defining the recreation role

of forests, determined by sequential fractional factorial technique. Due to an additional attribute, payment vehicle, implicit price for the attributes (special trees, forest clearings, forest paths, and waymarks/info-boards) could be derived by means of a multinomial logit model. On average people would be willing to contribute 0.3€ for an additional 1% of special trees, 0.8€ for additional 1% of forest clearings, 5€ for maintaining waymarks/info-boards and 0.06€ for each additional kilometre of paved paths. It is shown how this information can be used in forest management planning.

Harmonizing applications of economics and ecology to evaluate ecosystem services tradeoffs in public lands management, an Oregon example. Kline, J., Spies, T. (*U.S. Forest Service, USA; jkline@fs.fed.us; tspies@fs.fed.us*), Harmon, M. (*Oregon State University, USA; mark.harmon@oregonstate.edu*).

The ecosystem services concept has re-emphasized the longstanding desire among many forest managers and policymakers to describe and evaluate the multiple benefits of public forest management. However, operationalizing the ecosystem services concept in routine management applications is challenging due to the complexity and analytical limitations of integrated economic and ecological models. We consider these challenges in light of both the information needs of managers and the resources available for analysis. We propose that an economic-ecological analysis to support management involves a compromise between expediency and theoretical and analytical rigor, and suggest ways to present ecological information in a manner that is consistent with economic theory of tradeoffs. We illustrate potential approaches by drawing on an ongoing analysis of timber, carbon storage, and biodiversity tradeoffs associated with forest management in select landscapes of the Pacific Northwest and northern California (USA). Our work involves using established models describing forest growth (FVS), forest carbon (LandCarb 3), wood products (ForProd 2), and wildlife habitat capability models, to project and examine the outcomes of different management scenarios. We examine how tradeoffs vary as a function of management scenarios and landscape types, and consider the degree to which such information would be useful to public forest managers.

Remote sensing and field-level evaluation of payments for forest conservation: Ecuador's Socio Bosque Program. Mohebalian, P., Aguilar, F., Lopez, L. (*University of Missouri, USA; pmmrn@mail.missouri.edu; aguilarf@missouri.edu; lnl8t7@mail.missouri.edu*).

Payments for environmental services (PES) correct for externalities and improve the economic competency of natural land cover uses by providing a financial incentive to encourage conservation. Ecuador's diverse forest ecosystems have one of the highest rates of deforestation in South America. The Socio Bosque Program (SBP) is a type of PES instituted in 2008 by Ecuador's Ministry of the Environment (MAE) to prevent deforestation and degradation in line with United Nations' REDD+ program to reduce and prevent greenhouse gas emissions. The objectives of this study were to 1) quantify the capacity of the SBP to influence landowner behavior and reduce deforestation and degradation (additionality) and 2) identify contractual attributes that can promote greater landowner participation. This is one of the first studies to model individual landowner behavior, rather than using coarser-scale data, in reaction to a PES program in combination with remote sensing data to assess additionality. Also, it is a pioneer in evaluating forest degradation by using remote sensing and ground truthing in a low-land tropical humid forest. Analysis of contractual attributes of the SBP is critical to evaluate landowner participation and estimate costs linked to payment levels, and will help guide future efforts in Ecuador and the region.

An assessment of revenue loss from legal timber in Indonesia. Mumbunan, S. (*University of Indonesia, Indonesia; mumbunan@gmail.com*), Wahyudi, R. (*Article 33 Indonesia, Indonesia; yudi_ikhwah@yahoo.co.id*).

Research that looks at potential revenues of extractive rents from forest ecosystem services, its gap to collected revenues, while making specific reference to the administration of forest revenue chain, has been missing. This is one of the first studies to systematically look at such a relationship. Using official data for legal timber, this study assesses revenue loss from timber royalty fee (Provisi Sumber Daya Hutan, PSDH) and reforestation fund (Dana Reboisasi, DR), two important forest non-tax revenues in Indonesia whose tropical forest is under threat of extensive deforestation, particularly from commercial timber logging, and is one of the world's largest carbon emitters from deforestation and forest degradation. Results show that revenue realizations do not reflect potentials with two intriguing findings. First, PSDH weighted average revenues represent only 51% of its potential and are much lower with market price assumptions. Second, DR revenue shows a counter-intuitive pattern; its revenue realization is 138%, exceeding its official potential revenue. Plausible explanations for these findings are provided in relation to aspects of billing, payment, and reporting. This paper discusses policy relevance for the management of revenue from forest ecosystem services and the use of revenue instruments in forest-based climate change mitigation (REDD+).

Economic evaluation of carbon capture in the APA Serra de Baturité, Brazil, 2012. Plata Fajardo, A. (*Federal University of Paraná, Brazil; aplatafa@gmail.com*).

Forest carbon capture is a mechanism to reduce greenhouse gases. Trees, through the process of photosynthesis, absorb carbon dioxide (CO_2) from the atmosphere and store it as biomass. The environmental protection area (APA) was the motivation to develop this study. The main objectives were to quantify and assess the financial viability of the generation of carbon credits. The quantification of CO_2 storage was estimated by the non-destructive method (based on forest inventory estimates) and the economic criteria used to evaluate were the net present value (VPL), the equivalent annual value (EAV) and the internal rate of return (IRR). The results show that the rainforest of the APA Serra de Baturité captured, on average, 84.63 t CO_2/h, and according to market prices and costs in 2012, forest management for carbon capture would be not be viable in the Clean Development Mechanism. In contrast, the projects were viable if sold in the New Zealand Emission Trading Scheme (TIR = 135) and in the Over the Counter (TIR=74). To summarize, the carbon forest project in the APA Serra de Baturité is economically viable. Moreover, this study provides a suitable methodological guideline for economic evaluation of carbon capture projects.

Economics of forest fire management: accounting of benefits. Sanchez, J. (*U.S. Forest Service, USA; jsanchez@fs.fed.us*), Baerenklau, K. (*University of California, USA; kenneth.baerenklau@ucr.edu*), González-Cabán, A. (*U.S. Forest Service, USA; agonzalezcaban@fs.fed.us*).

The objective of the study is to provide fire managers relevant information for decision making for fire risk assessment that supports forest management strategies. Using a nonmarket valuation approach, this study evaluates the recreation values of the San Jacinto Wilderness in southern California. Our analysis utilizes survey data from a stated-choice experiment involving backcountry visitors who responded to questions about hypothetical wildfire burn scenarios. Benefits of landscape preservation are derived using a Kuhn-Tucker (KT) demand system. Model results suggest that recreationists are more attracted to sites with recent foreground wildfires. For example, recreational welfare estimates increased for sites that were partially affected by different types of wildfires, with the greatest gains being observed for the most recent wildfires. Welfare analysis indicates that seasonal aggregate losses for complete closure of particular sites ranged from $0.5 to $5 million. Results can be used to improve our understanding of how landscape and wildfire characteristics contribute to recreation values and thus our ability to value natural resources in a recreation context. It also provides relevant information for decision making.

Experimental differentiated valuation of forest services' socioeconomic importance in the frame of the Czech Republic. Šišák, L., Jarský, V., Kupcak, V. (*Czech University of Life Sciences Prague, Czech Republic; sisak@fld.czu.cz; jarsky@fld.czu.cz; kupcak@fld.czu.cz*).

Methods of forest services' socioeconomic importance valuation are differentiated by their relationships to the market, by the purpose of their use, and by input data availability; values are expressed relative to other usual soil covers (grassland, arable land, and solid soil cover). Valuation of direct market timber production forest service is based on the mean year income from timber sales, while hunting and game management forest service on market incomes from the respective activities. Valuation of mediated market impact hydrological forest services is performed by costs of prevention, soil protection services by costs of compensation, and CO_2 sequestration by shadow prices of trade with CO_2. Valuation of non-market health-hygienic and cultural-scientific forest services is based on expert approach using a comparative method, i.e., comparing their socioeconomic importance to the socio-economic importance of market services, as for example, timber production. Total value of forest services in the Czech Republic compared to sustainable grassland services reaches 1 973 million EUR annually, and 98 995 million EUR capitalized value, compared to arable land services value of 3 631 million EUR annually and 181 517 million EUR capitalized value, and compared to solid soil cover services value of 2 544 million EUR annually and 127 207 million EUR capitalized value.

Lessons learned from China for designing and implementing payments for ecosystem services initiatives. Yin, R. (*Michigan State University, USA; yinr@msu.edu*).

Inadequate work has been done to examine how to design and execute a PES program, and the existing literature has rarely treated PES as entailing multi-faceted, complex interactions of stakeholders, resource and governance systems, external social-ecological settings, and internal conditions and capacities. This paper aims to fill this critical knowledge gap by casting China's experience of restoring degraded cropland under the Sloping Land Conversion Program (SLCP) into the integrative framework for studying social-ecological systems and deliberating what can be learned from it. These efforts will lead to the emergence of a number of important lessons from the ecological, socioeconomic, and institutional perspectives. The timely and important messages conveyed will contribute to advancing the science and practice of PES-based ecological restoration and nature conservation.

Participatory and multi-criteria analysis for forest ecosystem management: a case study of Pohorje, Slovenia. Zadnik Stirn, L. (*University of Ljubljana, Slovenia; lidija.zadnik@bf.uni-lj.si*), Hodges, D. (*University of Tennessee, USA; dhodges2@utk.edu*), Grošelj, P. (*University of Ljubljana, Slovenia; petra.groselj@bf.uni-lj.si*).

The primary aims of forest management are to evaluate the effects of forest management strategies on human communities, landscapes, and the development of forest services, and to consider the possibilities for achieving a balance between the economic, environmental, social, and cultural sustainable uses of forests. Multi-criteria decision methodology offers the best alternative to address such forest management issues, particularly as they involve multiple stakeholders including local communities, public representatives, and environmentalists, each of which has different knowledge, experiences, and prospects. Group methods, based on participatory planning, can be applied to integrate such different interests into a joint decision. It is for this reason that the analytic hierarchy process (AHP) group decision model was designed. In the presented case study of the forest area at Pohorje, a mountainous area in northern Slovenia, Europe, the optimal alternative for Pohorje development was selected using the generated model. Six possible management strategies based on indicators of sustainability were identified and the strategies were compared by several stakeholders according to the results of a SWOT analysis performed at a workshop where individual chapters of forest management scenarios were discussed. The results reveal that most attention should be devoted to preservation of cultural heritage and local tradition and environmental and consumer-friendly usage of natural resources.

B-07 Silvicultural practices to facilitate forest restoration

Organizers: Byung Bae Park (Chungnam National University, Republic of Korea), Palle Madsen (University of Copenhagen, Denmark) & Bryan Finegan (CATIE, Costa Rica)

Forest restoration is more than tree planting: the case of fire-disturbed southern bog forests. Bannister, J., Bauhus, J. (*University of Freiburg, Germany; janlija@yahoo.com; juergen.bauhus@waldbau.uni-freiburg.de*).

Five years ago we commenced a long-term research project on Chiloé Island, North Patagonia, dealing with the study of the ecology and restoration of disturbed southern bog forests dominated by the slow-growing conifer *Pilgerodendron uviferum*. Using a multi-scaled approach, we focused research on the following questions: 1) can *P. uviferum* forests persist in the absence of large-scale disturbances; 2) to what extent natural regeneration from seeds of remnant *P. uviferum* trees may facilitate recolonization of disturbed forests, and 3) how important are microsite conditions for successful restoration planting of *P. uviferum* forests? To answer this, we mapped seed trees in disturbed forests at a landscape level and established seed dispersal, germination, and

active restoration experiments. Our results show that *P. uviferum* is a stress-tolerant conifer that can regenerate and grow under conditions of low light and low fertility. In disturbed forests, natural regeneration from dispersed seeds of remnant trees can effectively facilitate forest restoration. However, at the landscape scale, after high-severity fires, there are vast areas without seed trees of the species. In this context, a mixed passive-active restoration approach will be the most effective and efficient option for the restoration of degraded *P. uviferum* bog forests.

Achieving "groupy-clumpy" in restoration projects: innovative silviculture and monitoring in the Front Range Collaborative Forest Landscape Restoration Project. Dickinson, Y. (*Colorado State University, USA; yvette.dickinson@colostate.edu*), Colorado Front Range Roundtable Landscape Restoration Team (*Front Range Roundtable, USA; gali@behconsulting.com*).

Fire suppression during the past century has led to increased density of many lower montane forests of Colorado's Front Range. This increased density and canopy contiguity has reduced open-woodland habitat, and may increase the likelihood of large uncharacteristically severe wildfires and insect outbreaks. These concerns have led to calls for forest restoration to create spatially heterogeneous ("groupy-clumpy") forest stands with groups of trees, single isolated trees, and openings, and to reconstruct a complex mosaic of forest structure across the landscape. However, the creation of these structurally diverse stands and landscapes has been difficult to achieve and monitor using conventional methods. Furthermore, it has been difficult to reach a consensus regarding the specific desired future conditions in any detail. The Front Range Collaborative Forest Landscape Restoration Project has taken an adaptive management approach to these problems, making iterative improvements to the silvicultural prescriptions and monitoring methods employed. We will present the innovative approaches that the collaboration has developed for implementing and monitoring spatially heterogeneous restoration treatments, and discuss the successes and lessons learned by this project.

Successional trajectories in tropical restored forests using direct seeding of fast-growing species. Engel, V. (*São Paulo State University, Brazil; veralex@fca.unesp.br*), Parrotta, J. (*U.S. Forest Service, USA; jparrotta@fs.fed.us*), Nogueira, Jr., L. (*EMBRAPA, Brazil; lauro.nogueira@embrapa.br*), Sato, L. (*São Paulo State University, Brazil; lu_sato7@hotmail.com*), Martins, A. (*Usina São Manoel, Brazil; andreza_martins@yahoo.com.br*).

In tropical countries, where forest loss is an issue of major concern, cost-effective restoration techniques may facilitate large-scale ecosystem restoration programs. Among low-cost alternatives, some direct seeding methods may promote fast canopy cover and weed suppression. In 1997, we implemented a direct seeding experiment using five fast-growing, light-demanding native tree species in two sites with contrasting soil fertility levels (site 1, red Alfisol; site 2, red-yellow Ultisol) and landscape context, at Botucatu, São Paulo, Brazil. Initial sowing density was 10 000/ha. While stand canopy density fluctuated among sites and years, canopy species richness and basal area consistently increased in both sites, from 2.5 to 16 years after implantation. Biomass and net primary productivity also increased with age to 13 years, and slowly decreased thereafter. The number of native species that recruited respectively in site 1 and 2 (height $\geq$1.30 m) increased from 19 and 34 at 7 years to 64 and 56 at 16 years, while total density increased from 209.3 and 558.8 to 911 and 2 885 in the same sites. During the period, a shift in the canopy dominant species was observed, followed by an increase in the mortality rates of planted species and in the recruitment of native tree species.

A mixed species, clearcut silviculture system to restore native species composition and structure of old-growth forests in western Washington. Ettl, G. (*University of Washington, USA; ettl@uw.edu*).

The conversion of high-density *Pseudotsuga menziesii* plantations to more diverse forest species composition and structural attributes, similar to old-growth forests, has received considerable attention. Old-growth forest structure is known to provide habitat to *Strix occidentalis* and *Brachyramphus marmorat*, and therefore silviculture to more rapidly advance stand development has been proposed. A prescription known as variable density thinning has been commonly used to facilitate old-growth development. I describe an alternative multi-species system that begins (and potentially ends) with a clearcut regeneration harvest as a means of producing old-growth composition and structure. I use a conceptual model to present a multi-entry, 300-year rotation aimed at extracting timber, and facilitating multi-layered canopies. Site index and stand density diagrams, in conjunction with conceptual stand development diagrams were used to project an initial multi-species planting of 10 species through time. At regular increments trees are harvested by selecting poor positioned and short-lived species (e.g., *Alnus rubra*) first and moving toward enhancing large *Thuja plicata* and *Tsuga heterophylla*, with lesser volumes of *Pseudotsuga menziesii* by age 300. The approach will be compared to projections of stands under variable density thinning.

Potential plant functional groups for the restoration of moist forests in the region of Bajo Calima, Colombia. Fernandez Mendez, F. (*University of Tolima, Colombia; fmendez@ut.edu.co*), Bocanegra-Gonzalez, K. (*University of Tolima, Colombia, and Federal University of Lavras, Brazil; kellynda7_7@hotmail.com*), Melo Cruz, O. (*University of Tolima, Colombia; omelo@ut.edu.co*).

Functional traits of plants show the plants' succession behavior and serve to break up the complexity of highly diverse tropical forests into groups of potential use for restoration planning. In Bajo Calima, Colombia, where secondary forests are predominant, reproductive traits that indicate the temperament of species in different succession stages were selected. Based on this selection, six groups were determined: 1) large-sized seeds dispersed by birds and mammals; 2) medium-sized seeds dispersed by birds and mammals; 3) small berry fruits dispersed by birds; 4) small seeds dispersed by wind; 5) drupes dispersed by mammals and birds; and 6) palm species and other species dependent on mammals. It is suggested to use the first two categories in forests that are not heavily degraded, as their species have the potential for active restoration and enrichment; groups 3 and 4 should be used on sites that have suffered more strongly from human intervention as they reproduce easily and are easily dispersed. The two remaining groups are suited for further stages of restoration on sites improved with the first group and on sites that are not strongly degraded. Finally, it is proposed to start reproduction studies for the groups and include them in the restoration processes for the entire Pacific region of Colombia and, enrich the suggested methods with local knowledge.

Reintroducing native Fagaceae species into planation forests in central Taiwan: identifying and alleviating establishment limitations. Guan, B., Lo, Y., Li, Y. (*National Taiwan University, China-Taipei; btguan@ntu.edu.tw; yuehhsin.lo@gamil.com; b95605089@ntu.edu.tw*), Lin, Y. (*Tunghai University, China-Taipei; yichingtree@gmail.com*), You, C. (*Taiwan Forestry Bureau, China-Taipei; r87625036@ntu.edu.tw*).

Developing strategies to restore plantation forests that are either degraded or no longer serving timber production is essential for biodiversity conservation. To facilitate the reintroduction of native late-successional Fagaceae species into Japanese cedar (*Cryptomeria japonica*) plantations in central Taiwan, we first identified and subsequently experimented with methods to alleviate the establishment limitations. Based on the results from direct sowing of both fresh and germinating acorns, and planting seedlings and saplings of various ages, we identified acorn consumption by wildlife as the most critical factor hindering the establishment. To alleviate the limitation, thinning in combination with ground vegetation control, chemical repellents, and physical retardation methods were tested. Results showed that the most effective strategy is physical retardation, followed by silvicultural treatments. Chemical repellents, such as cinnamamide, commonly used in other areas, had no effect, even in high concentrations, likely because the Lauraceae species are also the native dominants. The results of the study suggest that, although expensive, direct seedling planting or establishing physical retardations to prevent seed consumption will be the most effective strategies. Seedling survival would also be enhanced by the combination of direct sowing of germinating seeds, thinning, and the retention of the understory vegetation cover.

Biodiversity response to trees retained at final harvest for conservation purposes: a meta-analysis. Gustafsson, L., Fedrowitz, K. (*Swedish University of Agricultural Sciences, Sweden; lena.gustafsson@slu.se; katja.fedrowitz@slu.se*).

Industrial forestry leads to a simplified forest structure and species composition. A main evolving approach to mitigate the impacts of logging on biodiversity is retention of trees at final harvest, and retention forestry is today practiced on several continents in boreal and temperate regions. Numerous studies have been performed on the effects of retention of trees on biodiversity but to date there has been no comprehensive review summarizing the effects on forest species and open habitat species, respectively, compared to open clearcuts as well as forest. We performed a meta-analysis following a systematic review protocol including 653 comparisons between treatment and control from 78 articles. Compared to clearcuts, the effect of retention trees was significantly positive for forest species. When using forests as control, the effect was significantly positive for open-habitat species. Results largely agreed between taxonomic groups. Our findings support retention forestry as a way to moderate logging effects on forest species while at the same time promoting species requiring disturbance. Sensitive forest-interior species as well as some rare disturbance-dependent species will need complementary conservation actions. For regions with a long tradition of industrial forestry, retention forestry is a way to restore the forest landscape.

Improving forest restoration in dipterocarp rainforest: a field trial with 32 native tree species. Gustafsson, M. (*Swedish University of Agricultural Sciences, Sweden; malin.gustafsson@slu.se*), Alloysius, D. (*Sabah Foundation, Malaysia; dalloysius@gmail.com*), Falck, J., Karlsson, A., Gustafsson, L., Ilstedt, U. (*Swedish University of Agricultural Sciences, Sweden; jan.falck@slu.se; anders.karlsson@slu.se; lena.gustafsson@slu.se; ulrik.ilstedt@slu.se*).

In the Malaysian state of Sabah (Borneo) most forests outside protected areas have been selectively logged. Many of these forests still hold the potential for high biodiversity and future forest production. Traditionally, forest rehabilitation aimed to increase production and biomass. Today the focus on restoration for biodiversity is increasing, but knowledge concerning tree species survival, growth, and adaptations are limited to a few species. The INIKEA Sow-a-Seed project started in 1998 in Sabah to restore rainforest degraded from logging and wildfire. The main aim is to improve biodiversity by planting a multitude of native tree species; mainly dipterocarps, but also other climax species and fruit trees. Today, about 100 tree species have been planted on >12 000 ha. In a species field trial experiment we examined survival, growth, and traits among 32 planted native tree species (20 trees/species). We aimed to link tree species responses to site factors to improve predictions of tree species survival and growth. Further we examined if species response to increased light can be predicted by species traits. Preliminary results indicate large differences between the tree species, and that wood density is an important trait, interacting with light intensity to determine individual tree growth.

Biodiversity benefits of restoration of boreal forests in Finland. Hekkala, A. (*Finnish Forest Research Institute and Thule Institute, Finland; anne-maarit.hekkala@metla.fi*), Tarvainen, O., Päätalo, M. (*Finnish Forest Research Institute, Finland; oili.tarvainen@metla.fi; marja-leena.paatalo@metla.fi*), Tolvanen, A. (*Finnish Forest Research Institute and University of Oulu, Finland; anne.tolvanen@metla.fi*).

Forest restoration is widely used in Finland to bring back essential components typical to natural forests, which have been reduced by efficient forest management. The structural variety of monocultural conifer stands is increased by adding dead wood and by re-introducing fire-disturbance, which has been almost eliminated from Fennoscandian forests. We conducted a large scale study on four Natura 2000 protection areas in Finland including three forest restoration methods: tree felling with and without subsequent burning and storm simulation. We studied the effects of these methods on vegetation composition, tree seedling establishment, and tree stand structure. The results of the 7-year study show that tree felling with subsequent burning have considerable effects on vegetation and tree stand structure, enhancing especially deciduous tree seedling establishment. Felling only does not affect vegetation or seedling establishment and the changes in tree stand structure are less substantial. The storm simulation creates patches of exposed soil, initiating vegetation succession and especially pine seedling establishment on these patches and hence causing more heterogeneity on the forest stand. Our results can be used by restoration practitioners or forest managers to decide what methods to use to enhance the diversity of previously managed forest stands.

Restoration of mixed-pine forest ecosystems of eastern Upper Michigan using variable-retention harvesting. Hix, D., Goebel, C., Nyamai, P. (*Ohio State University, USA; hix.6@osu.edu; goebel.11@osu.edu; nyamai.1@buckeyemail.osu.edu*), Corace III, R. (*U.S. Fish and Wildlife Service, USA; greg_corace@fws.gov*).

Compared with old-growth mixed-pine forests of the Lake States region of the United States and Canada, many current stands have developed under different disturbance regimes over the past 150 years. Based upon our work in these forests,

we hypothesized that variable-retention harvesting might allow us to both reduce the current live and dead fuels and increase the regeneration of the formerly dominant fire-adapted tree species (red pine, *P. resinosa* Ait; and eastern white pine, *P. strobus* L.). During 2010, harvests were implemented in the Seney National Wildlife Refuge. In three stands, the basal areas were reduced by 70% leaving a uniform spatial pattern of residual trees and in three stands the basal areas were likewise reduced leaving an aggregate spatial pattern. Two years following harvest, we observed a significant reduction in live fuels and higher densities of newly established eastern white pine seedlings in the treated stands compared to the unharvested control stands. Ordination suggested that fuel characteristics and overstory composition were factors strongly influencing the regeneration layer. Stands will be re-inventoried in 2014 to determine the success of these restoration practices, while we also examine the potential to utilize prescribed fire as a post-harvest treatment to facilitate red pine regeneration.

Additive partitioning approach evaluating the restoration efficiency of plant species diversity in a warm-temperate mountainous riparian forest in Japan. Ito, S., Asou, H., Hirata, R., Mitsuda, Y. (*University of Miyazaki, Japan; s.ito@cc.miyazaki-u.ac.jp; gb10001@student.miyazaki-u.ac.jp; demian1919@gmail.com; mitsuda@cc.miyazaki-u.ac.jp*).

This study examined the efficiency of different treatments of canopy removal conducted for restoration of the plant species diversity of a riparian forest by using the additive partitioning approach. In conifer plantations along a warm-temperate mountain stream in southern Japan, planted canopy trees were removed with different intensities of logging, small-scale clearcutting, heavy thinning (70%), and light thinning (30%), on different habitats (terraces and slopes). We assessed the species composition of the recovered vegetation in 120 quadrats located in the treated sites including a control. Two-way additive partitioning approaches were applied to evaluate the beta diversities from the aspects of the habitats and the treatments. The results of the habitat-based analysis demonstrated the similar alpha diversities at the quadrat level for each habitat, but significantly higher beta diversity within terraces accounting for 80% of the gamma diversity of the whole area. In contrast, the within-treatment diversity was generally low for every treatment, accounting for only 40% of the gamma diversity by single treatment which left 30% of unrealized richness. These results suggested that the different intensities of canopy removal promoting heterogeneous light environment particularly on terraces are effective to promote the plant species diversity of this riparian forest.

Pioneer species used as nurse crops: a powerful silvicultural method in forest restoration and forest adaptation. Madsen, P. (*University of Copenhagen, Denmark; pam@ign.ku.dk*), Stanturf, J. (*U.S. Forest Service, USA; jstanturf@fs.fed.us*), Nielsen, A. (*University of Copenhagen, Denmark; atn@life.ku.dk*), Madsen, E. (*Skåneskogens Utvecklings AB, Sweden; emm@skaneskogen.se*), Madsen, T. (*Store Hjøllund Plantage A/S, Denmark; tlmvrads@post.tele.dk*).

The use of pioneer tree species as nurse crops was widespread in the restoration efforts of the degraded lowlands of northwest Europe starting 150–200 years ago. In forest regeneration the method has been commonly used to support regeneration of late successional species on clear-cut sites. The nurse crop species offers shelter against particularly late spring frost and weeds, as well as protection against pests such as weevils or rodents by preventing the site from developing into favourable habitat. The use of pesticides and herbicides gained popularity in forestry following the Second World War and as such largely replaced the nurse crop method. However, today we view the method as even more relevant and needed than before. By using very fast starting species like *Populus* spp. and *Larix* spp. the method can greatly elevate forest productivity in the regeneration phase as well as by restoring forest microclimate and forest floor conditions. The method seems to pave the road for inexpensive regeneration techniques for a wide range of desired species needed to support forest adaptation capacity on challenging sites. We present results and concepts to foster exchange of scientific results and inspiration for further research and development of this method.

Differences in communities of trees along a tropical forest restoration gradient, Uganda. Owiny, A. (*Makerere University, Uganda, and University of Eastern Finland, Finland; owinyiarthur@yahoo.com*), Valtonen, A. (*University of Eastern Finland, Finland; annu.valtonen@uef.fi*), Nyeko, P. (*Makerere University, Uganda; pnnyekop@gmail.com*), Roininen, H. (*University of Eastern Finland, Finland; heikki.roininen@uef.fi*).

Understanding the effectiveness and amount of time required for replanted forests to recover is still a challenge. A critical concern is how well tree communities recover into a more species rich ecosystem. Our study consisted of six restoration forests ranging from 3 to 16 years old and three primary forests. We compared patterns of univariate and multivariate measures of tree communities. We also assessed the recruitment trends of nonplanted, naturally regenerating trees in the restoration areas. Multivariate and univariate analyses of trees showed that recovery responses were generally correlated with age of restoration. Species density, tree density, basal area, and diversity varied but increased with age of planting. The opposite pattern was found in dominance. Tree community composition showed a directional change; however, communities in the different aged restoration areas had not converged to the composition of primary forests. Restoration planting enhanced natural recruitment of tree seedling. Also, *Acanthus pubescens*, *Lantana camara*, and *Pennisetum purpureum* negatively correlated with species density, tree density, basal area, and diversity. Our results showed that restoration planting can reestablish forests with high species density, tree density, basal area, and diversity, but this is dependent on age and the extent of the herb, grass, and shrub cover.

The importance of silvicultural practices to facilitate forest ecological restoration. Park, B. (*Chungnam National University, Republic of Korea; bbpark@cnu.ac.kr*), Madsen, P. (*University of Copenhagen, Denmark; pam@ign.ku.dk*), Finegan, B. (*CATIE, Costa Rica; bfinegan@catie.ac.cr*), Kim, S. (*Korea Forest Research Institute, Republic of Korea; sands02@forest.go.kr*).

Both temperate and tropical forests host some of the most widespread and severe examples of forest degradation and deforestation, but also some of the most successful forest restoration efforts. Historically, a wide variety of forest regeneration methods originating from silvicultural practices have been used for ecological restoration efforts, but silvicultural practices have been viewed as different sets of methods and practices only for facilitating the survival and growth of the regeneration. Silvicultural practices concerned with present forest structures, species, and advance regeneration in areas subject to afforestation are often overlooked in forest ecological restoration processes. In this introductory talk, we will exchange and compile scientific knowledge and practical experiences on silvicultural methods used to facilitate forest ecological restoration ranging from regeneration establishment to harvesting systems. Particularly we will emphasize the effects of silvicultural practices in improving ecosystems resilience as well as products and ecosystem services in both temperate and tropical zones.

Silvicultural control of Armillaria root disease in Manitoba. Ramsfield, T., Myrholm, C., Mallett, K. (*Canadian Forest Service, Canada; tod.ramsfield@NRCan-RNCan.gc.ca; Colin.Myrholm@NRCan-RNCan.gc.ca; Ken.Mallett@NRCan-RNCan.gc.ca*).

Armillaria root disease, caused by *Armillaria ostoyae*, can be a serious problem during stand establishment in forest plantations. In 1992, a trial was established in the Sandilands region of Manitoba to investigate the efficacy of stump removal to reduce Armillaria root disease in the regenerating stand. Jack pine (*Pinus banksianna*) and red pine (*Pinus resinosa*) were planted into plots that either included stumps from the previous stand, or from which the stumps were removed. The trial was assessed annually for the first 10 years and then again in 2012 and 2013. Mortality caused by *A. ostoyae* was found to be significantly higher in both jack pine and red pine plots that were not treated by stump removal and basal area per hectare was found to be higher for both species in the plots from which the stumps were removed. Therefore, stump removal appears to improve productivity through root disease reduction in the regenerating stand, which benefits both carbon sequestration and traditional forestry objectives.

Growth and mortality assessment in underplanting *Nothofagus* seedlings as function of resource availability. Soto, D. (*Oregon State University, USA; daniel.soto@oregonstate.edu*), Donoso, P. (*Universidad Austral de Chile, Chile; pdonoso@uach.cl*), Puettmann, K. (*Oregon State University, USA; Klaus.puettmann@oregonstate.edu*).

Nothofagus spp. are important components of temperate forests in South America because they are pioneer species, especially in regions with catastrophic disturbances. Past harvests have resulted in thousands of hectares of high-graded *Nothofagus* forests with a high cover of competitive bamboos. To regenerate these forests, silviculturists have created gap openings and the subsequent top-soil scarification to improve natural regeneration has created opportunities for underplanting. This study quantified the performance of *Nothofagus dombeyi* and *N. Alpina* as a function of light availability and soil compaction after harvesting and top-soil scarification of partially harvested old-growth forests in the Chilean Andes. A Michaelis-Menten model was used to predict diameter and height growth of underplanted seedlings as influenced by light and soil compaction (grouped into four classes). The probability of mortality was predicted by logistic regression as a function of recent diameter growth and soil compaction. Results showed that *N. dombeyi* seedlings grew better in high- and low-light conditions. Increasing soil compaction had stronger detrimental effects on growth of *N. alpina*. In contrast, growth of *N. dombeyi* was not influenced by soil compaction, showing its greater plasticity and adaptation to environmental conditions and resource limitations.

Restoration strategies, methods, and operations. Stanturf, J. (*U.S. Forest Service, USA; jstanturf@fs.fed.us*), Löf, M. (*Swedish University of Agricultural Sciences, Sweden; magnus.lof@slu.se*), Madsen, P. (*University of Copenhagen, Denmark; pam@ign.ku.dk*), Park, Y. (*Daegu University, Republic of Korea; parkyd@daegu.ac.kr*), Lex Engel, V. (*São Paulo State University, Brazil; veralex@fca.unesp.br*), Blay, D. (*Forest Research Institute of Ghana, Ghana; ddblay@gmail.com*), Gardiner, E. (*U.S. Forest Service, USA; egardiner@fs.fed.us*).

Many tools in the restoration toolbox may be used to achieve more than one objective. Depending on local usage, similar methods may have different names. Adding vegetation is the most effective restoration technique and there are many kinds of available material. How the material will be deployed depends on initial conditions, whether or not an overstory is present, how much of the landscape will be restored, and the complexity of the planting design. The three "R's" of restoration strategy, reclamation, reconstruction, and rehabilitation, often entail use of native species, but the need to ameliorate harsh chemical or physical conditions may dictate species not native to the site. Passive restoration depends upon natural dispersal and recolonization processes; active restoration uses direct seeding or planting desirable species. Passive approaches limit the restored system to species already present or nearby; greater control of species composition is gained by active methods. Additional decisions are required; which species, how dense, and what spatial arrangement? A systematic grouping of designs according to whether there is no overstory present (i.e., replacement, native recolonization, afforestation, or conversion) or a full or partial overstory (transformation), and how much of the area is to be treated (all or partial) is discussed.

Posters

The evolution of forests in Israel: from monocultural forest to uneven-age, mixed-species forests designated for the provision of ecological services. Brand, D. (*Keren Kayemeth LeIsrael, Israel; davidb@kkl.org.il*).

In the last hundred years, human activities and overexploitation of natural resources in Israel have produced severe land degradation, erosion, and salination. The first pioneering stage of afforestation in Israel was mainly based on pure, even-aged Aleppo pine forests, which were established on hills and mountains. Aleppo pine was later replaced by brutia pine because of its susceptibility to pests. In the coastal plain and valleys, eucalypts dominate the planted forests, which were the outcome of a massive national programme to reclaim and restore Israel's degraded Mediterranean landscape. Over time, a more complex set of forest stands evolved, resulting from the recolonization of native tree and shrub species (oaks, *Pistacias*, carob) into the understory, the diversification of simplified stand structures, and the planting of mixed species. Israeli forests, both planted and natural are multifunctional, ecological landscape systems, which are managed for multiple services to the public and ecology of their surrounding regions. The Israeli Forest Service (KKL) wrote in 2013 a new "Forest Management Policy of Israel – Guidelines for Planning and Management" that defines several types of forests and the specific forest management they require. This new approach to forestry has a lot of advantages, as the mosaic of mixed, multiple-use forest has a greater degree of ecological stability, biological diversity, and landscape aesthetic value.

Assessment of nitrogen fertilization of a managed Douglas-fir forest stand in the Pacific Northwest and the application in sub-Saharan Africa. Daramola, T. (*University of British Columbia, Canada; t.daramola@yahoo.com*), Harrison, R. (*University of Washington, USA; robh@uw.edu*).

Success stories of afforestation and rehabilitation of degraded lands attracts governments' attention to the potentials of tree planting and establishment of large scale forest plantations as a potential carbon sink for climate change mitigation efforts. While

plans are ongoing to restore global forests through reforestation projects in developing countries, there is limited knowledge of fertilization treatments that could serves as catalysts to enhance tree growth, yield, and maximization of carbon sequestration. This study investigates the growth, yield, and carbon sequestration of a nitrogen-fertilized Douglas-fir forest stand in the Pacific Northwest and explores the potential for replicating such treatment and management practice in sub-Saharan Africa. The study used three fertilized and thinned plots and three unfertilized and thinned plots and compared their growth, yield, and carbon stock from 1987 to 2011. The study shows substantial amount of higher growth and yield on the individual fertilized plots than unfertilized plots, but there was a drastic decline in the growth rates after the end of the fertilization, which in turn allowed the growth rates of unfertilized plots to surpass growth of the fertilized plots during the following years.

Rehabilitation strategies and ecotourism development for mined-out and waste dump areas in Bagacay, Hinabangan, western Samar, Philippines. Exconde, A., Castillo, J., Santos, G., Cadiz, R., Calanog, L., Daño, A., Taguiam, C., Reyes, M., Aparente, M., Garcia, D. (*Ecosystems Research and Development Bureau, Philippines; angelitoexconde@yahoo.com.ph; alan536@yahoo.com; junbbs2006@yahoo.com; cadiz_cadiz@yahoo.com; lacalanog@yahoo.com; tonydanolb@yahoo.com; cgtaguiam@yahoo.com; mludcreyes@yahoo.com; slym_a@yahoo.com; digsgarcia@yahoo.com*).

This research study endeavored to rehabilitate identified sites in the Bagacay mined-out and waste dump area to improve soil condition and to restore the productive potential and aesthetic beauty of the site. Site assessment was followed by rehabilitation strategy of the area to test species adaptability, as influenced by soil amelioration and microbial application techniques, to identify potentially tolerant plants to initiate ecological succession in the area. A split-split plot in a randomized complete block design (RCBD) replicated three times was used to monitor four pre-selected species (narra, *Acacia auriculiformis*, *Acacia mangium*, and mountain agoho) planted on different soil amelioration treatments. Initial results of the project showed that *Acacia mangium*, in terms of height and diameter, performed best on the forest soil treated with inorganic fertilizer and lime. The project team will continue to monitor the performance of the outplanted species on the three experimental blocks. Results may vary depending on the environmental conditions and additional experimental analyses.

A silvicultural practice to facilitate forest restoration: a new seedling cultivation technology for regeneration establishment. Hernandez Velasco, M., Mattsson, A. (*Dalarna University, Sweden; mhv@du.se; amn@du.se*).

Forest restoration has become a primary task, not only to cope with an increasing demand on forest products, but also to fight climate change and compensate for an accelerated global deforestation. However, many of the current practices used in forestry nurseries to produce forest planting stock have adverse effects on the environment. The main objective of the ZEPHYR project, funded by the European Commission under the Seventh Framework Programme (FP7), is to develop an innovative zero-impact technology for the pre-cultivation of forest regeneration materials that is not affected by the outdoor climate. Among the main components to be improved are artificial lighting sources used for cultivation. Traditional fluorescence lamps are to be replaced by LED grow lights with spectra tailored to the seedlings' needs. The present work investigates biological responses of *Picea abies* and *Pinus sylvestris* to six different light spectra. The pre-cultivation has been done following standard growth protocols during 5 weeks with a photoperiod of 16 h at 100 μmol/m^2/s. This has been done under controlled closed conditions with a room temperature of 20 °C and a relative humidity of 60%. The analyses have shown clear differences among the treatments and their adapting capacity when transplanted.

Investigating the photosynthesis rate of selected framework species for carbon sequestration in restored forest in Thailand. Jantawong, K. (*Chiang Mai University, Thailand; foolish_fullmoon@hotmail.com*).

Climate change is caused by increased CO_2 and reduced natural forests. Forest restoration is an interesting approach for carbon sequestration. To improve carbon sequestration in forest restoration, the proper tree species with high photosynthesis rates need to be planted. The aim of this study was to investigate suitable species with the highest photosynthesis rates, measured as CO_2 absorption rate, from a selected framework of species. The eight species of seedlings selected were grown in a greenhouse at 25 °C and a relative humidity of 80%. The CO_2 absorption rate was studied by using LICOR (LI-6400) at a CO_2 range of 300–500 μmol/m^2/s with an interval of 20 and a light range of 50 to 2 000 μmol/m^2/s. Leaf samples (young, mature, and shade leaves representing different ages) from each species were selected for LICOR measurement. The results showed that *Melia toosendan*, *Gmelina arborea*, and *Hovenia dulcis* had the three highest CO_2 absorption rates (51.40, 50.95, and 46.07 μmol/m^2/s, respectively). These three species seem to be appropriate for planting to increase carbon sequestration in forest restoration.

Restoration of endemic dwarf pine (*Pinus culminicola*) populations in north Mexico. Jimenez, J., Aguirre Calderón, O., Treviño Garza, E., Alanis, E. (*Universidad Autonoma de Nuevo León, Mexico; jjimenez20@gmail.com; oscar.aguirrecl@uanl.edu.mx; eduardo.trevinogr@uanl.edu.mx; alanis_eduardo@yahoo.com.mx*).

Pinus culminicola (dwarf pine) was described by Andresen and Beaman in 1961 as a new endemic species at the peak of the protected area of Cerro El Potosí, in Nuevo Leon, Mexico. In 1998, wildfires burned 58% of the dwarf pine population. During the past 4 decades, a reduction of the area formerly covered by dwarf pine has been observed, due to human impact. Currently, only 30 ha of fragmented dwarf pine exist, and these include many old trees with low seed production and are subject to cattle grazing. The species is now considered endangered and is subject to special protection. A study was established to test the effect of cattle, small mammals, and elevation on the success of reforestation of an endemic dwarf pine species was implemented. Dwarf pine is under pressure from grazing, wildfires, and human activities. In conclusion, seedling survival was poor after 4 years for seedlings protected from cattle and small mammals, and no seedlings survived after being exposed to grazing and trampling for 3–4 years. After 4 years, surviving seedlings were still very small and thus susceptible to trampling and grazing both by cattle and small mammals.

Seeding regeneration potential of Taiwan beech (*Fagus hayatae*) in northeastern Taiwan. Lin, S. (*National Ilan University, China-Taipei; stlin@niu.edu.tw*), Yang, J. (*Taiwan Forestry Research Institute, China-Taipei; yjc@tfri.gov.tw*), Wu, Z. (*National Ilan University, China-Taipei; mookokoo@gmail.com*).

To explore the natural seeding regeneration potential of Taiwan beech (*Fagus hayatae*), we focused on viable seed supply and survival of germinated seedlings in a natural beech forest in northeastern Taiwan from 2009 to 2013. The results showed seed production of about 144.1/m^2 in 2010, and viable seed available for regeneration was about 8.2/m^2. As of April 2011, all seeds had either germinated or died; the deterioration rate of viable seeds was about 50% of that present in the transient soil seed bank. The mean germination rate was 4.4%, with no significant differences among canopy and soil surface treatments. The mortality of germinated seedlings peaked at about 60 d, at the cotyledon development stage. The survival pattern of germinated seedlings was analysed by a Cox model; survival rate after 2 years of seedlings under canopies was significantly lower than the survival rate in gaps. Taiwan beech could be regenerated naturally, from mast at seeding time, but it was difficult for seedlings to survive in the dwarf bamboo (*Yushania niitakayamensis*) understory.

Restoring old-growth features to managed forests in the eastern Italian Alps. Motta, R., Meloni, F., Nosenzo, A., Vacchiano, G. (*University of Turin, Italy; renzo.motta@unito.it; fabio.meloni@unito.it; antonio.nosenzo@unito.it; giorgio.vacchiano@unito.it*), Garbarino, M. (*Marche Polytechnic University, Italy; m.garbarino@univpm.it*), Berretti, R. (*University of Turin, Italy; roberta.berretti@unito.it*).

During the last millennia, all forests of the Italian Alps were heavily affected by human land use. Consequently, forest structures have been modified and there is no old-growth remaining. In the last decades, however, many forests have been withdrawn from regular management. At the same time, in currently managed forests, silvicultural systems able to develop or maintain old-growth characteristics are being required. The aim of this paper is to analyze the status and developmental dynamics of old-growth characteristics in mixed montane forests of the eastern Italian Alps. We selected three old-growth forests in Bosnia-Herzegovina and Montenegro (due to the lack of old-growth forests in the Italian Alps), two forests withdrawn from regular management for at least 50 years, and three currently managed forests. In each forest we analyzed the stand structure. Old-growth forests were characterized by significantly higher amounts of live and dead biomass, a higher variability of stand structures, and a rotated sigmoid shape of diameter distribution. We discuss the temporal dynamics of the development of old-growth characteristics in forests withdrawn from regular management, and use our results to evaluate the effectiveness of retention prescriptions currently in place in managed forests.

Assessing the outcomes of ecological restoration by afforestation along a new high-speed railway in northwestern Italy. Motta, R., Meloni, F., Vacchiano, G., Nosenzo, A. (*University of Turin, Italy; renzo.motta@unito.it; fabio.meloni@unito.it; giorgio.vacchiano@unito.it; antonio.nosenzo@unito.it*).

The building of a high-speed railway in north-western Italy has affected some natural forests and Natura 2000 sites. According to the current regulations, the developers had a statutory obligation to compensate for the ecological damage. Ecological compensation is understood as the set of measures carried out to substitute the habitats, ecological values, and functions that remain definitively damaged or lost. Compensation measures are usually determined by a combination of administrative goals set by competent authorities, availability of suitable sites, and other criteria. The purpose of this paper was to assess the outcome of 18 already completed afforestation projects along the high-speed railway in Piedmont (northwestern Italy), and to compare the current vegetation development with the expected goals. Most of the compensation projects were unsuccessful (e.g., very slow growth rate, very high tree mortality). This was due both to questionable planting techniques (e.g., tree species selection, poor or no soil preparation), and to the lack of adequate management (e.g., thinning) and monitoring in the following years. According to our results, we advocate the need to rethink a comprehensive approach to afforestation practices for ecological compensation, in term of spatial distribution of the projects, planting methods, tree species selection, and ecological goals.

Effect of soil condition improvement on *Calliandra calothyrsus* and *Antidesma bunius* growth in Batur Mountain Conservation Area, Bali, Indonesia. Narendra, B. (*Research and Development Center for Conservation and Rehabilitation, Indonesia; budihadin@yahoo.co.id*).

Batur Mountain Conservation Area has important value in supporting Batur Lake sustainability and the surrounding community life. This forest area is dominated by very critical land covered by sand and lava clots. Various efforts to rehabilitate the degraded land in this area have been carried out, but the results were limited in certain species, especially on land with deep solum. This study was conducted to evaluate the effects of soil condition improvement by increasing the organic matter to *Calliandra calothyrsus* Meisn. and *Antidesma bunius* (L.) Spreng. The trial used a completely randomized block design and the treatments were the addition of chicken manure and top soil in the planting holes. The observations made in the third year showed a significant plant growth response to the chicken manure addition. The manure addition treatment increased soil N and P contents 46 and 10 times, respectively, compared to the control and was highly correlated to the plant growth. Manure application on *Calliandra* was able to increase height growth by 51% and diameter by 75%, compared to the control. For the *Antidesma*, this treatment increased height growth by 30% and diameter by 13%, compared to the control.

Selection of appropriate legume cover crop in reforestation of former tin mining overburden in Bangka Island, Indonesia. Narendra, B. (*Research and Development Center for Conservation and Rehabilitation, Indonesia; budihadin@yahoo.co.id*), Pratiwi, P. (*Ministry of Forestry, Indonesia; pratiwi.lala@yahoo.com*).

Tin mining in Bangka Island has resulted in degraded forest, among other overburdens. Reforestation activities are often hampered due to the poor condition of the soil, especially the lack of soil organic material. In the early stages, reforestation is done by planting legume cover crops (LCC) to protect soil from erosion and reduce runoff, and also to increase soil organic matter. Selection of LCC species should be based on the ability to adapt to the tin-mined environment, to cover the soil surface, and to produce biomass. In addition to suitable species, cropping patterns and soil microorganisms' support were expected to boost the growth of LCC. This study tested the planting of two LCC species, *Calopogonium mucunoides* and *Pueraria javanica*, combined with the application of mycorrhiza and rhizobium. The aim was to determine the effect of treatments to the viability, soil cover ability, and biomass. The analysis revealed that 6 months after planting, both of these species showed the ability to

adapt and the differences between the species were not significant. *P. javanica* showed significantly greater ability to cover the soil surface and produced more biomass than *C. mucunoides*. So far, the use of rhizobium and mycorrhiza, or a combination of both, has not shown a significant effect.

Trial of 1-year-old containerized seedlings for recovering tide-water control forests destroyed by tsunami. Ochiai, Y., Yamada, T., Ito, T. (*Forestry and Forest Products Research Institute, Japan; yukihito@affrc.go.jp; kenchan@ffpri.affrc.go.jp; itouta@ffpri.affrc.go.jp*).

On 11 March 2011, a tsunami after an earthquake destroyed almost all the tide-water control forests on a coastal area of the Pacific Ocean side of Tohoku area, Japan. Most of the species in the forests were *Pinus thunbergii* (Kuromatsu). It is urgent to replant Kuromatsu to recover the forests. Before the tsunami, the common planting material was 3-year-old bare root seedlings. Because of a shortage of planting material, 1-year-old containerized seedlings were tried and showed better survival rate and root formation. The survival rate was low if the bare root seedlings were planted during summer; however, the containerized seedlings planted during summer showed a high survival rate. Kuromatsu has a large and long taproot in natural stands, but the taproots of bare root seedlings are cut before planting and do not develop well after planting. On the other hand, taproots of containerized seedlings are maintained and develop well after planting, which might be effective for tide-water control.

An example of an ecologically sustainably territory in Cuba. O'Farrill Colebrook, A., Hechavarria Kindelan, O., Toirac Arguelle, W., Villamet Pineda, P., Frometa Cobas, A., Manzanares Ayala, K. (*Instituto de Investigaciones Agro Forestales, Cuba; abilio@forestales.co.cu; orlidia@forestales.co.cu; wilmer@forestales.co.cu; finteg@enet.cu; adelafrometa@gmail.com; humberto@forestales.co.cu*).

The study was carried out in the dry zone of the xerophytic corridor in the south of Guantánamo, Republic of Cuba. This zone is characterized by a high salt content in the soil, the deterioration of the forest ecosystem, and low production level of food for the communities. The average temperature is 26 °C and the mean precipitation amounts to 800 mm/year. In order to minimize these problems, a methodology called Analogue Forestry that has been used in Sri Lanka since 1990 was applied to the Cuban situation. Its 12 principles were applied, through which we determined biodiversity, soil structure, and forest attributes. A diversification of farms with regard to species for wood, fruit, medicine, ornamentals, and lianas was achieved. Thirty-seven forest species, including 13 native and 10 introduced species of similar function (analogous) as the ones that existed before the degradation, were studied. The application of agro-ecological methods improved the quality of soils, achieving a higher survival rate of plantations and an increase in food production for the local communities. The technological costs were identified and the economic potential in the medium and long term were defined. The integration of men, women, boys, and girls, from children to teenagers, into the restoration process made sustainability of the zone possible.

Enrichment of restored forests with *Euterpe edulis* (Arecaceae): soil water deficit limits its successful establishment. de Oliveira, R., Engel, V., Ota, L. (*São Paulo State University, Brazil; rodrigo.minici@florestal.eng.br; veralex@fca.unesp.br; lizmsota@gmail.com*), Ré, D. (*Serasa, Brazil; danilo.scorzoni@gmail.com*).

Euterpe edulis Martius, a keystone species of the Brazilian Atlantic Forest, is endangered by its high demand as food source (heart-of-palm) and predatory exploitation. Recently, the exploitation for fruit pulp (açaí) emerged as an alternative for the sustainable management of the species, both in natural and restored areas. However, being a specialist of wet habitats, its establishment in areas outside their optimal distribution zone might be difficult. We hypothesized that soil water deficit is the main barrier to its initial establishment in sites with a more pronounced dry season. Different irrigation frequencies were tested using a 3 × 2 factorial randomized block design (no irrigation; irrigation every 7 or 21 d; and with or without using a hydrophilic gel to retain water in the rhizosphere) throughout one dry season. The survival was monitored over three dry seasons. Irrigation every 7 d provided the highest probability of survival (71%) after the first dry season. However, after the second dry season, survival dropped to only 38%. After the third one there was no survival. There was no effect of the hydrogel. The results indicate that irrigation during only one dry season is not enough to ensure success in establishing species in restored areas.

Management determination by silvicultural groups in restoration plantings in the Brazilian Atlantic Forest. Ota, L., Engel, V. (*São Paulo State University, Brazil; lizmsota@gmail.com; veralex@fca.unesp.br*), Ré, D. (*Serasa, Brazil; danilo.scorzoni@gmail.com*), de Oliveira, R. (*São Paulo State University, Brazil; rodrigo.minici@florestal.eng.br*), Parrotta, J. (*U.S. Forest Service, USA; jparrotta@fs.fed.us*).

One of the major difficulties in the management of mixed planting with high diversity is the growth heterogeneity between species. A possible solution would be evaluating the species within more homogeneous groups. This study aimed at elucidating whether grouping the species by pre-determined successional and silvicultural criteria would be effective for volume estimation and management cycles of two mixed plantation systems for forest restoration in Brazilian Atlantic Forest. System A was an agroforestry system and System B was a consortium between firewood and timber species. We made direct determination of the real cubic volume for 240 standing trees belonging to 10 species, using the Wheeler pentaprism, and the volumes were estimated by the Smalian method. Volumetric equations obtained were compared for four grouping criteria. The parameters of the multivariate analysis were DBH, form factor, and total height. The results were compared with adjusted R^2 and the standard error of the residuals. The best grouping by diameter and abundance, clustered only two spotlight species (Group I), and all other species (Group II). For System A, we estimated a cutting cycle of 15 years for Group I and 20 years for Group II. For the System B, the estimated cycle was 15 years for both groups.

Future strategies for restoration of ridge-mountains at Baekdu Daegan in the Republic of Korea. Park, Y., Kwon, T. (*Daegu University, Republic of Korea; parkyd@daegu.ac.kr; foren95@daegu.ac.kr*), Ma, H. (*Gyeongsang National University, Republic of Korea; mhs@gnu.ac.kr*).

The Baekdu Daegan Mountain System (BDMS) is a 1 500-km series of mountain ranges that runs from Mount Baekdu in North Korea to Mount Jiri in the Republic of Korea as the backbone of the Korean peninsula. The BDMS in South Korea stretches over

684 km and covers an area of 263 427 ha. This is about 4% of the total forest area with a distribution of about 1 300 terrestrial plant species, almost one fourth of the total plant species in the Republic of Korea. Thus, BDMS is a biodiversity hot spot that is also of great cultural and spiritual significance. However, parts of the ridge were breached by road construction during the Japanese occupation in the 1920s and 1930s. The Korea Forest Service (KFS) has begun to link and restore the ridge line in mountains recently and restoration work was completed in three sites by 2013. Although this is the first year after restoration, there are already signs of success with increasing numbers of wildlife. Nonetheless, there are problems and limitations to restore the natural vegetation and ecological value. Therefore, we hope to discuss future management strategies based on first year monitoring for forest vegetation and other ecological studies.

Management of natural regeneration of Spanish elm (*Cordia alliodora*) for the purpose of forest restoration of dry forests of Colombia. Rodríguez Santos, N., Melo Cruz, O., Fernandez Mendez, F. (*Universidad del Tolima, Colombia; natha8902@hotmail.com; omelo@ut.edu.co; fmendez@ut.edu.co*).

The study was carried out in parts of dry tropical forests in the valley of the Magdalena River in Colombia, South America. On an area of 40 ha, an ecological evaluation was carried out in sections of 0.1 ha. Trees of a DBH of 5.0 cm or more were measured. It was found that *Cordia alliodora* R. & P. accounted for >50% of the individuals and generated clustered patterns in the forest. In a second phase of monitoring the dynamics of natural regeneration of the species, a network of 45 permanent plots of 25 m^2 each was established. The habitat was evaluated, inventoried, and characterized. It was found that the recruitment rate was 60% higher than mortality, which allowed new cohorts of *C. alliodora* to establish themselves successfully. Environmental requirements are as follows: 40% light intensity, 55% canopy cover, and up to 30% soil humidity. In the studied area, silvicultural measures were carried out on individuals of *C. alliodora* with a DBH of 5.0 cm or higher. These were monitored with regard to their growth. The medium diameter growth rate for the species was found to be higher than 1.8 cm/year, i.e., rapid growth. Silvicultural management strategies will allow the reincorporation of degraded dry forest areas into the forest economy of the region for the wellbeing of the communities.

Seed rain assessments and forest plantation composition in sites undergoing restoration in Brazil. Sato, L., Engel, V., Podadera, D., Machado, D., Almeida, D. (*São Paulo State University, Brazil; lu_sato7@hotmail.com; veralex@fca.unesp.br; diegopodadera@gmail.com; deivid.machado@ig.com.br; daniellesoaresalmeida@gmail.com*).

Seed dispersal is a key factor in forest dynamics as the arrival of propagules of different species may drive successional development in a community. Understanding seed rain distribution along the landscape is important in sites undergoing restoration because it can help in assisting natural regeneration processes. Our study analyzed seed rain in two 15-year-old plantation models (M1 and M2) that differed in initial number of species (M1=5; M2=41) and were located at two different degraded sites (S1 and S2) characterized by different soil types and land-use histories in Botucatu, midwestern São Paulo state, Brazil. We assessed month-by-month seed composition and density present in collectors located at each plantation model and also in native forest fragments from April 2012 until February 2013. Seed density was higher in M2 for both sites but seed composition varied between sites and treatments. There was a strong correlation between seed rain and forest canopy composition in all restored treatments. Although predominant dispersal syndrome was anemochory for M1 in S1, the same treatment in S2 had zoochory as the main syndrome. M2 treatments were represented mostly by zoochory followed by anemochory in both sites. These results suggest that seed rain, thus natural regeneration processes, is more influenced by local composition and local ecological processes than by those occurring in surrounding fragments.

The fire ecology of American chestnut regeneration: implications for restoration. Saunders, M., Belair, E. (*Purdue University, USA; msaunder@purdue.edu; ebelair@purdue.edu*), Clark, S. (*U.S. Forest Service, USA; stacyclark@fs.fed.us*), Landhäusser, S. (*University of Alberta, Canada; simon.landhausser@ualberta.ca*), Jenkins, M. (*Purdue University, USA; jenkinma@purdue.edu*).

American chestnut (*Castanea dentata*) was a foundational species in many eastern North American forest types before it was functionally lost from these forests in the early 1900s due to chestnut blight (*Cryphonectria parasitica*). Over the past 30 years, there has been considerable effort to cross-breed resistance from blight-resistant Chinese *Castanea* despite a limited understanding of the disturbances that promoted the species. Instead, chestnut has been assumed to be favored by fire similar to co-occurring *Quercus* in these forests, largely because of its copious sprouting ability after topkill. However, these observations have been limited to mature individuals with large pre-existing rootstocks and not with young regenerating seedlings and saplings. Using a 5-year-old underplanting trial, we compared the fire resistance of chestnut to northern red oak (*Q. rubra*) by 1) topkilling individuals with a simulated prescribed burn and tracking sprouting response, 2) excavating individuals to estimate biomass allocations, and 3) determining levels of non-structural carbohydrates in terminal leaders and roots for topkilled versus unburned individuals. Our results suggest that chestnut regeneration can tolerate fire, although not at the severity or frequency that red oak can. This may hamper chestnut restoration in oak forests that are being regenerated through frequent prescribed burns.

Identification of degradation levels of dry evergreen forests for restoration in Sri Lanka. Suduhakuruge, B., Kumara, C. (*Forest Department, Sri Lanka; bandumala03@yahoo.com; rmcsupun@gmail.com*).

The main objective of this study was to develop a ranking system for prioritizing degraded forests for restoration. For this study 10 open forests of different stages of disturbances and 2 closed canopy forests were selected using recently updated forest cover maps. The ranking system was based on the forest degradation indicators of basal area, biodiversity indices, biomass, and regeneration capacity. Line transects were walked along a fixed bearing, using a compass, and sampled at regular intervals within plots of 100 m × 5 m. Within each plot, all the trees were identified, trees >10 cm DBH were measured for DBH and trees <10 cm DBH were only counted. Basal area, biomass, and diversity of different forests were calculated by common formulas used in forest inventory. According to the results, closed canopy forests were characterized by a high density of trees (600 trees >10 cm DBH per hectare and 4 205 trees <10 cm DBH per hectare) and with a basal area of about 45 m^2/ha. Compared to the closed canopy forests, open forests represented a low density of trees with a comparatively low basal area. Using the calculated indicators, open forests were classified into three groups: slightly, moderately, and highly degraded forests. This study indicates the need for applying different restoration techniques to rehabilitate degraded forests of different degradation stages.

The recovery of forest understorey in new forests on former agricultural lands: planted versus naturally regenerated stands. Tullus, T. (*Estonian University of Life Sciences, Estonia; tea.tullus@emu.ee*), Roosaluste, E., Tullus, A. (*University of Tartu, Estonia; elle.roosaluste@ut.ee; arvo.tullus@ut.ee*), Tullus, H., Lutter, R. (*Estonian University of Life Sciences, Estonia; hardi.tullus@emu.ee; reimo.lutter@emu.ee*).

During the recent decades, the abandonment of agricultural lands has promoted the emergence of new forests in Northern and Eastern Europe, which are either formed as an outcome of secondary succession or established as plantations. Due to the agricultural legacy, the restoration of typical forest flora may be a long process in these new stands. When compared to naturally regenerated stands, even-aged, monospecific, and intensively managed plantations offer less heterogeneous conditions for the understorey. Our aim was to compare understorey vegetation characteristics between planted and naturally regenerated stands on abandoned agricultural sites, focusing on the aspect of forest understorey recovery. Data were collected from 73 experimental plots located across Estonia in 24 hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) and 11 silver birch (*Betula pendula* Roth) plantations and in 11 naturally regenerated birch (*B. pendula and B. pubescens*) stands, 13–20 years after stand establishment. All stand types were dominated by apophytic grassland species. In naturally regenerated stands the number of forest species and forest-grassland ecotone species was significantly higher, indicating that the recovery of the forest understorey had progressed further. Total species richness was the highest in sparser and more-light-transmitting hybrid aspen plantations where the number of both grassland and fallow species was high.

B-08 Forest regeneration: challenges and prospects

Organizer: Magnus Löf (Swedish University of Agricultural Sciences)

Experimental restoration ecology in tropical rain forest areas with clearcutting and abandonment in southeastern Brazil. Cardoso-Leite, E., Devides Castello, A., Coelho, S., Vicentin, A., Martinez, A., Tonello Polly, K., Franco, F. (*Federal University of San Carlos, Brazil; cardosoleite@yahoo.com.br; caroldcastello@gmail.com; samucabeca@hotmail.com; ale_vicentin@hotmail.com; alice.engflorestal@gmail.com; kellytonello@ufscar.br; fernandosf@ufscar.br*).

The Atlantic rainforest is one of the most biodiverse ecosystems of the world, but has been destroyed by land conversion in agricultural areas. This study was conducted in two different situations; clearcut and implementation of pasture (P) and simple clearcut (N), both with 5 years of abandonment. Experimental restoration units were deployed to analyze the most efficient model (faster recovery and lower cost) comparing passive and active restoration (planting seedlings and seeds). In N we planted seeds (SE) and seedlings (SL) and in P we used SE, SL, and agroforestry system (AF). We monitored species richness, total height, crown diameter, and grasses control (shading) three times during 18 months. In N, the active restoration SL data showed higher richness, height, and diameter, but the passive restoration showed greater control of grasses. In P, SL showed greater richness, height, and diameter and greater control of grasses, AF showed intermediate data for these variables, and SE had the lowest values for all variables. Thus, the most appropriate method for P was active restoration SL and for N, the passive restoration, taking into account the lower costs for the latter.

Natural regeneration of whitebark pine: factors affecting seedling density. Goeking, S., Izlar, D. (*U.S. Forest Service, USA; sgoeking@fs.fed.us; dizlar@fs.fed.us*).

Whitebark pine (*Pinus albicaulis*) is an ecologically important species in high-altitude areas of the western United States and Canada due to the habitat and food source it provides for Clark's nutcrackers, red squirrels, grizzly bears, and other animals. Whitebark pine stands have recently experienced high mortality due to wildfire, white pine blister rust, and a mountain pine beetle outbreak, leading to questions about the species' long-term viability. The purpose of our study is characterize the age- and size-class structure of whitebark pine at the landscape level, as well as identify factors that influence whitebark pine seedling density. We considered variables describing stand composition and structure, understory community composition, topographic characteristics, and climatic regime. Logistic regression models identified 10 variables as potentially important predictors of presence/absence of whitebark pine seedlings, including forest type, cover of *Vaccinium scoparium*, seedling density of other species, forb cover, and summer minimum and maximum temperature. Although whitebark pine regeneration is abundant in many areas, long-term monitoring will be necessary to assess the survival of younger size and age classes, especially as these classes become potentially susceptible to insects and/or white pine blister rust over time.

Regeneration patterns and persistence of the of the rare tree species *Sorbus torminalis* in Central European oak coppice forests. Kunz, J., Pyttel, P., Kohoutek, D., Bauhus, J. (*University of Freiburg, Germany; joerg.kunz@waldbau.uni-freiburg.de; patrick.pyttel@waldbau.uni-freiburg.de; dbj.kohoutek@gmx.de; juergen.bauhus@waldbau.uni-freiburg.de*).

The abandonment of coppice forests is thought to be the major reason for the rarity of *Sorbus torminalis* in Central Europe. To support management and conservation efforts, we examined the dynamics and growth of *S. torminalis* regeneration before and after coppicing. The study was carried out in aged oak coppice forests, which had been unmanaged for >80 years. To describe tree regeneration processes retrospectively for the unmanaged period we inventoried all individuals <1.3 m tall. Species regeneration and growth after coppicing was studied within an area of 0.5 ha which was felled and fenced during winter 2008/2009. Over a period of 5 years (2009–2013) regeneration was annually inventoried and growth-increment of every individual was recorded. Tree-ring analyses showed that root sprouts were of different ages, hence no clear pulse of regeneration was identified. Following coppicing and fencing, *S. torminalis* increased its number in the regeneration layer continuously, root sprouts accounted for 70% of *S. torminalis* regeneration. We observed that the average annual height growth of sprouts declined steadily due to competitive interactions. Our results indicate that *S. torminalis* establishes a persistent bank of root sprouts in undisturbed forests. Release of these individuals occurs through disturbances such as harvesting.

Natural regeneration in a disturbed tropical seasonal forest fragment: implications for wildlife habitat restoration. Martins, L., Engel, V., Sampaio, R., Sato, L. (*São Paulo State University, Brazil; leonardoamartins@gmail.com; veralex@fca.unesp.br; ritacamilasampaio@gmail.com; lu_sato7@hotmail.com*).

In Atlantic forest seasonal semideciduous ecosystems, some fragments have a high conservation value due to the presence of residual populations of endangered species. In these fragments, vegetation dynamics and canopy species regeneration monitoring may indicate the need for management in order to facilitate forest succession processes. Our study aimed at studying the responses of a 630-ha tropical seasonal Atlantic forest fragment to anthropogenic and natural disturbances. We sampled three sites (A: low anthropogenic interference, B: logging activities up to 40 years ago, C: site disturbed by a tornado 9 years ago) and two height classes of natural regeneration (1: individuals <50 cm height, 2: individuals whose height was >50 cm and <130 m. Results showed that site C, although presenting higher richness and diversity indexes when compared to the other sites, had a much lower density, mainly in the first height class. This indicates low recruitment rates of canopy regeneration species due to a high dominance of lianas and bamboo species, which can delay successional development in this fragment. These results suggest the necessity of a directed management plan to increase regeneration recruitment rates and density, by means of liana and bamboo growth control.

Post-fire regeneration in mountain forests of the Alps: role of biological legacies and impact of restoration strategies. Marzano, R. (*University of Torino, Italy; raffaella.marzano@unito.it*), Garbarino, M. (*Università Politecnica delle Marche, Italy; m.garbarino@univpm.it*), Lingua, E. (*University of Padova, Italy; emanuele.lingua@unipd.it*).

Fire regimes are widely expected to be altered worldwide due to ongoing climate and land cover changes. Many parts of the European Alps, and particularly the inner-Alpine continental valleys, have already experienced increases in temperature and frequency of drought periods as well as major changes in socioeconomics and land cover/use. Interactions of climate change with disturbance events may trigger relevant changes in forest species composition, becoming a major factor shaping Alpine forest ecosystems in the future. Windows of opportunity for tree regeneration in sites where conditions are limiting may become increasingly less frequent. In this work we present a network of study sites along the Italian Alps where we investigate post-fire regeneration dynamics and the impact of post-disturbance management practices, with a long term monitoring approach. Recruitment patterns were assessed at different spatial scale, analyzing the influence of biotic and abiotic factors on seedling establishment. Preferential recruitment was associated with the availability of safe sites for germination. Intra- or interspecific facilitation mechanisms and sheltering effects of abiotic elements were found to be determinant in tree seedling establishment and survivorship. Post-disturbance management greatly affected the resilience of the ecosystems, influencing recruitment both directly and indirectly.

Effects of canopy cover and browsing damage on aspen regeneration following MPB-caused lodgepole pine mortality across north-central Colorado, USA. Pelz, K., Smith, F. (*Colorado State University, USA; kapelz@gmail.com; frederick.w.smith@colostate.edu*).

The mountain pine beetle (*Dendroctonus ponderosae* Hopkins) (MPB) has killed lodgepole pine on millions of hectares throughout western North America. Aspen (*Populus tremuloides* Michx.) is a shade-intolerant species that commonly co-occurs with lodgepole. Prolific aspen regeneration occurs following disturbance; it is predicted to increase following MPB-caused mortality. However, browsing can limit successful aspen recruitment and widespread recent sudden aspen decline may lead to low suckering. We quantify overstory mortality and aspen sucker densities, age, and damage in 30 stands across north-central Colorado. High sucker densities are present in many MPB-affected areas, but suckering is not consistent, partly due to patches of aspen clone mortality. The majority of aspen suckers are browsed in many areas. Variation in browse damage is likely related to animal populations and local protection from browsing by downed logs. High browsing is likely to result in low tree recruitment, especially where initial sucker density is low. Our results indicate that intervention to reduce browsing may be necessary to protect recruits particularly where aspen health is already questionable.

Intervention strategies for community-driven restoration of an iconic canopy species with specific regeneration niche requirements. Ruthrof, K., Hardy, G. (*Murdoch University, Australia; K.Ruthrof@murdoch.edu.au; g.hardy@murdoch.edu.au*), Matusick, G. (*The Nature Conservancy, USA; gmatusick@tnc.org*), Valentine, L. (*University of Western Australia, Australia; leonie.valentine@uwa.edu.au*).

Regeneration is a necessity for sustained forest conservation. *Eucalyptus gomphocephala* has a specific regeneration niche; mass recruiting in ashbeds following fire events. However, there are few regeneration opportunities in contemporary urban environments. Importantly, it is the conservation of urban ecosystems that will be vital in maintaining connection between people and the environment. For *E. gomphocephala*, ashbeds necessary for regeneration usually occur following hot fire. This may not occur following low-intensity, fuel reduction burns that are prescribed for many *E. gomphocephala* forests. However, ashbeds can be created by constructing and burning coarse woody debris (CWD) piles. In a series of collaborative projects with the community, including local and state agencies, we investigated whether regeneration could be facilitated through broadcast seeding naturally occurring ashbeds following wildfire and creating CWD piles prior to prescribed burns, which were subsequently seeded. We found that seeding into naturally occurring ashbeds facilitated regeneration. We also found artificial creation of ashbeds contained sufficiently high numbers of seedlings for successful regeneration. These studies provide tools that can be used to preserve the natural demographics of *E. gomphocephala* populations in urban environments by leveraging natural recruitment processes and community involvement.

Effects of forest fragmentation on the successional dynamics of secondary forests in the San Juan-La Selva Biological Corridor, Costa Rica. Santiago García, R., Finegan, B. (*CATIE, Costa Rica; rsantiago@catie.ac.cr; bfinegan@catie.ac.cr*), Mulkey, S. (*Unity College, USA; SMulkey@unity.edu*), Bosque Pérez, N. (*University of Idaho, USA; nbosque@uidaho.edu*).

The San Juan-La Selva (SJLS) Biological Corridor in Costa Rica was created to conserve biodiversity and provide connectivity between two protected areas. It is a human-dominated landscape where agricultural intensification has increased over the last few

years, creating a fragmented landscape of secondary forest patches within an existing matrix of agriculture, mature forests, and human development. It has created unique combinations of previous and surrounding land uses, patch structure, distance between remnant patches, and environmental variables. We are investigating how these variables determine the spatial variation of the structural, compositional, functional, and phylogenetic characteristics of these forests. We established 25 0.25-ha plots in which trees, saplings, and seedlings were recorded and measured, along with soil samples. Functional and reproductive traits are being analyzed. Phylogeny data will be obtained from current databases and analyzed using Phylomatic and Phylocom software. Multivariate Mantel correlograms indicate that distance decay relationships were similar for environmental variables and composition and diversity across plots. Floristic and environmental variables were significantly autocorrelated up to 30 km, indicating that distance between patches is a strong predictor. With these results, we will be able to quantify the relative importance of landscape and environmental variables driving succession of secondary forests.

Current pictures and feasibility of quasi-clearcutting in Japan. Toyama, K. (*University of Tokyo, Japan; toyama@uf.a.u-tokyo.ac.jp*).

In Japan, forest cover rate is about 66%, and about 40% of total forest is planted softwood forest for timber production. However, many stands are unprofitable due to severe geographical conditions or past unsuitable management. Recent governmental policies are promoting commercial thinning based on enhancement of forest road networks, which is hard to apply to stands with less profitability. This research focuses on feasibility and drawbacks of quasi-clearcutting and small-scale harvesting in Japanese forestry, which is expected to lead to better profitability in logging and successive natural regeneration in stands with less profitability. A case study showed, in an example of quasi-clearcutting, that marginal areas of a clearcut stand can be left uncut mainly for passive and economic reasons, whereas standing trees can be left uncut and isolated as shelterwood with a more active intent by woodland owners and managers. Simulation showed that both can be reasonable in profitability. This research also analyzes the spatial tendency of natural regeneration of hardwood trees in planted old softwood stands, which can be applied to create a potential map of stands suitable for quasi-clearcutting and natural regeneration.

B-09 What future for tropical silviculture?

Organizers: Robert Nasi (CIFOR, Indonesia) & Plinio Sist (CIRAD, France)

Dry forests of Ecuador: potential for natural forest management and carbon sequestration? Guenter, S. (*Thünen Institute of International Forestry and Forest Economics, Germany; sven_gunter@yahoo.de*), Cifuentes Jara, M., Villalobos, R., Casanoves, F. (*CATIE, Costa Rica; mcifuentes@catie.ac.cr; rvillalo@catie.ac.cr; casanoves@catie.ac.cr*), Segura Ramos, D. (*Ministry of the Environment, Ecuador; dsegura@ambiente.gob.ec*).

Dry forests worldwide suffer high land use pressure, deforestation and fragmentation. Many authors give this ecoregion highest priority for conservation due to its high vulnerability and high level of endemism. Only 17% of the original dry forest cover remains in Ecuador. High land use pressure accompanied by exploitation of timber species, fuel wood collection, and general low growth rates frequently results in limited potential for timber production in seasonally dry forests in comparison to humid forests. Non wood forest products and payments for carbon sequestration are frequently discussed as alternative or complementary solutions to improve the potential for natural forest management. The recently finished national forest inventory of Ecuador provides a solid database for discussing these questions for the specific case of seasonally dry forests. In this paper we analyze the datasets from 207 plots distributed in seasonally dry forest in order to identify the potential for natural forest management, carbon sequestration, and conservation. We analyze harvestable volumes and diameter structures of species and compare them with potential post-harvest structures. Based on growth data from other authors we conclude on most critical species and regions for recovery of post-harvest structures within the legal framework of Ecuador.

Tropical shelterwood system and its impact on the heterogeneous forests of West Africa: the Nigerian experience. Isikhuemen, E. (*University of Benin, Nigeria; ekeoba.isikhuemen@uniben.edu*).

The tropical shelterwood system (TSS) was introduced to the forests of West Africa in the early 1940s. In 1944, TSS treatment commenced in Nigeria with a number of silvicultural prescriptions which included canopy opening, frill-girdling, poisoning of undesirable species, and climber-cutting. By the time the system was annulled in the early 1970s, >250 000 ha of forests had been treated. This paper examines, 3 decades after treatment cessation, the effects of TSS on tree demography in a plot consisting of four treatments: heavy poisoning and climber-cutting (Treatment 1), selective poisoning and climber-cutting (Treatment 6), climber-cutting only (Treatment 12), and control (Treatment 13). Logging impacts on classes I and II economic trees were also considered. Results reveal a regrowth forest dominated by juveniles: saplings (40.8%) and poles (48.9%). The listed classes I and II economic species constituted 32% of total species and 34% of families encountered. *Guarea cedrata* and *Celtis* spp. were third and fifth, respectively, among the top 10 species with most abundant individuals. The preponderance of juveniles (saplings and poles) of listed economic species, despite the paucity of mature trees, suggests TSS treatment effects.

Adaptation of eucalypt trees to water and nutrient deficiencies: insights from Brazilian experiments question conventional recommendations. Laclau, J. (*CIRAD, France; laclau@cirad.fr*), Gonçalves, J., Battie-Laclau, P. (*University of São Paulo-ESALQ, Brazil; jlmgonca@usp.br; placlau@cena.usp.br*), Christina, M. (*CIRAD, France; mathias.christina@cirad.fr*), Nouvellon, Y. (*CIRAD, Brazil; yann.nouvellon@cirad.fr*), Stape, J. (*North Carolina State University, USA; stape@ncsfnc.cfr.ncsu.edu*), Moreira, R. (*University of São Paulo-ESALQ, Brazil; rmoreira@usp.br*), Le Maire, G., Bouillet, J. (*CIRAD, France; guerric.le_maire@cirad.fr; jpbouillet@cirad.fr*).

Drought is a major abiotic stress that will be exacerbated by climate changes in many forest ecosystems. A scarcity of fertilizers for the management of tropical plantations is also predicted due to finite reserves of phosphorus and potassium (K) worldwide. Identifying management practices enhancing tree tolerance to drought and nutrient deficiencies is, therefore, of primary interest.

Carbon, water, and nutrient fluxes have been monitored intensively over entire rotations in experiments manipulating rainfall and nutrition in *Eucalyptus grandis* plantations in southern Brazil. These studies question the relevance of some silvicultural practices well established in regions with relatively high annual rainfall. The early tree growth does not always need to be maximized; weeding can also be important after canopy closure; K fertilization is not always beneficial to face drought; it is not always necessary to split the applications of N and K fertilizers to prevent losses by leaching; and sodium application can enhance tree growth in K-deficient soils. We show that studies carried out at a single site can have broad applications for the management of tropical plantations, provided that they improve our comprehension of the mechanisms driving tree growth. In addition to multi-local trials, multidisciplinary research at a few sites associated to modelling and remote sensing is needed to adapt silvicultural practices to global changes.

Sustainable pathways for primary forest under a changing climate: ecological, social, and economic constraints. Mackey, B. (*Griffith University, Australia; b.mackey@griffith.edu.au*), DellaSala, D. (*Geos Institute, USA; dominick@geosinstitute.org*), Kormos, C. (*The WILD Foundation, USA; cyril@wild.org*), Zimmerman, B. (*International Conservation Fund of Canada and the Environmental Defense Fund, Canada; b.zimmerman@wild.org*), Young, V. (*Forests Alive Pty Ltd, Australia; virginia@forestsalive.com*).

This paper reviews the evidence for ecologically sustainable forest management in primary tropical forests in terms of wood supply, biodiversity conservation, greenhouse gas mitigation, and adaptation to projected climate change impacts. We identify ecological, social, and economic constraints on the sustainable use of primary tropical forests and recommend approaches that will retain their defining characteristics. Globally, only around 18% of the world's natural distribution of primary forests persists. Tropical primary forests are under increasing pressure as developing countries seek to exploit their natural resources. Furthermore, it is now 95% certain that rapid, human-forced climate change will impact on all biomes including the tropics. Decades of monitoring and evaluation now point to the limitations of industrial-scale logging as a conservation strategy in primary tropical forests. A development pathway is needed that maintains the defining characteristics of primary tropical forests so that their greenhouse gas mitigation function is maximised and to help ensure their resilience and adaptive capacities remain intact. Two case studies are presented of community-based forest management in the Brazilian Amazon and Southeast Asia which illustrates how alternative development pathways can be designed and implemented.

Forest resilience depends on stand variations: forest dynamics of an Amazonian forest 30 years after logging. Mazzei, L., Ruschel, A. (*EMBRAPA, Brazil; lucas.mazzei@embrapa.br; ademir.ruschel@embrapa.br*), Silva, J. (*Federal Rural University of the Amazon, Brazil; silvanatalino734@gmail.com*), Schwartz, G. (*EMBRAPA, Brazil; gustavo.schwartz@embrapa.br*), de Carvalho, J. (*Brazilian National Council for Scientific and Technological Development, Brazil; olegario@pq.cnpq.br*), Kanashiro, M., Lopes, J. (*EMBRAPA, Brazil; milton.kanashiro@embrapa.br; carmo.lopes@embrapa.br*).

A polycyclic selective cutting system has been used in the Brazilian Amazon; current protocols were mainly developed through harvesting experiments established since 1975. Such experiments represented a remarkable start on the further application of reduced impact logging in Brazil. One of those experiments, specifically about logging for timber production, was carried out at the Tapajós National Forest in 1979. The timber volume harvested was 72 m^3/ha or 16 trees/ha that immediately removed 25% of the total carbon stock in the forest. In the present study, the circumstances where natural forest management can be applied as a conservation tool were evaluated using data from the Tapajós National Forest logged area. Hence, three types of forest ecosystem values were assessed along 30 years of forest dynamics to determine forest resilience: 1) commercial volume, 2) floristic composition and diversity, and 3) carbon stock. The results showed that variations in stand structure and forest composition due to harvesting led to a recovery of the carbon stock, which provided 62 m^3/ha of merchantable volume. The forest resilience for timber production depends on these variations through time, representing the silvigenesis stage 30 years after logging.

Harvest regulation for multiresource management, old and new approaches. Mendoza, M. (*Colegio de Postgraduados, Mexico; martinmendoza@yahoo.com*).

Current Mexican forest management is the product of a history started in 1926. The earlier approaches aimed directly or indirectly to attain the normal, fully regulated forest model. Around 1980 the first considerations about multi-resource and environmental impact were mandated over all private timber operations. Concerns about water quality, biodiversity, legally protected natural areas, and endangered species were the motives for promoting in 2012, and afterwards, voluntary best management practices, because timber-oriented silviculture was deemed insufficient to take proper care of non-timber values in the forest. In this research, two Mexican traditional forest management schemes (SICODESI, Plan Costa de Jalisco), enhanced with best management practices, were compared with a management method specifically designed to manage landscape attributes. Results from a full 10-year cutting cycle for the three management techniques showed that traditional schemes, even when modified to comply with best management practices, failed to secure a forest dynamic favorable to responsible stewardship of non-timber values. The landscape technique used multiple means to drive forest dynamics to fulfill multi-resource objectives constrained by self-financing and competitive profitability in private and communal ownerships, relative to similar timber operations from the international scene.

Past, present, and possible futures of the western Congolian lowland rainforest. Pietsch, S. (*University of Natural Resources and Life Sciences, Austria; stephan.pietsch@boku.ac.at*), Gautam, S. (*Tree Canada, Canada; sisir_gautam@yahoo.com*), Bednar, J. (*University of Vienna, Austria; bednarje@gmail.com*), Petritsch, R., Schier, F. (*University of Natural Resources and Life Sciences, Austria; richard@petritsch.or.at; schier.franziska@googlemail.com*), Stanzl, P. (*VMS, Gabon; stanzl225@aon.at*).

Past climate change caused severe disturbances of the Central African rainforest belt, with forest fragmentation and re-expansion due to drier and wetter climate conditions. Besides climate, human-induced forest degradation affected biodiversity, structure, and carbon storage of Congo basin rainforests. Information on climatically stable, mature rainforest, unaffected by human-induced disturbances, provides a means of assessing the impact of forest degradation and may serve as benchmarks of carbon carrying capacity over regions with similar site and climate conditions. Biogeochemical (BGC) ecosystem models explicitly consider the

impacts of site and climate conditions and may assess benchmark levels over regions devoid of undisturbed conditions. We will present a BGC-model validation for the western Congolian lowland rainforest (WCLRF) using field data from a recently confirmed forest refuge, show modelled data comparisons for disturbed und undisturbed forests under different site and climate conditions as well as for sites with repeated assessments of biodiversity and standing biomass during recovery from intensive exploitation. Next we explore climatic thresholds for WCLRF resilience and stability and identify management-induced shifts in stable states. Finally, we will compare different modelling scenarios, which provide different ecosystem services like timber yield, carbon sequestration, or biodiversity conservation and assess the prediction horizon of each scenario.

Multiple-use forest management in Madre de Dios, Peru: the sustainability of Brazil nut production and timber in an integrated system. Rockwell, C., Guariguata, M. (*Center for International Forestry Research, Peru; rockwell_cara@yahoo.com; m.guariguata@cgiar.org*), Menton, M. (*Global Canopy Programme, UK; mcsmenton@gmail.com*), Arroyo-Quispe, E. (*Universidad Nacional Amazónica de Madre de Dios, Peru; eriks_24988@hotmail.com*), Quaedvlieg, J., Warren-Thomas, E. (*Center for International Forestry Research, Peru; juliaquaedvlieg@gmail.com*; *em.warren.thomas@gmail.com*).

Historically, both Brazil nut fruits (*Bertholletia excelsa*, Lecythidaceae) and timber of other commercial species have been exploited for economic gain in the southwestern Amazon region. However, some researchers and smallholders have expressed concern that the integration of these livelihood strategies may not be sustainable. Our study evaluates the effects of logging on *B. excelsa* tree fecundity and the density and spatial distribution of juvenile stems (10–40 cm DBH) in five Brazil nut concessions in Madre de Dios, Peru. From 2013 to 2014, fruit count and nut weight data were collected for more than 500 reproductive trees. Logging impact was characterized as a function of logging intensity (based on neighborhood and timber volume extracted), gap size, distance to nearest logging gap, and logging damage to the tree. Exhaustive line-transect censuses were conducted in these same forest sites to search for juvenile stems. Logging impact on juvenile density and spatial distribution was assessed as a function of distance to nearest logging disturbance, local logging intensity, and canopy openness. The results from our evaluation of this complex smallholder system contribute to our growing knowledge of multiple-use forestry systems, a management strategy that has thus far proved difficult to evaluate in the literature.

Current state and new trends in the silviculture and sustainable management of tropical production forests. Sist, P. (*CIRAD, France; sist@cirad.fr*), Gourlet-Fleury, S. (*CIRAD, France; sylvie.gourlet-fleury@cirad.fr*), Nasi, R. (*Center for International Forestry Research, Indonesia; r.nasi@cgiar.org*).

We present likely new trends for the future of forest management in the tropics and their consequences regarding sustainability in managed timber production forests. Based on the impact of silvicultural practices on forest ecology and dynamics across the three main tropical forest areas (Amazon, Congo Basin, and Southeast Asia), we discuss under which conditions silviculture can be an efficient tool for the conservation and sustainable use of >400 million ha of production forests. The main challenge appears finding extraction intensity thresholds and modalities compatible with the maintenance of environmental services and stand recovery. Most of the tropical production forests will enter soon or have already entered their second felling cycle. In these forests, logged 25 to 40 years ago, the volume has not been recovered and young trees expected to make up the next harvest are lacking in number as no silvicultural treatments were applied. We show that silvicultural treatments tailored to the specific conditions of these forests will have to be implemented to maintain production and ensure future sustainability.

Managing high-value tropical timber species for carbon capture. Ward, S. (*Mahogany for the Future, Inc., USA; mahoganyforthefuture@gmail.com*).

Future tropical timber lands will be managed for multiple purposes, including carbon capture. High value timbers can contribute through their use in reforestation, agroforestry, and plantations, and by helping to maintain natural forest cover. Using examples from the tropical timber Meliaceae and other high-value species, this talk considers potential management practices, and their consequences, for increasing carbon capture by these species. These practices could include extending the cutting cycle to increase forest biomass and plantation strategies to maximize growth. Potential management changes for carbon capture will be considered in scenarios involving small producers, concessions in natural forest, in re- or afforestation, and watershed protection. Potential carbon capture by high value timber, including as long-term storage in finished wood products, will be compared to carbon storage by fast growing species and to carbon sequestration in forest preserves. Also to be considered are the components necessary for these species to play a major role in carbon capture, including profitability, secure land tenure, and appropriate regulatory structures. For example, carbon credits and certification of sustainability might render long-term forest management for these species profitable.

Posters

Tree diversity and soil nutrient studies of logged-over forest in Peninsular Malaysia. Amlin, G., Suratman, M., Md Isa, N. (*University of Technology, Malaysia; gufrinamlin@yahoo.com; nazip@salam.uitm.edu.my; nurundin@pahang.uitm.edu.my*).

The biodiversity and soil nutrients are important factors for maintaining the stability and ecosystem services of forests. These components are also important as indicators of forest recovery after various disturbances. The objectives of the study were to evaluate the species diversity and soil nutrients of logged-over lowland dipterocarp forest at Krau Wildlife Reserve (KWR), Pahang, Malaysia. The plot design was carried out within 50 quadrat plots with the size of 20 m × 20 m (2 ha). A total of 8 951 saplings with the size of 1.5 m height and <10 cm DBH were collected and identified; consisting of 53 families, 136 genera and 254 species. The Shannon-Weiner (H′) and Simpson (D) indices show high diversity with values of 4.2 and 0.9, respectively; however, no dipterocarp species found in the study site. The carbon (C) and nitrogen (N) contents were considered low with C:N ratio about 10.33; however, the exchangeable cations (Ca, Mg, K, and Na) were considered high. It can be concluded that the species diversity and soil nutrients of lowland dipterocarp secondary forest at KWR 30 years after logging is relatively low as compared to the other primary forests in Peninsular Malaysia.

Post-logging stand dynamics of a tropical rain forest in the Brazilian Amazon. de Avila, A. (*University of Freiburg, Germany; angela.de.avila@waldbau.uni-freiburg.de*), Ruschel, A. (*EMBRAPA, Brazil; ademir.ruschel@embrapa.br*), de Carvalho, J., Silva, J. (*Federal Rural University of the Amazon, Brazil; olegario@pq.cnpq.br; silvanatalino734@gmail.com*), Mazzei, L. (*EMBRAPA, Brazil; lucas.mazzei@embrapa.br*), Castro, T. (*Federal Rural University of the Amazon, Brazil; ccastro.tatiana@gmail.com*), Bauhus, J. (*University of Freiburg, Germany; juergen.bauhus@waldbau.uni-freiburg.de*).

Sustainable forest management requires an understanding of forest dynamics following logging disturbance. In this study we analysed the effects of four disturbance intensities on stand dynamics compared to the structure before logging and to a control treatment. Trees ≥5 cm DBH were measured on eight occasions in 41 permanent sample plots (0.25 ha) located in the Tapajós National Forest, Pará. Disturbance intensities, which comprised logging (1982) and thinning (1993–1994), ranged from 19 to 53% of basal area reduction in relation to its original value. Stand basal area returned to similar levels within 30 years except for the highest disturbance intensity. Number of stems per hectare increased with disturbance intensity. In disturbance levels <20%, the self-thinning process that started in dense stands after logging reduced density to levels similar to those before logging. Mortality was high soon after logging but following this period recruitment exceeded mortality for about 5 years. Annual mortality/recruitment rates declined over time but they were still higher than in the unlogged forest. Although these results indicate that the forest appears to recover its general structure under certain disturbance intensities, further studies are needed to evaluate the recovery of other ecological and productive features.

***Mezilaurus itauba* sustainable management in the Brazilian Amazon.** Canetti, A. (*EMBRAPA, Brazil; alinecanetti@gmail.com*), Braz, E. (*EMBRAPA, Brazil; evaldo@cnpf.embrapa.br*), Mattos, P. (*EMBRAPA, Brazil; patricia.mattos@embrapa.br*), Oliveira, M. (*Federal University of Paraná, Brazil; marianaferraz.floresta@gmail.com*).

The specific understanding of the structure and growth of each species is the key to successful management in the Brazilian Amazon. *Mezilaurus itauba* was selected to be studied because its timber is very important to the economy of the state of Mato Grosso, in the Amazon region. It was sampled on 100 ha, where the growth of all commercial species were measured both before and 6 years after logging. The recruitment, mortality, and diameter structure of the species were measured at the study site. First, a matrix model was used to simulate species recovery within the cutting cycle (35 years) leaving aside 10% of commercial trees as mother trees, following the Brazilian forest legislation for native forests. The simulation indicated a recovery rate of only 14% of the original stock. Then, we tested a reduction of 33% of the cut rate, maintaining all the trees between 55 and 65 cm of diameter class center. The simulation in this case indicated a recovery of 78% of the original stock. These analyses showed that it is necessary to introduce in the Brazilian legislation the possibility of considering new alternatives for the management of the natural forests.

Natural regeneration management of pau-mulato in Amazonian estuary floodplains forests. Carneiro Guedes, M. (*EMBRAPA, Brazil; marcelino.guedes@embrapa.br*), Furtado Castilho, N. (*Federal University of Amapá, Brazil; nubiaabrobio@gmail.com*), de Sousa Rodrigues, D. (*State University of Pará, Brazil; dani_enflor23@yahoo.com.br*).

The pau-mulato (*Calycophyllum spruceanum* (Benth) K. Shum.) is one of the important species of Amazonian estuary floodplain forest, representing 25% of the wood processed at small, family riverine sawmills. Its wood (density=0.7 g/dm^3) is commonly used in house construction. In the area of the Florestam project (forests of the Amazonian estuary), in the floodplains of the municipality of Mazagão-AP, Brazilian Amazon, we studied the potential for pau-mulato natural regeneration and evaluated the effect of thinning on growth. The pau-mulato density (63 220 trees/ha) was high in fallows derived from shifting cultivation, when prepared with fire, and in early succession (10–18 months), forming a true monospecific pau-mulato stand. After the thinning treatment, maximum (1.71 cm/year) and minimum (0.11 cm/year) diameter growth occurred at densities of 125 and 1 416 trees/ha (control), respectively. Pau-mulato responded positively to thinning, improving development after selective removal. The regeneration management allowed the choice of best individuals, without the costs of planting seedlings. The results confirm the potential to manage pau-mulato for wood supply and income to riverine sawmills in the Amazonian estuary, due to a guaranteed market and traditional use by families, and its rapid growth and high regeneration.

The vegetation recovery of tropical rain forests under different commercial logging methods on Hainan Island, China. Ding, Y., Zang, R. (*Chinese Academy of Forestry, China; ydingcaf@gmail.com; zangrung@caf.ac.cn*).

In this study, we assessed the natural recovery after commercial logging with three different methods, including repeated logging, selective logging, and managed selective logging in tropical montane rainforest of Hainan Island. Our results showed that commercial logging enhanced the number of species in recovered communities in the tropical montane rainforest, due mainly to the increase of species richness of small stems (<10 cm DBH). There were significantly more stems in logged forests than in old-growth forests, but the basal area of logged forests were apparently less than old-growth forests. Rates of species accumulation of saplings and young trees in forests after logging were less than those in old-growth forests. After approximately 20–25 years of recovery, the community structure of forests after managed selective logging was similar to the old-growth forest. The long-lived pioneer species richness, stem density, and basal area increased significantly in the forests after logging, especially after repeated logging. However, there was little variation in species richness proportion of late succession and shade-tolerant species among different forest communities. Forests harvested with selective logging and managed selective logging had higher recovery potentials and rates, but it took time to recover to pre-logged levels.

Eucalyptus stocking and soil preparation in a frontier region of northern Brazil: necessity of changing concepts from traditional regions. Hakamada, R. (*University of São Paulo, Brazil; rodrigo_hakamada@yahoo.com.br*), Lemos, C., Almeida, A., Silva, R., Batistuzzo, G. (*International Paper, Brazil; Cristiane.Lemos@ipaper.com; adriano.almeida@ipaper.com; renato.meulman@ipaper.com; guilherme.batistuzzo@ipaper.com*).

The northern region of Brazil is a forest plantation frontier, with projections of 3 million ha of new plantations by 2020. There have been many studies worldwide regarding stocking and soil preparation in *Eucalyptus*, but none have been reported about this

region. So, our objectives in this paper are to present the results of spacing and soil preparation in a 3-year-old *Eucalyptus grandis* x *E.urophylla* plantation. To study spacing, a Nelder design trial was planted with stocking ranging from 228 to 7,150 trees/ha and soil preparation was evaluated in a trial with three levels of soil preparation: pitting and subsoiling at 30 or 60 cm depth. Traditional stocking rates for Brazil, ranging from 1 000 to 1 500 stems/ha, resulted in 15% mortality, which increased to 100% when stocking rate increased. Complete survival was achieved with <800 trees/ha. The effect of soil preparation intensity also differed from the traditional region, with a positive effect on survival and initial growth with increasing subsoiling depth. Results indicated that in this region, where water is the main constraint of wood growth, silvicultural practices must be studied and adapted with a focus on water relations.

Testing a silvicultural recommendation: Brazil nut responses 10 years after liana cutting. Kainer, K. (*University of Florida, USA; kkainer@ufl.edu*), de Oliveira Wadt, L. (*EMBRAPA, Brazil; lucia.wadt@embrapa.br*), Staudhammer, C. (*University of Alabama, USA; cstaudhammer@ua.edu*).

Although liana cutting benefits for tropical timber management have been documented, benefits for non-timber forest product (NTFP) management have not. We tested the silvicultural recommendation that lianas should be cut from Brazil nut trees (*Bertholletia excelsa*) to improve host tree fecundity and thus, commercial nut yields. Our 10-year experiment was conducted where local harvesters collect Brazil nuts as part of their forest-based livelihoods. We cut 454 lianas from 78 of 138 host trees ≥50 cm DBH. Treated trees were better producers 3.5 years after liana cutting, and by years 9 and 10 produced three times more fruits than untreated trees. Number of lianas rooted within 5 m of the host tree explained production levels, suggesting both above- and belowground liana competition. Once host crowns were liana free, branch regrowth was highly visible, and crown reassessments suggested that liana cutting improved crown form. Liana cutting may induce non-producing trees to become producers and may circumvent mortality of heavily infested trees. Only lianas associated with Brazil nut trees should be cut to conserve liana ecosystem functions. Liana cutting could be applied to other tropical trees to boost NTFP fruit and seed production and increase host tree fecundity.

Eighteen years of post-logging recovery in a mixed dipterocarp forest Sabah, Borneo: evaluation of modified RIL and climber cutting. Lussetti, D. (*Swedish University of Agricultural Science, Sweden; daniel.lussetti@slu.se*).

Commercial logging is a driver of rainforest degradation in Sabah, Borneo. Destructive felling and log extraction techniques together with short rotations cause disruption to stand structure and long-term timber yields of natural tropical forests. Since the residual stand is relied upon to produce future yields, reduced impact logging (RIL) methods need to be evaluated. By reduced impact logging, we mean implementation of a series of pre- and post-logging guidelines designed to protect residual stand from injury, minimize soil damage, and protect critical ecosystem processes. The experiment compared two types of logging (with and without pre-climber cutting): conventional selective logging (CL) and supervised selective logging (SL). In SL both pre-marked skid trails and directional felling were implemented. A randomised complete block 2 × 2 factorial design was used, including 20 gross treatment plots, each of 5.76 ha with a central 1-ha net plot. Post-logging data (18 years) showed that almost full basal area recovery had been reached, though with changed species and diameter class compositions. The amount of trees <40 cm DBH had increased, while large trees were reduced. SL reduced establishment of pioneer species (*Macaranga*) compared to CL.

Potential of natural forest production in Sinop County in the Amazonia region, Brazil. Muñoz-Braz, E. (*EMBRAPA, Brazil; evaldo.braz@embrapa.br*), Basso, R., Abreu, M. (*Elabore Ltda, Brazil; elabore@terra.com.br; elaboresinop@gmail.com*), Mattos, P. (*EMBRAPA, Brazil; patricia.mattos@embrapa.br*), Oliveira, M. (*Federal University of Paraná, Brazil; marianaferraz.floresta@gmail.com*), Zachow, R. (*Forest Service, Brazil; randolfzachow@hotmail.com*).

The timber sector is very important to the state of Mato Grosso, Brazil, especially for Sinop County, as timber production is the main source of employment in the region. This paper analyzed two forest sites, 50 ha each, that were logged 6 years ago. The current composition of the forest was assessed by a new census. Extraction scenarios were simulated to identify the potential cut rate by a matrix model. The growth values of the five most abundant species were supplemented with growth rings measurements, obtained by dendrochronology. The commercial potential of trees with a diameter at breast height ≥50 cm was 60 m³/ha. A minimum of 50% of the commercial stock should be reserved to guarantee future sustainable logging. With well-planned logging, avoiding damage to the forest, an initial cycle of 25 years would be sufficient to recover 30 m³/ha. It was observed that the forest growth was very dependent on the remaining commercial stock. It should be emphasized that fixed wood volume cutting rates and fixed cycles should be avoided by legislation as they are not consistent with the diversity of sites and forest subtypes of the Amazon region.

Growth pattern of *Qualea albiflora* and *Goupia glabra* in Amazon forest, Mato Grosso State, Brazil. Oliveira, M. (*Federal University of Paraná, Brazil; marianaferraz.floresta@gmail.com*), Mattos, P., Muñoz-Braz, E., Canetti, A. (*EMBRAPA, Brazil; patricia.mattos@embrapa.br; evaldo.braz@embrapa.br; alinecanetti@gmail.com*), Basso, R. (*Elabore Ltda, Brazil; elabore@terra.com.br*), Rosot, N. (*Federal University of Paraná, Brazil; ncrosot@ufpr.br*).

The aim of this study was to analyze the growth dynamics of commercial tree species in Amazonian forest in Sinop region, Mato Grosso State, Brazil. Stem discs were collected from *Qualea albiflora* and *Goupia glabra* in a compartment of primary forest. The growth rings series were cross-dated. To determine the growth pattern, six models were tested. The best model was chosen based on statistical results and graphical analysis. The equation that best reflected the growth of *Qualea albiflora* was logistic and of *Goupia glabra* was Gompertz. From the graphical analysis of the curves from the average and current annual growth, it was observed that there was an optimum production with diameter of approximately 30 cm (51 years) for *Qualea albiflora* and 35 cm (70 years) for *Goupia glabra*. The highest average growth was observed in the 65-cm-class center for *Q. albiflora* (0.8/year) and 25-cm-class center for *G. glabra* (0.5 cm/year). Thus, it can be considered that the diameter class center immediately below the minimum logging diameter (MLD) of 50 cm may supply the timber stock for the next cycle, considering the diameter to be achieved, if it is applied at an adequate cut rate.

Species grouping for timber management in Brazilian eastern Amazon. Ota, L. (*São Paulo State University, Brazil; lizmsota@gmail.com*), Vidal, E. (*University of São Paulo-ESALQ, Brazil; edson.vidal@usp.br*), Ré, D. (*Serasa, Brazil; danilo.scorzoni@gmail.com*).

Legislation for timber logging in the Brazilian Amazon defines logging cycles of 25 to 35 years for mechanized operations and 10 years for manual or semi-mechanized operations. Our study site, periodically assessed since 1993, was 49 ha of forest (50% harvested and 50% not harvested). We identified 186 species from 57 families. Of those, only 45 were on the lists of commercial species from two timber companies. Three of them had a density lower than 0.03 individuals/ha, the lowest density for a legal harvestable species. The 42 species able to be harvested had very different behaviors and characteristics and should not be managed similarly. Our study aimed to define groups of species with similar behaviors for timber management. Therefore, we clustered species into four groups by their mean annual increment and density per hectare. The first group was composed of only one species (*Tachigali paniculata* Aubl.), with the highest average annual increment and the lowest simulated cycle. The other groups were comprised 10, 15, and 16 different species. Other grouping methods should be tested for better decision-making and for the legislation's adjustment proposal.

Temperature effects on tree and bird richness in a managed forest for timber in east Amazonia (Brazil). Quimbayo Cardona, M. (*University of Tolima, Colombia; miguelq@ut.edu.co*), Magro, T. (*São Paulo University, Brazil; teresa.magro@usp.br*), Vidal, E. (*University of São Paulo, Brazil; edson.vidal@usp.br*).

This study was carried out in Paragominas, at the Roberto Bauch Forest Management Center, Pará. This Amazon region produces >50% of the native forest timber in Brazil, consequently affecting wildlife and vegetation cover. Fieldwork was conducted from October 2010 to April 2011 during dry and wet seasons in six areas of 100 ha each: five areas were managed for timber (1997, 2000, 2003, 2006, and 2009) and one managed area was not logged. Logging activities change forest structure, modify microclimatic conditions (temperature, light intensity, and humidity), and affect wildlife populations. We located randomly 18 plots of 20 m × 50 m in the forest (three plots per area). Birds were recorded at each plot using a point count survey. All individual trees with DBH >10 cm were recorded, as well as the temperature and humidity of the plot. One hundred and nine tree species and 235 bird species were found. We used multiple regression analysis; data were transformed and organized as standard deviation units to maintain its similar nature. We determined Spearman correlations between temperature and tree richness, and found a negative or inversely proportional relationship. Bird species richness showed a significant relationship with temperature ($P < 0.05$), ($r = 0.813$), but there was no significant relationship between tree richness and temperature ($P > 0.05$), ($r = 0.004$).

Forest structure and biodiversity of managed tropical rainforest for timber in east Amazonia (Brazil). Quimbayo Cardona, M. (*University of Tolima, Colombia; miguelq@ut.edu.co*), Magro, T. (*São Paulo University, Brazil; teresa.magro@usp.br*), Vidal, E., Zarate do Couto, H. (*University of São Paulo, Brazil; edson.vidal@usp.br; htzcouto@usp.br*).

This study was carried out in Paragominas (Pará), at the Roberto Bauch Forest Management Center. Pará state produces >50% of the native forest timber in Brazil, affecting wildlife and vegetation cover. Fieldwork was conducted from October 2010 to April 2011 during dry and wet seasons in six managed areas for timber: five logged areas (1997, 2000, 2003, 2006, and 2009) and one not logged. We located randomly 18 plots of 20 m × 50 m in the forest (three plots per area). All individual trees with DBH >10 cm were recorded. One hundred and nine native tree species were registered, representing 33 families; the highest relative abundance families were Fabaceae (20.18%) and Sapotaceae (13.76%). Fifteen species were identified as endemic to the Amazonian tropical rainforest, and 44 species were listed as potentially endangered by logging activities. The highest species richness was found in the 1997 logged area (51 species), followed by the not logged area (50 species) and the 2006 logged area (50 species); the 2000, 2003, and 2009 logged areas had 46, 45, and 43 species, respectively. *Lecythis idatimom* (Lecythidaceae) had the highest importance value index (IVI) in all managed areas. Diagrams of canopy dispersion and vegetation profile showed heterogeneity in at least five different strata with emergent trees in all managed areas.

Development of *Pericopsis elata* seedlings around seed bearers in a logging forest of southeastern Cameroon. Ruth Laure, N., Samuel Réné, G., Din, N. (*University of Douala, Cameroon; nnangaruth@yahoo.fr; gwethsamuel@yahoo.fr; ndongodin@yahoo.com*).

Pericopsis elata is a high economic value timber species of west and central Africa listed in appendix II of CITES and in the IUCN red list as endangered because its low natural regeneration rate does not replace the logged population. Factors that influence its regeneration rate have not yet been sufficiently understood to propose an appropriate silvicultural method. This study aimed to evaluate the influence of seed bearers to the development of seedlings of *P. elata*. In logging forest, located in southeastern Cameroon, delimited square plots of 1 ha were arranged into five sub-plots of 20 m × 20 m where the diameter and height of seedlings from seed bearers were measured. The results showed that the development of seedlings was easily expressed by the increase in height rather than diameter. At the 17th month, the mortality rate appeared very high at roughly 71%. There was no correlation between the distance from the seed bearers and the rate of seedling mortality. Additional analysis regarding factors such as light, gap size, and seed and seedling predation are required to understand the dynamics of seedling regeneration to design silvicultural practices.

A simplified method for yield regulation of the Miombo Woodlands in the context of participatory forest management. Sanfilippo, M. (*Cooperation for the Development of Emerging Countries (COSPENGO), Italy; massi_ag@yahoo.it*), Salis, A. (*FAO, Italy; antonellosalis@gmail.com*).

An appropriate system of yield regulation is a basic requirement for sustainable forest management. Most of the existing methods are complex and require dynamic data collected through permanent sample plots and, as a result, are unsuitable for small scale participatory forest management (PFM) projects. Even though volume is commonly used as the variable to regulate yield, we argue that few forest users in the Miombo ecoregion are able to implement forest management prescriptions expressed in terms of harvestable volume. We propose a simplified method for yield regulation using number of trees as the variable and without data

obtained from permanent sample plots. The data needed to calculate sustainable yield are collected through forest inventories, tree ring analysis, and basic surveys of forest users. Our paper will describe the method and explore the results of trials in the Miombo ecoregion in Angola. We believe our simplified method can decrease uncertainties in yield regulation, improve communication between forest users and forest professionals, and guarantee a safe future for Miombo Woodlands.

Characteristics, structure, and tree species diversity of a tropical exploitation forest after 40 years of regeneration. Schier, F., Pietsch, S (*University of Natural Resources and Life Sciences, Austria; schier.franziska@googlemail.com; stephan.pietsch@boku.ac.at*).

Biodiversity increases tropical forest resilience against climate change, contributes to the mitigation of global warming, and maintains livelihood benefits. Biodiversity plays an important role in climate regulation as it potentially influences forest biomass production and forest capacity for carbon sequestration. This study examines the impact of repeated disturbances on the regeneration potential of a tropical exploitation forest protected against subsequent logging during the last 40 years. Forest data were collected during a field assessment on a total sample area equal to 1 ha. Important forest properties including woody biomass and carbon stock as well as forest structure and diversity were analyzed. The results suggest that a protected forest can restore many of its primary characteristics. Although signs of previous logging still exist in the forest structure, analysis indicates that forest recovery is proceeding. The woody biomass and carbon estimates approximate those of mature forests. However, repeated exploitations had resulted in a decline in forest diversity. In the present case, declining biodiversity had no long-term effects on biomass carbon stocks, since increasing timber volume due to forest maturation directly results in carbon benefits. The study concluded that a degraded forest ecosystem can be restored to provide essential ecosystem services under proper forest management.

Impact of logging operations on the remnant forest of a humid tropical forest in the Imataca Forest Reserve, Venezuela. Ussher, E., Vilanova, E., Gutierrez, N. (*Universidad de Los Andes, Venezuela; ernestoussher@gmail.com; vilanova@ula.ve; nestorgutierrez@ula.ve*).

Reduced impact logging (RIL) has been rarely applied in the management of natural forests in Venezuela. The forest state enterprise (Empresa Forestal Nacional, EFN) recently created, within its operational framework, the application of RIL as a norm for logging operations in Venezuela. We did a preliminary assessment of the harvesting impacts carried out by the EFN in the Imataca Forest Reserve. Following the methods proposed in 2004 by Sabogal and others, we assessed a total of 178 harvested trees, focusing on the effects of felling, skidding, and road construction. Results indicated that logging intensity was still low (1.7 tree/ha). On average, one harvested tree can open a logging gap of 357.0 ± 309.4 m^2, affecting an average of seven trees in an irreversible way; 9% was caused by tree-vine connectivity. The impacts of logging operations on the remnant forest were comparable with damage caused in other forests even without RIL. An important factor that may explain the relatively low impact is the low harvesting intensity. Therefore, it is necessary to carefully assess the planning and application of RIL. Finally, it is very important to define guidelines for other enterprises which will eventually start new operations in Venezuelan forest reserves.

B-10 How does biodiversity help to manage high-value timber species, and vice-versa?

Organizers: Sheila Ward (Mahogany for the Future, Puerto Rico/USA), Emmanuel Opuni-Frimpong (Forest Research Institute of Ghana) & Nicholas Brokaw (University of Puerto Rico)

Effects of tree species diversity on stem quality: plot and tree level results from six European regions. Benneter, A., Bauhus, J. (*University of Freiburg, Germany; adam.benneter@waldbau.uni-freiburg.de; juergen.bauhus@waldbau.uni-freiburg.de*).

Stem quality is influenced by a tree's ability to capture sufficient resources for growth and is influenced by neighboring trees, e.g., through shading and crown collisions. We collected data on crown size, stem form, and tree health for more than 12 000 trees in 210 study plots in six European regions (Finland, Germany, Poland, Romania, Italy, and Spain) within naturally diverse forests in order to assess the impact of tree species diversity on these characteristics. Results show that quality variability among regions, stands, and individual trees is high across species. On the stand level, there was a slight tendency towards lower stem quality with increasing diversity. However, individual trees of high quality were present in all diversity levels and for all target species. The influence of the immediate neighborhood's species composition is modified by a set of regional, individual, and stand characteristics. The neighborhood effect is likely the key factor regarding individual tree quality and, according to early results, quality is not negatively affected by diversity in neighborhoods. If this finding can be further validated, this study provides support for the hypothesis that diverse stands are capable of providing highly valuable timber while at the same time providing various other ecosystem services.

Enrichment of Central African logged forests with high-value tree species: testing a new approach in degraded forests. Doucet, J. (*University of Liege, Belgium; jldoucet@ulg.ac.be*), Tekam, P., Lagoutte, P. (*Pallisco SARL, Cameroon; patricetekam@gmail.com; exploitation@pallisco-cifm.com*), Dainou, K., Bourland, N. (*University of Liege, Belgium; kdainou@ulg.ac.be; nils.bourland@aigx.be*), Ward, S. (*Mahogany for the Future, Inc., USA; mahoganyforthefuture@gmail.com*).

Enrichment of logging gaps in Central African forests provides contrasting outcomes for different species, since these gaps do not always optimally meet their ecological requirements. In order to bypass this difficulty, we tested a new silvicultural method in south-eastern Cameroon. Multi-species plantations were implemented in 15 patches (0.2–1.1 ha) of degraded forest. Each plantation was divided into 225 m^2 subplots and 25 seedlings of a given species were planted per subplot. Species varied between adjacent subplots to 1) match the light requirements of specific species with the degree of shade from remaining trees, 2) maintain biodiversity, and 3) prevent the spread of disease. Selected indigenous species included were either potentially threatened

(e.g., *Pericopsis elata*), useful non-timber (e.g., *Irvingia gabonensis*), heavily logged (e.g., *Entandrophragma* spp.), or suffering from a lack of regeneration (e.g., *Triplochiton scleroxylon*). Preliminary results usually indicated similar or better performance in these subplots than in enriched logging gaps. Since the cost of this silvicultural procedure was similar to that of logging gap enrichment, we suggest that both may be integrated to forest management strategies in order to ensure high structural and floristic diversity of the Congo Basin timber production forests.

Relationship between selected indicators of forest stand diversity and quality of timber production in even-aged and uneven-aged stands. Merganic, J., Merganicova, K., Marusak, R., Stolarikova, R., Tipmann, L., Dragoun, L. (*Czech University of Life Sciences, Czech Republic; merganic@fld.czu.cz; merganicova@fld.czu.cz); marusak@fld.czu.cz; stolarikova@fld.czu.cz; tipmann@fld.czu.cz; dragoun@fld.czu.cz*).

The current trends in Central European forestry place strong emphasis on multipurpose utilisation of forests and their products. Therefore, objective analyses that deal with contradictory society demands, such as timber production and diversity, are required. The present study examines the connection between the quality of timber production and species and structural diversity of forest stands. The study is based on the regional forest inventory of the University Forest Establishment in Kostelec nad Černými lesy, Czech Republic. The inventory was performed from 2009 to 2011 on 1 188 sample plots that represented 86 strata defined on the basis of three variables: site (5 categories), age (12 categories), and canopy cover (5 categories). On every sample plot, we quantified 171 partial biodiversity indicators. Quality of timber production was evaluated visually in the field as an estimate of stem quality (3 classes) and in post-processing using local assortment tables (5 assortment classes). In total, we analysed 117 648 different variants of the relationship between the diversity indicator and the quality of timber production. The results indicate that the relationship between diversity and timber quality changes with the stand age or the developmental stage of forest stands.

Managing for high value timber and biodiversity in the Congo Basin. Nasi, R. (*Center for International Forestry Research, Indonesia; r.nasi@cgiar.org*), Van Vliet, N. (*Center for International Forestry Research, Colombia; vanvlietnathalie@yahoo.com*), Billand, A. (*CIRAD, France; alain.billand@cirad.fr*).

Multiple-use forest management is considered by many as a preferable alternative to single-use, generally timber-dominant, management models to ensure a greater biodiversity. In this presentation we will briefly explore the major land-uses in the Congo Basin and their actual or potential for sustaining biodiversity in a production context. We then focus on the most extant production systems (shifting cultivation, industrial logging concessions, and main commodity crops) to analyze the existing issues and options for actively managing both valuable timber species and biodiversity with a special emphasis timber stands, wildlife, and the potential role of certification. We highlight a few promising but yet unfinished examples in the region and we review these cases to draw lessons and recommendations. We contend, however, that true multiple-use could only be realized by expanding beyond boundaries of formal management units through new innovative land-use units, allowing a spatial cohabitation of the interests of local people, of conservation proponents and of extractive industries in the same management unit.

Restoration of degraded lands with mahogany in mixed-species plantations promotes biodiversity and conservation of valuable timber species. Opuni Frimpong, E., Nyarko-Duah, N., Opoku, S (*Forestry Research Institute of Ghana; eopunifr@mtu.edu; nayanyd@yahoo.com; pokoyour@gmail.com*), Storer, A. (*Michigan Technological University, USA; storer@mtu.edu*), Burton, A. (*Forestry Research Institute of Ghana; ajburton@mtu.edu*).

The need to restore the African mahogany and other valuable timbers in degraded landscapes of the Upper Guinean forest of Ghana is very urgent. Ecologists, sivilculturists, geneticists, entomologists, and other professionals in forestry are undertaking various studies towards developing systems to restore degraded lands with forest cover that will have the ecological integrity and biodiversity which are the desired character of the tropical forest. Restoration of the African mahogany, which naturally grows well in the diverse tropical forest, was hampered in plantations with monocultures by severe mahogany shoot borer, *Hypsypyla robusta* (Moore) attacks. Studies were conducted across three ecological regions in Ghana where mahogany grows naturally to assess the performance of this valuable timber species in plantations of mixed timber species compared to pure stands. The studies reveal that mixed cultures not only promoted restoration of biodiversity in forest landscapes but also reduced damage by the ubiquitous shoot borer. The observed reduction in attack was not the same across the three major ecological regions of Ghana. Conservation of mahogany in plantations and other landscapes may require plantings with diversified species to reduced pest attack and improve the desired tree forms of mahogany.

Combining high-quality timber production, biodiversity conservation and forest aesthetics: the case of *Sorbus* species in Europe. Skovsgaard, J. (*Swedish University of Agricultural Sciences, Sweden; jps@slu.se*).

Some *Sorbus* species such as *S. aucuparia* are among the most abundant tree species in the forest and landscape throughout Europe, while others such as *S. domestica* and *S. torminalis* are among the rarest. The group of rare species also includes a large range of local hybrids or so-called micro-species that are often red-listed. Those species that are found mainly in the forest are generally managed for their contribution to biodiversity (rare species) and forest aesthetics (flowers and autumn foliage) or simply disregarded or considered inferior in silviculture. Nevertheless, species like *S. torminalis* and *S. domestica* represent a considerable potential for economic forestry as their timbers are among the highest valued in the market. Based on recent research results and experience from forestry practice this presentation reviews the options and obstacles for combining high-quality timber production with biodiversity conservation and forest aesthetics. Natural regeneration and planting for re- or afforestation are given special attention as these processes are crucial for enlarging the representation and improving the quality of *Sorbus* forest species in Europe.

Posters

Effects of overstory species diversity and composition on pest damage to high value species and understory ant diversity in Ghana. Bosu, P. (*Forestry Research Institute of Ghana; paul_bosu@yahoo.com*), Stephens, S. (*Colorado State Forest Service, USA; S.stephens@colostate.edu*), Wagner, M. (*Northern Arizona University, USA; Mike.wagner@nau.edu*).

Experimental mixed-species and pure plantations were established using 11 native timber species in various combinations and ratios to evaluate the impact of the mixtures on endemic pests of three high value species (*Milicia excelsa*, *Khaya ivorensis*, and *Pericopsis elata*) and diversity of ground foraging ant species in the plantations. Although pest incidence was still prevalent in all the plantations after 2 years, the level of damage reduction achieved was, in many instances, enough to sustain the vulnerable species through critical growth stages. Results from a pitfall trapping of ants showed no significant differences in traditional diversity measures or functional group composition between treatments 1 year after planting. However, 2 years after planting we found significant differences in species richness. Several trends were observed that may indicate that these ant communities are currently in transition and will likely become more distinct over time as the plantations develop.

***Cedrela montana* in tropical montane rain forests of southern Ecuador: key species for sustainable management and conservation of biodiversity hotspots?** Guenter, S. (*Thünen Institute of International Forestry and Forest Economics, Germany; sven_gunter@yahoo.de*), Hildebrandt, P., Calvas, B. (*Munich University of Technology, Germany; hildebrandt@mytum.de; baltacha_c@yahoo.es*), Segura Ramos, D. (*Ministry of the Environment, Ecuador; dsegura@ambiente.gob.ec*).

The Andean forests of southern Ecuador are highly threatened ecosystems affected by increasing rates of deforestation. *Cedrela montana*, as one of the most valuable tree species in Ecuadorian montane rain forest, could play a key role in establishing silvicultural systems for sustainable forest management. During 10 years of research at the Estación Cientifica San Francisco we gathered a pool of data about the ecology and silviculture of this species based on permanent plots of about 11 ha. While other species such as podocarps are of similar timber value, our results indicated a higher economic potential of *C. montana* due to better growth rates and higher abundance, though not yet abundant enough for establishing species-specific silvicultural systems. However, our results revealed that mature diameter growth could not be improved by silvicultural treatments. Trials with assisted regeneration showed best performance of seedlings for canopy openness of about 20% in the first years indicating a certain potential for enrichment plantings. Increased mortality in later years indicates that further interventions may be necessary in order to sustain growth and foster survival. Based on the 2013 national forestry inventory, we discuss how silviculture of *C. montana* could contribute to conservation of southern Ecuador as a biodiversity hot spot.

Restoration of high-value broadleaved forests in southern Sweden: synergistic effects on biodiversity and economy. Löf, M. (*Swedish University of Agricultural Sciences, Sweden; magnus.lof@slu.se*).

Restoration of broadleaved forests in southern Sweden is a key issue for many threatened species and also for sustainable timber production, adaptation of forest management to climate change, and for social values. The governmental goals include increasing the area of these ecosystems using economic support systems for management of high-value timber tree species, increasing biodiversity, and ecosystem resilience. This is in contrast to short-term management goals of many private forest owners in the region, who depend on high volume growth of forests. Afforestation with broadleaves using planting or direct seeding is one method of restoration. Rehabilitation using enrichment planting or natural regeneration for conversion of conifer monocultures to broadleaves are other examples. In most cases, restoration of these broadleaved forests is very expensive. Therefore, there is an urgent need for new cost-efficient regeneration and management methods. It is almost impossible due to incomplete knowledge of past forest states, climate change, and economic aspects to return the forest to its original state. A broad conception of restoration allowing more diverse goals, pragmatic approaches including economic aspects for the private forest owner, and innovative harvesting systems will be discussed.

***Steniscadia poliophaea* (Noctuidae) is a major seedling herbivore of big-leaf mahogany trees in Amazonian forests.** Norghauer, J. (*University of Bern, Switzerland; julian.norghauer@ips.unibe.ch*), Free, C. (*Rutgers University, USA; cfree14@gmail.com*), Grogan, J. (*Mount Holyoke College, USA; jgrogan@crocker.com*).

We present the intriguing case of a moth, *Steniscadia poliophaea*, which only eats expanding leaves of seedlings and saplings of big-leaf mahogany (*Swietenia macrophylla*). This moth occurs in Brazil (Pará, Acre) and Peru, but apparently not in Central America or Mexico. We added mahogany seeds over 3 years into canopy gaps in unlogged forest (Pinkaití, Pará) to test for Janzen-Connell (JC) effects on recruitment as driven by vertebrate seed predators and this specialist moth herbivore. Data was used in a new growth and yield model to test whether these predators can limit the population size of mahogany. Including JC effects on first year recruitment and JC effects from the moth on subsequent seedling growth and mortality capped the number of adults (≥30 cm diameter) at 30 trees/100 ha, leveling population growth. We conclude that *S. poliophaea* is an underappreciated pest of mahogany in Amazonian forests. Without silviculture to protect vigorously growing seedlings and saplings from this enemy, natural recruitment will be limited to scattered gaps far downwind of adults. Attack by these pests thus may result in very large areas of forests needed to sustain mahogany regeneration and yield, indirectly safeguarding forest biodiversity. We will also explore these consequences.

Can monoculture forest plantation harbor biodiversity similar to naturally regenerated tropical rainforest ecosystems over time? Onyekwelu, J., Olabiwonnu, A. (*Federal University of Technology, Nigeria; onyekwelujc@yahoo.co.uk; adezhollax@yahoo.com*).

Little is known about the potential of forest plantations to conserve biodiversity. This study assessed biodiversity conservation in *Gmelina arborea* plantations, which was compared with those of degraded and primary rainforests. Overstory, sapling, and seedling species were inventoried in eight 400-m^2-sample plots, 25-m^2-quadrants and 4-m^2 sub-quadrants, respectively. Eight tree species belonging to 7 families; 13 species to 10 families, and 24 species to 17 families were encountered in *Gmelina* plantation overstory, sapling, and seedling layers, respectively. Biodiversity indices were significantly lower in *Gmelina* plantation overstory than primary and degraded forests. However, biodiversity indices of the sapling layers of *Gmelina* plantation and the natural forests were not significantly different. Family and species diversities were significantly lower in *Gmelina* plantation overstory (8, 7) than primary (8, 28) and degraded (18, 30) forest overstories. At the sapling layer, family and species diversities of *Gmelina* plantations (10, 13) compared favourably with those of primary (9, 15) and degraded (9, 16) forests. Species richness

was 24, 18, and 25 at seedling layers of *Gmelina* plantation, primary, and degraded forests, respectively. Twenty five percent of species found in seedling layer of *Gmelina* plantation were absent in natural forests. Thus, plantation understory harbours high biodiversity, with the ability to conserve biodiversity over time.

Growth and productivity of *Khaya grandifoliola* in the dry semi-deciduous forest of Ghana: a comparison in pure and diverse species stands. Opuni Frimpong, E., Opoku, S. (*Forestry Research Institute of Ghana; eopunifr@mtu.edu; pokoyour@gmail.com*), Owusu, S. (*Michigan Technological University, USA; saowusu@mtu.edu*), Burton, A. (*Forestry Research Institute of Ghana; ajburton@mtu.edu*), Storer, A. (*Michigan Technological University, USA; storer@mtu.edu*).

This study compares the growth and productivity of *Khaya grandifoliola* in mixed and pure plantations to that of *Tectona grandis* in pure stands. The plantation was set up with pure *K. grandifoliola* plots; mixed species plots of *K. grandifoliola, Terminalia ivorensis*, and *Cedrela odorata;* and pure *Tectona grandis* plots. The results 5 years after planting in the field indicate that there was better diameter growth for *K. grandifoliola* in pure than in mixed stands. However, the total height and merchantable height growth of *K. grandifoliola* were not statistically different between the pure and mixed stands. *Khaya grandifoliola* performed better in pure than in mixed stands for basal area and volume. *Khaya grandifoliola* had more branches in the pure than in the mixed stands, but there were no differences in the level of *Hypsipyla* attack. There was no significant difference in diameter growth between *K. grandifoliola* and *Tectona grandis* in pure stands. In spite of the vulnerability of *K. grandifoliola* to pest attack, its growth and productivity compared favourably to teak, an exotic species with negative impacts on biodiversity. Thus *K. grandifoliola* is a suitable plantation species for mitigation against climate change and for conservation of diversity in mixed plantations.

Single-tree management for high-value timber species in a mixed conifer-hardwood forest in northern Japan. Owari, T., Okamura, K., Fukushi, K., Kasahara, H., Tatsumi, S. (*University of Tokyo, Japan; owari@uf.a.u-tokyo.ac.jp; kokam@uf.a.u-tokyo.ac.jp; kfukushi@uf.a.u-tokyo.ac.jp; kasa@uf.a.u-tokyo.ac.jp; jeyms23@gmail.com*).

High-value hardwoods such as monarch birch (*Betula maximowicziana*) and castor aralia (*Kalopanax pictus*) are important elements of cool-temperate mixed forests in Hokkaido, northern Japan. The production of fancy wood from these species brings significant income through extremely high log prices (max. >20 000 USD/m^3), and the presence of large-sized canopy trees in a stand may offer great ecological value. A single-tree management system for high-value hardwoods has been applied at the University of Tokyo Hokkaido Forest, where nearly 2 000 trees having superior quality are registered as high-value trees. All trees are numbered, and the DBH, species name, vitality, and stem damages (if any) are recorded. The geographic locations of each individual are identified using the global navigation satellite system. The status of high-value trees is continually observed so as to harvest them at the proper time. To explore how the single-tree management for high-value timber species contributes to maintain the structural diversity of forests, we examined the structural attributes (e.g., species composition, diameter distribution) of the stands in which registered high-value trees are located.

Comparison of species composition and stand structure between a secondary forest and a mahogany plantation on Mt. Makiling. Park, P., Han, A. (*Seoul National University, Republic of Korea; pspark@snu.ac.kr; phoya@naver.com*), Barile, J. (*Makiling Center for Mountain Ecosystems, Philippines; jojobarile@yahoo.com*), Lee, Y. (*Korea Forest Service, Republic of Korea; shorea@foa.go.kr*), Gadia, G., Lee, D. (*Seoul National University, Republic of Korea; gelliegadia@gmail.com; leedk@snu.ac.kr*).

Mahogany plantations are favored in tropical countries for their capacity to facilitate increases in carbon sequestration and biomass accumulation as well as economic income of the land. High biodiversity is the most distinct characteristic of tropical forests while plantations are increasing for many reasons. This study compared species composition and stand structure between a mahogany plantation and a secondary natural forest to provide better options for forest practices. In addition, monthly litter fall biomass was monitored to investigate temporal processes in the secondary forest. The secondary forest had more than twice as many woody species as the mahogany plantation. The secondary forest showed a reverse J-shaped height distribution and a multi-canopy structure with the overstory of 20–25 m with a few emergents, and mid canopy layer of 10–20 m. The overstory layer in the mahogany plantation ranged from 30 to 35 m. The litter fall production peaked in May or June, and also increased between September and November. Flower and fruit biomass was about 3 and 20% of the leaf litter biomass, respectively. Silvicultural prescriptions to consider the diverse structure and complex processes of natural forests should be developed to counterbalance the decrease in tropical natural forests.

Growth and stem quality of oak trees established in cluster plantings respond differently to intra- and interspecific neighbourhood competition. Saha, S., Kühne, C., Bauhus, J. (*University of Freiburg, Germany; somidh.saha@waldbau.uni-freiburg.de; christian.kuehne@waldbau.uni-freiburg.de; juergen.bauhus@waldbau.uni-freiburg.de*).

Oak cluster planting consisting of widely spaced groups and narrowly spaced nests has become an alternative to high density and less diverse row planting. Space between the clusters is occupied by natural regeneration, however, and could hamper oak growth and quality in clusters. We aimed to analyse the effects of interspecific and intraspecific competition on growth and quality of oaks in clusters. We also analysed whether the spatial position of oaks within groups influenced their quality development. Field inventory was carried out in seven sites in southern Germany. Mid- and late-successional trees had stronger competitive effects on growth of target oaks in clusters than the conspecific oaks and pioneer trees. Effects of intraspecific competition were higher in nests than groups. Oak quality development benefited from intraspecific competition but self-pruning was not further promoted through additional interspecific competition. Within groups, inner oaks had a higher probability of developing into crop trees than outer oaks. We concluded intra- and interspecific competition had different effects on oak trees and that these effects differed between nest and group plantings. Spatial separation between oaks and naturally regenerated trees help to decrease the overall competitive effect on target oaks and foster high tree species richness between the clusters.

B-11 Forest management for wildlife conservation

Organizers: Thomas Rooney (Wright State University, Dayton, Ohio, United States) & Nobuhiro Akashi (Hokkaido Research Organization. Japan)

An evaluation of the effects of sika deer on forest regeneration based on observation of browsed shoots. Akashi, N., Unno, A., Uno, H. (*Hokkaido Research Organization, Japan; akashi-nobuhiro@hro.or.jp; unno-akira@hro.or.jp; uno@hro.or.jp*).

The impact of deer browsing on forest vegetation can be irreversible, with the understory vegetation degrading rapidly when the level exceeds a certain threshold. Therefore, to maintain forest biodiversity, population management must be implemented before the effects of deer predominate. We investigated sika deer (*Cervus nippon yesoensis*) browsing on trees and seedlings at sites with different deer densities in Hokkaido, northern Japan, to develop a method for evaluating the effects of browsing on forest vegetation at an early stage of increase in deer density. The ratio of seedlings and trees with browsed twigs (browsing ratio) increased with deer abundance and was also influenced by the dwarf bamboo coverage and snow depth. The browsing ratio of seedlings was negatively correlated with the annual height growth of the seedlings and with the annual changes in the density of seedlings and small trees; seedlings disappeared when negative height growth was observed, and the decrease in seedling density persisted. These results suggest that continuous observations of browsed shoots on seedlings provide a useful index of the impact of deer on the regeneration dynamics of forests.

The attractiveness of managed Scots pine forests of different ages as a foraging site for bats. Grzywiński, W. (*Poznań University of Life Sciences, Poland; witold.grzywinski@up.poznan.pl*), Ciechanowski, M. (*University of Gdańsk, Poland; mateusz.ciechanowski@biol.ug.edu.pl*), Jaros, R. (*Polish Society for Nature Conservation, Poland; radek@salamandra.org.pl*), Kmiecik, A., Kmiecik, P., Węgiel, A., Węgiel, J. (*Poznań University of Life Sciences, Poland; aniabartnik@autograf.pl; kmiecik_p@poczta.onet.pl; wegiel@up.poznan.pl; jolanta.wegiel@up.poznan.pl*).

Planned forest economy involves sustainable use of forest resources, most of all timber. It consists of harvesting mature stands and reforestation of cleared areas, which creates a complex spatial structure of forests. In Central Europe, bats are strongly associated with forest habitats. For nearly all bat species, forests are an important foraging habitat. The aim of the study was to analyze the effect of forest operations in Scots pine stands (resulting in different ages of their particular patches) on their attractiveness for foraging bats. The research comprised pure pine stands in large forest complexes in western Poland. Four development stages of stands were selected: 1) clearcut sites, areas fallowing for 1 year before reforestation, 2) plantations 3–5 years old, 3) middle-aged stands 41–80 years old, and 4) mature stands >80 years old. The foraging bats were monitored with ultrasound detectors Pettersson D-1000X. The highest foraging intensity of bats was noted in open areas, plantations and clear sites, with less activity inside mature stands. The results suggest that bats can adapt to artificial habitat mosaics in managed Scots pine forests by selecting some of their developmental stages as optimal foraging habitats.

Epigaeic beetle assemblages in boreal forests: relationships to environmental factors and management history. Johansson, T., Hjälten, J. (*Swedish University of Agricultural Sciences, Sweden; therese.johansson@slu.se; joakim.hjalten@slu.se*), Dynesius, M. (*Umeå University, Sweden; mats.dynesius@emg.umu.se*), Roberge, J., Olsson, J. (*Swedish University of Agricultural Sciences, Sweden; Jean-Michel.Roberge@slu.se; jorgen.m.olsson@slu.se*).

In boreal forests, intensive management for timber production has decreased the habitat quality for many species, resulting in altered species compositions. Here we compare the assemblages of epigaeic beetles in young (10–25 years), middle-aged (40–60 years), and old forest (>80 years) stands in an intensively managed forest landscape. Epigaeic beetles were sampled in pitfall traps and environmental data were collected. The assemblage composition of epigaeic beetles differed significantly among stand age classes. Generally, young stands hosted fewer species and lower abundances compared with middle-aged and old stands. The most important exceptions to this pattern were the Carabidae and Leiodidae, which had similar species richness in all three stand types. The cover of bryophytes and lichens and the basal area of spruce and birch were environmental factors having the strongest effect on beetle assemblage composition. Our results suggest that management history, in terms of clear-cutting versus selective cutting and thinning, has a limited effect on the assemblage composition of epigaeic beetles. Small differences between middle-aged and old stands indicated that the assemblages were able to colonize and reproduce in stands developing after clear felling. However, high proportions of young stands might affect the landscape-scale assemblage composition of epigaeic beetles.

Long-term effects of forest management on reindeer grazing in northern Sweden: a scenario analysis approach. Korosuo, A., Sandström, P., Eriksson, L., Öhman, K. (*Swedish University of Agricultural Sciences, Sweden; Anu.Korosuo@slu.se; per.sandstrom@slu.se; Ljusk.Ola.Eriksson@slu.se; karin.ohman@slu.se*).

In the boreal forests of northern Sweden, timber production and reindeer husbandry operate on same lands. While timber production is an important economic value for the forest owners, the indigenous rights of the Sami to protect their traditional livelihood, reindeer husbandry, and requires consideration in forest management. The most critical factor is the availability of reindeer lichen, which is the main fodder of reindeer during the winter months. The amount of lichen in the landscape has decreased considerably, due to forest management. In this case study, we present three forest management scenarios, each for 100 years, and analyze their effects on the reindeer pasture area. The results predict a continuing decrease of pasture area with the current forest management practice. However, the alternative management scenario shows that this negative development could be halted by increasing continuous cover forestry and precommercial thinnings, with economic losses of about 5% in timber production. The findings of this study add a valuable viewpoint to the discussion on alternative forestry practices, and highlight the importance of considering several ecosystem services when analyzing the impacts of different forest management alternatives.

Partial retention harvest benefits songbird assemblages in the boreal forest of Canada. Odsen, S., Spence, J., Acorn, J. (*University of Alberta, Canada; odsen@ualberta.ca; john.spence@ualberta.ca; john.acorn@ales.ualberta.ca*).

Increasing emphasis on biodiversity and ecosystem services has led to a shift away from traditional forestry methods. In fire-driven systems, partial retention harvest has been proposed as a sustainable alternative to conventional clear-cutting, by retaining structural legacies that resemble more closely a post-fire landscape. This study assesses the effects of various partial retention prescriptions on breeding songbird assemblages over 15 years following harvest. Field research was conducted at the Ecosystem-Based Management Emulating Natural Disturbance (EMEND) project, in the boreal forest of northwestern Alberta, Canada. Songbird assemblages were evaluated 1 year pre-harvest and reassessed six times within the first 15 years post-harvest. The resulting time series indicates that, compared to clear-cutting, tree retention at any level mitigates the early (<10 years) impacts of harvest on species assemblages, and enhances recovery toward the pre-harvest state 15 years post-harvest. Old-growth and open-area specialists respond strongly to harvest, while retention mitigates the strength of this response. These results support the use of variable retention harvest in place of conventional clear-cutting. Given that long-term declines have been observed in mature forest species as well as early successional specialists, a mixed approach with an emphasis on landscape heterogeneity is recommended.

Simulating the long-term effects of tree retention and forest set-asides on the availability of biodiversity structures at the landscape scale. Roberge, J., Lamas, T., Lundmark, T., Ranius, T., Felton, A., Nordin, A. (*Swedish University of Agricultural Sciences (SLU), Sweden; Jean-Michel.Roberge@slu.se; tomas.lamas@slu.se; Tomas.Lundmark@slu.se; thomas.ranius@slu.se; adam.felton@slu.se; Annika.Nordin@slu.se*).

As a result of environmental policies developed during the past 2 decades, several new biodiversity conservation measures have become implemented in forestry. Due to the slow rate at which forest systems develop, especially at higher latitudes, the full landscape-scale effects of recently implemented biodiversity conservation approaches may take a long time to materialize. This study aimed to simulate and contrast the long-term effects of tree retention and set-asides on the future availability of two structures of importance to boreal forest biodiversity: large trees and dead wood. We used Heureka software to project the future development of two Swedish landscapes characterized by distinct initial forest conditions, with and without retention and set-asides, over 200 years. Under a management scenario maximizing net present value of timber, current levels of tree retention and set-asides led to increased or decreased availability of large conifers depending on the initial forest age distribution in the landscape. Large deciduous trees increased in both landscapes as a result of retention and dead wood amounts were nearly doubled. This study underscores the relatively long delivery times required for the provision biodiversity structures through conservation measures in boreal forestry, and highlights differences in the contributions of distinct measures.

Bird and insect pollinators respond similarly to aspen forest stand development in northern Wisconsin, USA. Roth, A., Phifer, C., Flaspohler, D., Webster, C. (*Michigan Technological University, USA; amroth@mtu.edu; ccphifer@mtu.edu; djflaspo@mtu.edu; cwebster@mtu.edu*).

As worldwide demand for bioenergy derived from forest products grows, the maintenance of forest ecosystem services can be threatened. In the north temperate zone, fast growing aspen trees (*Populus* spp.) are seen as a likely feedstock. We examined the effects of aspen forest stand development on bird and insect pollinator species richness and abundance in northern Wisconsin, USA. We selected a chronosequence of aspen stands from 4 to 45 years old that were clearcut with no green-tree retention. In 2007–2009, we used transect surveys to determine breeding bird richness and abundance in 27 stands. Forest pollinators were surveyed in seven stands in 2013 using pan traps along four randomly distributed transects. Results from the pan traps suggest that pollinator abundance is greatest in youngest stands, declines in middle-age stands, and increases in the oldest stands. This pattern is similar to that seen for bird abundance and species richness for young and middle-age stands. Further analysis will relate pollinator richness and forest stand metrics, vegetation composition, and remotely sensed landscape characteristics. Our results provide insight into how stand development for a fast-growing, intensively managed tree species influences biodiversity, suggesting similar responses among two very different taxa.

The effects of landscape heterogeneity and ungulate density on understory vegetation in northwestern Pennsylvania. Royo, A. (*U.S. Forest Service, USA; aroyo@fs.fed.us*), Kramer, D. (*University of Georgia, USA; dwkramer@uga.edu*), Stout, S. (*U.S. Forest Service, USA; sstout@fs.fed.us*), Nibbelink, N., Miller, K. (*University of Georgia, USA; nate2@uga.edu; kmiller@warnell.uga.edu*).

Ungulate browsing can dramatically shift plant community composition. Nevertheless, our ability to predict the localized effects on plant communities by any given ungulate density remains woeful at best. Theory suggests ungulate foraging behavior and impacts on vegetation are mediated via variations in habitat structure and quality at landscape scales. Thus, linking ungulate densities to landscape context may improve predictive ability. We used a long-term (10 year) vegetation and white-tailed deer (*Odocoileus virginianus*) population monitoring dataset, combined with spatial analyses of four seral stages (open, early-, mid-, and late-successional patches) throughout a 30 000-ha area to evaluate how deer density, variation in habitat attributes, or both determine influence plant communities. We found 5-year mean deer density (2007–2011) had a significant positive relationship with herbaceous cover, species richness, and sapling density. Additionally, deer density and patch density were both selected as strong predictors of seedling density and herbaceous cover. Deer density and patch isolation (i.e., Euclidean nearest neighbor distance) were selected as joint predictors of sapling density. These preliminary results suggest variation in landscape configuration affects plant community response to browsing. Further work is needed to rigorously disentangle the direct and indirect, mediating, effects of deer and landscape structure on vegetation.

Pinyon jay nest and cache site selection in pinyon-juniper woodlands of the Great Basin. Witt, C. (*U.S. Forest Service, USA; chriswitt@fs.fed.us*).

Pinyon jays (*Gymnorhinus cyanocephalus*) are the principal dispersal agent for pinyon pine seeds in the Intermountain West region of the United States. However, pinyon jays have exhibited significant population declines over much their range in recent decades, even as pinyon-juniper woodlands appear to have been expanding over the past 150 years. In order to identify habitat

preferences for nesting, seed caching, and roosting within the pinyon-juniper ecosystem and relate it to ongoing pinyon-juniper expansion, we measured stand and tree parameters of pinyon jay nest and cache sites in Idaho and Nevada using Forest Inventory survey methodology. Sites differed in physical structure, with nest sites containing higher canopy cover and stand basal area than did cache sites. Cache sites were located at the ecotone boundary between sagebrush steppe and woodland communities or in openings within a sparsely-stocked pinyon-juniper stand. Nest sites tended to be within the internal area of the stand, away from openings and edges. These findings suggest that pinyon-juniper woodland management practices could be beneficial to pinyon jays if done in a way that preserves adequate nesting habitat near openings or the woodland edge that borders open shrublands and grasslands.

B-12 Forest management in montane communities

Organizers: Pil Sun Park (Seoul National University, Republic of Korea), Raffaele Cavalli (University of Padua, Italy), Roberto Tognetti (University of Molise, Italy) & Karl Stampfer (University of Natural Resources and Life Sciences, Austria)

Forest operation engineering and management for sustainable use of mountain forests. Cavalli, R., Grigolato, S., Bhochhibhoya, S. (*University of Padova, Italy; raffaele.cavalli@unipd.it; stefano.grigolato@unipd.it; silu.bhochhibhoya@studenti.unipd.it*).

Forests cover a significant proportion of mountain regions around the world, except those that are particularly dry or cold year-round. In Europe, for instance, forests cover 41% of the total mountain area and are the prevalent land cover except in the mountains that extend into the Arctic regions. Mountains are fragile and often remote regions, whose human communities are often vulnerable to environmental, economic, and social changes both locally and globally. In recent decades, there have been two distinct trends in the area covered by mountain forests: 1) gradual rarefaction of rural activities, including sometimes forest exploitation, in industrialized countries, and 2) maintenance of high dependency of communities on their forests in developing countries. Faced with these contrasting trends, forest operation engineering and management (FOEM) can play an important role developing solutions that are fit to the specific mountain forest situation. Two different situations are considered in order to evaluate the potential of FOEM in offering approaches to sustainably manage and use mountain forests: Italian northeastern Alps (Italy) and Sagarmatha area (Nepal). Technical proposals are mainly targeted to the economic and socio-cultural aspects connected to the management and use of forest resources.

Stand structure and vegetation of the deciduous mixed oak forests in the montane zone of the western Qinling Mountains, China. Dai, C., Saha, S., Gärtner, S., Huss, J., Reif, A. (*University of Freiburg, Germany; dai.chunling@waldbau.uni-freiburg.de; somidh.saha@waldbau.uni-freiburg.de; stefanie.gaertner@waldbau.uni-freiburg.de; juergen.huss@waldbau.uni-freiburg.de; albert.reif@waldbau.uni-freiburg.de*).

Qinling Mountains are known to be highly species diverse in China; however, a comprehensive study on the phytosociology, forest structure, and composition has not been done there. We studied the phytosociology, stand structure, vascular plant diversity, and status of natural regeneration in semi-natural stands of the temperate deciduous oak forests (300 ha) protected since 1998. We systematically selected 120 inventory plots (plot size was 400 m^2 for vegetation and 452 m^2 for stand structure) in an altitudinal gradient from 1 500 to 2 200 m located in the western Qinling Mountains. We made a complete inventory of vegetation, site, and forest structure of each plot. A total of 448 species of vascular plants, including 56 tree species, were identified. Seven different forest types were defined, reflecting high floristic β-diversity. The community of *Carex rubrobrunnea* var. *taliensis-Quercus aliena* var. *acutiserrata* had the highest floristic β-diversity. The stand basal area of the tree diameter distribution showed the highest frequency of young trees, representing recovery of forests. We concluded that protection from human disturbances should be continued to develop stands with different height cohorts for providing habitat for native flora and for achieve the full potential of the mixed mountain forests in Qinling Mountains.

The role of Lawu montane forests: ecological and economical aspects of *Lithocarpus sundaicus* for local people. Gangga, A. (*International Forestry Students' Association (IFSA), Indonesia; gangga.gangga@gmail.com*), Nurhidayat, S. (*Gadjah Mada University, Indonesia; safaatnurhidayat@yahoo.com*).

Lawu montane forest, one of the tropical forest types in Indonesia, degraded rapidly (by 142.56 ha/year) in the period of 2000–2005. This study aimed to determine the dispersion and growth of vegetation in Lawu montane forest and was conducted in three height zones: (1) Zone I = 1 600–1 700 m above sea level, (2) Zone II = 1 700–1 800 m above sea level, and (3) Zone III = 1 800–1 900 m above sea level. Each zone was established with three plots, using nested sampling, sized 10 m × 10 m for the poles tree growth level and 20 m × 20 m for the trees growth level. The composition of vegetation in Lawu montane forest generally was 13 tree species. The highest tree growth was pasang (*Lithocarpus sundaicus* (Bl.) Rehd.). The use of this species was variable by local people; however, the existence of it is potentially lost by the continuing of degradation. This paper will discuss about how local people take part in the sustainability of the species in particular as well as the ecosystem of Lawu montane forest in general and the interaction between the people and the forest.

State of the art and perspectives of European cable yarding technologies and systems. Karl, S. (*University of Natural Resources and Life Sciences, Vienna, Austria; karl.stampfer@boku.ac.at*), Cavalli, R. (*University of Padova, Italy; raffaele.cavalli@unipd.it*).

Cable yarders have a long tradition in Central European Alps. Their versatility, good production characteristics, and low environmental impact have ensured their sustained success. However, there are concerns about harvest costs, worker safety, and more recently the decline of specialist skills. This presentation aims to present state-of-the-art European yarder technology, identify the major scientific and practical achievements in cable yarding in the last 10 years, and identify the major challenges ahead.

Prospective challenges of cable logging in Japan. Sakai, H. (*University of Tokyo, Japan; sakaih@fr.a.u-tokyo.ac.jp*).

Cable logging is indispensable in Japan where most slopes are steep and difficult. A Lidger Wood system composed of three interlocked winches with a steam engine was introduced from the United States at the beginning of the 20th century. After World War II, light weight yarders with gasoline engines were invented by airplane engineers, and cable systems such as North bend, Tyler, and later, endless Tyler with a capstan drum for endless line, prevailed. In the 1970s, double endless system with a hoisting carriage was invented and accepted mainly in private forests. Tower yarders had been attempted with the increasing need for thinning, but they had two obstacles, one was lack of forest road in the 1960s and the other was lack of loaders and refusal by operators to set guylines in the 1980s. In Japan, it is difficult to construct a forest road on the upper position of a mountainous slope, so downhill yarding is required. One solution is the interlocked running skyline system, which is also used in Norway. Based on this history, a new generation of cable logging with electronics and hydraulics has been required. Cable logging with the minimum and an effective road network has less effect on environment and soil erosion than vehicle systems.

Multifunctional governance of mountain forests in Europe. Sarvasova, Z. (*National Forest Centre, Slovakia; sarvasova@nlcsk.org*), Cienciala, E., Beranova, J. (*Institute of Forest Ecosystem Research, Ltd., Czech Republic; cienciala@ifer.cz; beranova@ifer.cz*), Vanco, M. (*National Forest Centre, Slovakia; vanco@nlcsk.org*), Ficko, A. (*University of Ljubljana, Slovenia; andrej.ficko@bf.uni-lj.si*).

This paper is based on the results of the FP7 research project of the advanced multifunctional forest management in European mountain ranges project (ARANGE). We mapped forest governance systems for all major mountain ranges in Europe using seven case studies from the Iberian Mountains, western Alps, eastern Alps, Dinaric Mountains, Scandinavian Mountains, western Carpathians, and western Rhodopes. Current public and private governance systems relevant to the implementation of multifunctional forest management were surveyed. An online survey was administered to forest authorities, managers, and mountain forest owners to target the following elements of governance: participation and stakeholders interactions, inter-sectoral coordination, multi-level coordination, decision structures and processes, responsibilities, and use of expertise. The results from the survey and other policy related knowledge from the ARANGE project are discussed in relation to enhancing the resilience of four ecosystem services: timber production, protection against gravitational natural hazards, climate change mitigation via carbon sequestration and bioenergy production, and nature conservation and the maintenance of biodiversity. The results of this study and the conclusions of the ARANGE project about multifunctional management of mountain forests in Europe will hopefully facilitate the formulation of recommendations to policymakers.

Posters

Impact of anthropogenic disturbances on high value NTFPs in temperate moist oak forest: a case study from the eastern Himalayas, India. Chakraborty, T., Saha, S. (*University of Freiburg, Germany; tamalika.chakraborty@waldbau.uni-freiburg.de; somidh.saha@waldbau.uni-freiburg.de*).

The eastern Himalayas are a famous biodiversity hotspot. Climate change and increasing rate of over-exploitation of non-timber forest products (NTFPs) in the region could lead to significant loss of some species. However, field-based assessments on the impact of human disturbance on high-value NTFPs are rare in the region. In this study we aimed to find the impact of anthropogenic disturbances on high-value NTFPs in the West Kameng district of Arunachal Pradesh, eastern Himalayas, India. At first, we selected 12 tree species and 5 herbs in the region, based on market research and socioeconomic study, and categorized them as high-value NTFPs for the region. Then we selected two study sites (dominated by *Quercus griffithii*) in the region for assessing occurrence and density of those 17 plant species. Inventory plots were installed systematically along the varying distances from the village. High over-exploitation led to very poor importance value index (IVI) values for *Taxus baccata*, and *Illicium griffithii*. For herbs, *Panax pseudo-ginseng, Andrographis paniculata,* and *Swertia chirayita* had lower IVI values, due to high exploitation. Our study revealed that there is an urgent need to control the wild collection of high-value NTFPs, some of which are critically endangered (e.g., *Taxus baccata*).

Tree species diversity and abundance as indicators of understory diversity and abundance in French mountain forests: variations in ecological space. Gosselin, F. (*National Research Institute of Science and Technology for Environment and Agriculture, France; frederic.gosselin@irstea.fr*), Zilliox, C. (*AgroParistech, France; christophe.zilliox@gmail.com*), Herpigny, B., Courbaud, B. (*National Research Institute of Science and Technology for Environment and Agriculture, France; basile.herpigny@irstea.fr; Benoit.Courbaud@irstea.fr*).

Trees are one of the main components of forest ecosystems; they modify resource levels (light, nutrients, water) that affect understory vegetation composition and diversity. Tree species diversity is used as a biodiversity indicator in various European and French monitoring schemes for sustainable forest management. Moreover, tree species basal area has been found to better indicate floristic biodiversity than tree species richness or diversity. Herein we empirically check this finding by analyzing data from mountain spruce-fir forests in France with Bayesian statistical models. We insist on the magnitude of the relationship and its variation in geographical and ecological space. Our results indicate that both tree species abundance and tree species richness and dominance are good indicators of some parts of understory vascular plant species richness and abundance. The effect of dendrometric indicators on floristic biodiversity varied among ecological groups and along ecological gradients such as aspect, soil acidity, region, and altitude. As a result, plots with north-facing and south-facing slopes exhibited opposite relationships of species richness with tree species abundance, and so did plots located on acidic and basic sites. Our study supports evaluating biodiversity indicators to determine when they actually have non-negligible relationships with biodiversity, i.e., for which ecological groups and in which ecological contexts.

Improved methods for timber extraction in southwest China. Jaeger, D., Hoffmann, S. (*University of Freiburg, Germany; dirk.jaeger@fobawi.uni-freiburg.de; stephan.hoffmann@fobawi.uni-freiburg.de*).

According to the seventh national forest inventory, the Chinese forest covers an impressive 193.33 million ha with a standing volume of 13.363 billion m^3. But considering China's high population, it is only about one fourth of the world's average forest cover per capita. To secure and further increase available domestic timber resources the Central Government of China gradually reformed its forest policy and started to implement the Six Key Forestry Programs (SKFPs) in the year 2000. Most of the SKFPs favor multiple use forest management for protection and ecological improvement of existing forests as well as increased afforestation, securing future timber supply. In terms of forest area increase, this attempt has been very successful, so far, resulting in a forest area increase of in total 16 million ha since 1998. With the reforestation of mountainous terrain and a partial shift to single-tree harvesting, predominant manual felling and, in particular, extraction techniques, need to be adapted or replaced by more ergonomic, economic, and environmentally friendly techniques. The study reviews the potential for cable crane yarding in southwest China and holistically compares the use of mobile tower yarders and excavator shovel yarders.

Seasonal changes in understory composition on Mt. Joongwang, Korea. Park, P., Park, J., Jung, J., Jang, Y., Kim, H. (*Seoul National University, Republic of Korea; pspark@snu.ac.kr; candler1@snu.ac.kr; jb1373@snu.ac.kr; wkddbfla1209@naver.com; kuku60@naver.com*), Park, B. (*Chungnam National University, Republic of Korea; bbpark@cnu.ac.kr*), Sung, J. (*Korea Forest Research Institute, Republic of Korea; jhs033@korea.kr*).

Rough topography and high elevation result in high heterogeneity among microsite environments in montane forests, resulting in diverse species composition within a small area. Understory species in high elevation deciduous forests have often a unique life cycle and order of temporal distribution due to their adaptation to their specific environment of distinctive seasonal changes. Thus climate or light condition during their appearance can be critical for their maintenance in the site. This study investigated seasonal changes in understory species composition, with understory light condition and soil temperature in a cool temperate deciduous forest in Korea. Daily mean photosynthetically active radiation (PAR) was the highest in late April and early May, just before spring leaf flush. Species richness was the highest in June when spring and summer species overlapped. Distinct seasonal changes in understory species composition indicate the temporal niche of understory communities. Three-year monitoring showed that soil temperature and species richness were different in 2011–2013. Yearly fluctuation of spring climate caused by climate change may confuse the order of temporal distribution of understory species and their temporal niche.

Landscape patterns in mountain pasture-woodlands under changing environmental conditions. Snell, R., Bugmann, H. (*ETH Zurich, Switzerland; rebecca.snell@usys.ethz.ch; harald.bugmann@env.ethz.ch*).

Pasture-woodlands are unique semi-natural landscapes that result from the combined influences of climate, management, and intrinsic vegetation dynamics. Highly heterogeneous landscape patterns result from fine-grained intensive management and grazing by cattle, which lead to different successional stages between grassland and forest. Pasture-woodlands are expected to change in the future due to increasing land abandonment and climate change. However, our ability to predict how these landscapes will change is limited, due to the disparate scales in time and space that govern the dynamics of these systems. To improve our understanding of the processes and interactions that shape these systems, we modified a dynamic forest landscape model to simulate a pasture-woodland landscape in the Jura region (Switzerland). This involved the inclusion of an herbaceous layer, grazing from cattle, and additional management routines. The new model version allows us to address the following questions: 1) what are the effects of current and possible future land management practices on the long-term development of the landscape patterns that are so characteristic of pasture-woodlands? 2) how are these trajectories influenced by future climate change? and 3) how is the provisioning of various ecosystem services affected by changes in these driving conditions?

B-13 Oak regeneration to maintain biodiversity around the world

Organizers: Kurt Gottschalk, Brian Lockhart (U.S. Forest Service), Aytekin Ertas (Istanbul University, Turkey) & Eduard Hochbichler (University of Natural Resources and Life Sciences, Austria)

The development of prescribed fire as a silvicultural treatment for sustaining biodiversity in upland oak ecosystems in eastern North America. Brose, P., Ristau, T., Stoleson, S. (*U.S. Forest Service, USA; pbrose@fs.fed.us; tristau@fs.fed.us; sstoleson@fs.fed.us*).

Oak-dominated ecosystems have been a major part of the upland landscapes of eastern North America for millennia. Because of this long-term dominance, they have developed a rich diversity of flora and fauna. They owe this long-term dominance and concomitant biodiversity, in part, to the cultural burning practices of Native American tribes and the European settlers that eventually replaced them. Cultural burning practices essentially ceased in the early 1900s and this cessation has contributed to the oak regeneration problem that is now widespread throughout eastern North America. This presentation retraces the fire history of the upland oak ecosystems of eastern North America with an emphasis of the development of prescribed fire techniques to regenerate and restore these ecosystems and maintain their intrinsic biodiversity.

Effects of solar radiation transmittance variability on the regeneration of *Quercus aliena* var. *acutiserrata* in the western Qinling Mountains, China. Dai, C., Gärtner, S., Reif, A. (*University of Freiburg, Germany; dai.chunling@waldbau.uni-freiburg.de; stefanie.gaertner@waldbau.uni-freiburg.de; albert.reif@waldbau.uni-freiburg.de*).

In the western Qinling Mountains (33°30′-34°49′ N, 104°22′-106°43′ E) oak species occur but there is very limited knowledge about their regeneration ecology. We analyzed the influence of solar radiation transmittance in forest canopy gaps and below canopy on the regeneration of *Quercus aliena* var. *acutiserrata* in uneven-aged deciduous oak forests. Forty-four plots were established on transects along gradients of canopy closure from closed canopy to the gap opening, in four different gap compartments. In each 12.6-m^2 plot, the regeneration of tree species (DBH <5 cm) was recorded, a hemispherical photograph was taken. Along the gradient the solar radiation transmittance decreased significantly from inside the gaps to the closed forests. No significant differences in density of juveniles of this oak species (height class <50 cm, or >130 cm) between the four gap

compartments were detected, apart from the height class 50–130 cm. The range was between 3 700 and 6 200 trees/ha. A reason could be that generally the gaps were small (<200 m^2), caused by individual tree harvest. The natural regeneration of this oak species seems to be relatively shade tolerant.

Regenerating oak forests to maintain biodiversity: oak forests around the world. Gottschalk, K., Lockhart, B. (*U.S. Forest Service, USA; kgottschalk@fs.fed.us; blockhart@fs.fed.us*), Hochbichler, E. (*University of Natural Resources and Life Sciences, Austria; eduard.hochbichler@boku.ac.at*).

Oak (*Quercus* spp.) forests occur across five continents of the Northern Hemisphere and provide critical biodiversity and unique habitats for other plants and animals. Oak regeneration is a challenging process around the world as changing land use patterns, forestry practices, fire patterns, and climate reduce the areas where conditions favorable to oak regeneration occur. Oak forests are an important component to biodiversity as they provide valuable wildlife habitat, forage, mast, and other critical ecosystem services. For example, work has shown much larger and diverse bird communities in oak-dominated forests versus maple-dominated forests. Climate change and land use change interact to create changed fire patterns on the landscape. In many parts of the world, oak forests are sustained by fire and these changed fire patterns threaten the sustainability of oak-dominated forests via disruption of the regeneration cycle. This presentation will provide an overview of oak forests, their biogeography around the world, and their common ecological basis.

The effect of the host plant phenotypic variation on leaf miner and gall forming insect associations. Lakatos, F., Tuba, K., Varadi, M., Takacs, V. (*University of West Hungary, Hungary; flakatos@emk.nyme.hu; tubak@emk.nyme.hu; vmelinda@gmail.com; takacs.violetta@gmail.com*).

The native oaks (*Quercus* spp.) are determining species for continental forest ecosystems in Europe. These tree species are able to reserve related insect communities by their special features and their interactions. Detailed knowledge of these species is an important factor in the preservation of genetic diversity, in nature protection, in reforestations, and in conservation ecology. In our trials we investigated three pedunculate oak (*Quercus robur*) provenances under similar conditions as a planted forest. The phenotypic features of the host and the leaf miner and the gall forming insects were determined. Both the leaf miner and the gall forming insects established an abundant association on young trees. The insects can be divided into three groups: 1) abundant, generally common species; 2) species with lower frequency; and 3) species linked to a defined phenotypic feature. The results of the cluster analysis showed the separation of the three provenances considering their phenotypic characteristics and the leaf miner and gall forming insect associations.

Protected forests and habitat management alternatives in oak-rich forests in southern Sweden. Leonardsson, J., Götmark, F. (*University of Gothenburg, Sweden; jenny.leonardsson@gu.se; frank.gotmark@gu.se*).

The management of protected forests is dominated by minimal intervention. Secondary succession can, however, create closed canopies and may disfavor biodiversity. Management alternatives for protected temperate forests are needed, to test responses in biodiversity. In the long-term Swedish Oak Project, we evaluate by experiments the effects of minimal intervention and conservation thinning on the woody vegetation. On average 25% of the basal area was cut during the winter 2002–2003, in 25 closed-canopy forests. Eight years later, in 2010, regenerating trees and shrubs (taller than 130 cm) were measured and classified as growing from seeds or vegetative sprouts. The results indicate that regeneration in treatment plots was about five times higher than the regeneration in reference plots (minimal intervention). Oak regeneration in treatment plots increased, but was low compared to other species. The regeneration among shrubs was strongly dominated by sprouting; among trees, sprouting versus seedling regeneration varied between species. Vegetative stems were generally taller than stems of seedlings. Survival of stumps and sprouting ability were analyzed, and varied among species. Within species, stump survival and sprout height was unrelated to stump diameter. Our long-term project on reserve management is unusual, and the results are directly useful in conservation management.

Regeneration of oaks by direct seeding: a review. Löf, M. (*Swedish University of Agricultural Sciences, Sweden; magnus.lof@slu.se*).

There is a need to compensate for forest clearing into degraded ecosystems that erode environmental services and contribute to climate change. Thus, to fulfill needs for wood and biomass production as well as environmental and climatic targets, there is globally an ambition to restore 150 million ha of forest by 2020. Regeneration of valuable and nut-bearing trees in the temperate zone, e.g., oaks, by planting is expensive and alternative cost effective methods are needed. Direct seeding of oaks may reduce the cost by >50% compared to planting. However, significant disadvantages include problems with seed handling, competition with natural vegetation at regeneration sites, and the often high consumption and dispersal rates of acorns by granivorous rodents. These animals use olfactory cues to detect buried seeds. The aim of this overview is to summarize the knowledge about direct seeding of oaks, on how rodents find buried seeds, and on how forest management can minimize seed predation. Future research needs for successful direct seeding of oaks will be discussed in a forest restoration context.

Large-scale patterns of *Quercus ilex*, *Quercus suber* and *Quercus pyrenaica* regeneration in central-western Spain. Plieninger, T. (*University of Copenhagen, Denmark; tobias.plieninger@ign.ku.dk*), Moreno, G. (*University of Extremadura, Spain; gmoreno@unex.es*), Rolo, V. (*Mendel University, Czech Republic; rolo@unex.es*).

In central-western Spain, oak forests and woodlands support outstanding levels of biodiversity, but there is increasing concern about a lack of regeneration. We hypothesize that this regeneration lack is operating on a large geographic scale; there are differences in the abundance of regeneration between three oak species; oak regeneration is governed mainly by forest management and structure; and shrubs act as important physical protectors of seedlings and saplings. We analyzed whether densities of oak seedlings and saplings in several size classes were related to stand-structure, understory, and physiographic variables potentially affecting regeneration. Results revealed that regeneration failure was common for all size categories, from small

seedlings to large saplings for the three oak species studied. Regeneration was positively correlated with tree cover and density, especially of small and medium-sized trees, and negatively correlated with the presence of large trees, indicating that regeneration failure is mostly associated with more open, uniform, and/or aged woodlands. Regeneration densities of *Q. ilex* and *Q. suber* were positively correlated with all understory variables, suggesting that the presence of pioneer shrubs represent a major safe site for early tree recruitment, independent from specific shrub species.

Oak (*Quercus robur* and *Q. petraea*) cluster planting increases tree species richness and stand productivity and fosters oak growth and quality. Saha, S., Kühne, C. (*University of Freiburg, Germany; somidh.saha@waldbau.uni-freiburg.de; christian.kuehne@waldbau.uni-freiburg.de*), Kohnle, U. (*Forest Research Institute of Baden-Württemberg, Germany; ulrich.kohnle@forst.bwl.de*), Bauhus, J. (*University of Freiburg, Germany; juergen.bauhus@waldbau.uni-freiburg.de*).

We examined how tree growth, quality, tree species diversity, and stand productivity differed between uniformly planted clusters (widely spaced groups, and very narrowly spaced nests) and traditional row planting. We carried out a mixed effect meta-analysis (25 cluster and row planting trials) on inventory data to compare oak growth, quality and survival between cluster and row planting in Germany, Austria, and Switzerland. Tree species diversity and stand productivity were calculated in seven trials comprising both oak cluster and row planting in southern Germany. Our meta-analysis showed that tree survival, growth, tree stability, branch-free bole length, and number of potential future crop tree did not differ significantly between group and row planting. However, effect sizes of these variables in nest planting were inferior to row planting. Natural regeneration in group planting was significantly higher than row planting; however, stand productivity did not differ significantly between group and row planting. Tree species diversity was significantly higher in cluster planting than row planting. Significant silvicultural and ecological gains could be made, at least for several decades, if group plantings are more broadly pursued for reforestation purposes. Our study also demonstrated first time the effectiveness of meta-analysis in experimental silviculture.

B-14 Ecosystem services provided by planted forests

Organizers: Peter Freer-Smith (Forest Research, UK), Eckehard Brockerhoff (Scion, New Zealand) & Jean-Michel Carnus (National Institute for Environmental and Agricultural Science and Research, France)

Promoting management practices targeting the conservation of biodiversity and ecosystem services in cork oak landscapes. Bugalho, M. (*Technical University of Lisbon and WWF Mediterranean Program, Portugal; mbugalho@wwfmedpo.org*), Silva, L. (*WWF Mediterranean Program, Portugal; lsilva@wwfmedpo.org*).

Forests harbor more than half of the terrestrial species of the world and generate ecosystem services of local, regional, and global importance. Forest ecosystems need to be sustainably managed for maintaining biodiversity and the flux of ecosystem services. Payments for ecosystem services (PES) is a conservation tool that can be used to promote the sustainable use of forest ecosystems. Here we describe a PES-like scheme which aims to incentivize the sustainable management of cork oak (*Quercus suber*) landscapes of southern Portugal. When sustainably managed, planted, and naturally regenerated, cork oak stands generate ecosystems services, such as long-term carbon storage or prevention of severe wildfires, and sustain plant and vertebrate species of conservation concern. PES can be used to incentivize good management practices in cork oak stands. Target areas for PES implementation were identified using the high conservation value forests (HCVF) framework, associated with a WebGIS mapping tool. This approach allowed identification of geographical areas where PES-promoted management practices are likely to simultaneously benefit conservation of biodiversity and ecosystem services. Described methodology can be used to inventory biodiversity and ecosystem services, and potentially implement similar PES schemes, in forest ecosystems elsewhere.

Managing plantations worldwide to benefit forest biodiversity and enhance ecosystem services. Deal, R., Hennon, P. (*U.S. Forest Service, USA; rdeal@fs.fed.us; phennon@fs.fed.us*), O'Hanlon, R. (*Department of Agriculture, Food and the Marine, Ireland; publications@rohanlon.org*), D'Amore, D. (*U.S. Forest Service, USA; ddamore@fs.fed.us*).

There is increasing interest worldwide in managing forests to maintain or improve biodiversity, enhance ecosystem services, and assure long-term sustainability of forest resources. Important goals of forest management are to increase stand diversity, provide wildlife habitat, and improve forest species diversity. We synthesize results from natural spruce forests in southeast Alaska and suggest strategies for managing Sitka spruce plantations worldwide to benefit biodiversity and enhance a variety of forest ecosystem services. We also discuss the roles of fungi in increasing both biological and structural diversity in Sitka spruce forests. New silvicultural systems that use partial cutting in older spruce forests could alleviate some of the problems associated with conventional even-aged management and increase both stand structural diversity and biodiversity. We found that mixed red alder-conifer stands in Alaska provided more heterogeneous structures than the pure conifer stands that typically develop after clearcutting. Well-planned silvicultural systems that include hardwood species such as alder or birch could provide trees for timber production, and improve wildlife habitat and a variety of other ecosystem services that are often compromised in pure conifer young-growth forests.

Forest plantation landscape management for water ecosystem services provisioning in Brazil. Ferraz, S., Paula Lima, W., Bozetti Rodrigues, C. (*University of São Paulo, Brazil; silvio.ferraz@usp.br; wplima@usp.br; cabreuva@gmail.com*), Voigtlaender, M. (*Forestry Science and Research Institute (IPEF), Brazil; mvoigtlaender@gmail.com*), Cassiano, C., Garcia, L., Hakamada, R. (*University of São Paulo, Brazil; carla_cassiano@hotmail.com; larajangada@gmail.com; rodrigo_hakamada@yahoo.com.br*).

Forest plantations in Brazil are increasing in recent years, reaching about 6 million ha in 2012, due to internal and external demand growth for fiber and wood. Forest management plans are seeking environmental sustainability of those planted areas,

guided by recent restrictions enforced by Brazilian government, environmental certification, and society pressure. Based on long-term monitoring data of many experimental catchments installed on forest plantation areas, we show examples of forest management alternatives at macro- and meso-scales that could contribute to improve water-related ecosystem services in forest plantation landscapes. At the macro-scale, we assess water use in different forest plantation areas in Brazil by analyzing the theoretical thresholds for the management of evapotranspiration. Results show that it is important to consider the inherent risk offered by natural climatic constraints of water availability. At the meso-scale, using hydrological modeling, we found that the proportion of native forest plays an important role in the reduction and regulation of water use, and therefore a system of mosaic management may be able to stabilize water flow across plantation landscapes. Finally, we discuss forest plantation management alternatives to avoid impacts and to offer water ecosystem services.

Biodiversity and productivity of planted forests. Forrester, D., Bauhus, J. (*University of Freiburg, Germany; david.forrester@waldbau.uni-freiburg.de; juergen.bauhus@waldbau.uni-freiburg.de*).

Mixed-species forests and plantations sometimes have greater levels of ecosystem functions and services, including productivity, than monocultures. Whether or not mixtures are more productive depends on the net effects of different types of interactions, and these are dynamic, changing through space and time with resource availability or climatic conditions. This paper discusses the processes driving these dynamics using the production ecology equation, where plant growth is a function of resource availability, multiplied by the fraction of resources that are captured by the trees, multiplied by the efficiency with which the resources are used. This equation is used with a literature review to examine how relative complementary effects in mixtures depend on the types of species interactions and how resource availability or climatic conditions change. It was found that complementary effects increased as soil nitrogen or water availability decreased when mixtures contained nitrogen-fixing species, or when interactions were assumed to reduce competition for water. In contrast, complementary effects increased with increasing site quality, and it was assumed that as growing conditions improved, competition for light increased and complementary effects resulted from interactions that improved light absorption or light-use efficiency.

Ecosystem services of planted forests through provision of habitat. O'Halloran, J., Irwin, S. (*University College Cork, Ireland; j.ohalloran@ucc.ie; s.irwin@ucc.ie*), Oxbrough, A. (*Edge Hill University, UK; Oxbrouga@edgehill.ac.uk*), Wilson, M., Fuller, L., O'Callaghan, C (*University College Cork, Ireland; mark.wilson@ucc.ie; L.Fuller@ucc.ue; 109555285@umail.ucc.ie*).

Planted forests represent a growing proportion of the world's forests, and increasingly contribute to the provision of vital ecosystem services including provision of habitat. Planted forests are typically less diverse than natural forests, which may limit their capacity to deliver particular ecosystem services. However, in landscapes with little remaining natural woodland, resulting from deforestation or a tradition where forests were absent, planted forests play an important role in providing habitats and other ecosystem services. Here we review the provision of habitats for forest specialist taxa, generalist taxa, and taxa of conservation concern. We identify the current state of knowledge, and identify forest management measures by which the provision of ecosystem services from planted forests can be enhanced, at the stand, forest, and landscape scales. Our focus will be to review key taxa, such as invertebrates and birds, and present case studies to illustrate the importance and risks that planted forests provide.

International Congress of Planted Forests: main issues and research needs for planted forests. Orazio, C. (*European Forest Institute, France; christophe.orazio@efi.int*), Farrell, T. (*European Institute for Cultivated Forests (IEFC), Ireland; epfarrell@gmail.com*), Kollert, W. (*FAO, Italy; walter.kollert@fao.org*), Jactel, H., Carnus, J. (*National Institute for Agricultural Research (INRA), France; herve.jactel@pierroton.inra.fr; carnus@pierroton.inra.fr*), Freer-Smith, P. (*European Forest Institute, UK; peter.freer-smith@forestry.gsi.gov.uk*).

We will present the main issues and research need identified in the recently published summary report of the third International Congress on Planted Forests. It is based on outcomes from three scientific workshops and a plenary meeting that took place on 16–21 May 2013. Planted forests are vital but vulnerable resources that can contribute in a sustainable fashion to some of humanity's most pressing needs (poverty alleviation, food security, renewable energy, mitigation of and adaptation to climate change, and biodiversity conservation) as well as the preservation of natural forests. Thirty-three countries have greater than 1 million ha of planted forest area. Together these countries comprise 90% of the world's 264 million ha of planted forest which, in turn, equals almost 7% of the total global forest area. The report takes into account key research findings from Africa, Asia, Europe, Oceania, Latin America, and North America related to vulnerability, viability, and governance of planted forests. The research needs identified came from fields as various as 1) governance, economics, and trade and markets; 2) vulnerability and risk management; and 3) ecosystem services and landscape restoration; and from cross-sectoral areas that ranged from poverty alleviation and rural development to climate change and monitoring of greenhouse gas emissions.

Ecosystem services of UK woodlands: downscaling scenarios and assessments from national to landscape scale. Quine, C., Ray, D. (*Forest Research, UK; chris.quine@forestry.gsi.gov.uk; duncan.ray@forestry.gsi.gov.uk*).

In 2011, the UK National Ecosystem Assessment (UKNEA) highlighted the major contribution that woodlands make to ecosystem services and the lack of market value for many of them. Since then follow-on (Phase 2) work has started to explore in detail the range of possible policy response options within different socio-political and climatic scenarios. There is growing interest in how to incorporate these concepts into sustainable forest management, and the future management of planted forests (including those composed of exotic tree species). In this paper we summarise the woodland-specific findings of the UKNEA and describe new work to assess the delivery of a suite of ecosystem services from wooded landscapes now and into different socioeconomic futures. In particular, we describe the application of methods for assessing a range of ecosystem services to contrasting case study sites in the UK using a range of climate change and policy futures scenarios. We assess the delivery of key goods and services in these futures, based on decisions on potential forest planning and silvicultural system choices from forest policy, woodland management incentives, and acceptance of risk. We conclude by ranking forest types, forest management alternatives, and climate change adaptation tactics for different woodland regions of the UK.

Effects of planted forest biodiversity on pollination services. Taki, H. (*Forestry and Forest Products Research Institute, Japan; htaki@affrc.go.jp*).

Pollination services provided by animal biodiversity are a critical ecosystem service. Pollinators can increase the production of about 75% of essential crops worldwide, and the proportion of flowering plants depending on pollinators is estimated to be >85% of all flowering plants. Both managed and wild pollinators use native natural, semi-natural, or human-altered ecosystems for their food and/or habitat. Forests can be key land types for pollinators among such terrestrial ecosystems worldwide. Planted forests account for a large proportion of forest area in some countries. More of the world's commercial timber is produced by planted forests than by natural and semi-natural forests. The obvious increasing demands for timber are mainly met by growing more timber on planted forests. Such intensive silvicultural management, in addition to the simplified structure and composition of planted forests, might have negative influences on pollinator biodiversity. However, planted forests may still contribute to conservation and restoration of biodiversity through various means. Recent studies have shown examples enhancing planted forest biodiversity which enhances pollinators and pollination services.

The economic value of forest ecosystem services provided by New Zealand's planted forests. Yao, R., Payn, T. (*Scion, New Zealand; richard.yao@scionresearch.com; tim.payn@scionresearch.com*).

Globally, there is an increasing interest for enhancing the provision of ecosystem services from productive landscapes. The importance and value of ecosystem services from such landscapes are now starting to be recognized in local, national, and global scales. New Zealand's 1.72 million ha of planted forests constitute a productive ecosystem mainly recognised for the provision of wood and fibre. This ecosystem is increasingly recognised for providing other services such as recreation, climate change mitigation, habitat provision, improved water quality, bioenergy, erosion control, and flood mitigation. This study describes key ecosystem services provided by planted forests and reports estimated economic values for these services. It also explains that planted forests can be managed for the sustainable provision of multiple ecosystem services such as timber, recreation, and erosion control. However, the outcomes of managing a bundle of these services can have both tradeoffs and synergies. Findings from this study also suggest that the estimated economic values for emerging services, such as recreation and biodiversity, remain very limited. It is recommended that studies using state-of-the-art methods of economic valuation that account for both time and space should be undertaken to provide better representation of ecosystem services values in future policy decision making.

B-15 Forest ecosystem services contributing to agriculture

Organizers: Kimiko Okabe (Forestry and Forest Products Research Institute, Japan) & Ian Thompson (NRCan-Canadian Forest Service)

The impact of retention harvesting on bee and hoverfly assemblages in the boreal forest of northern Alberta. Amos, J. (*University of Alberta, Canada; jamos@ualberta.ca*), Langor, D. (*Canadian Forest Service, Canada; david.langor@nrcan-rncan.gc.ca*), Spence, J. (*University of Alberta, Canada; jspence@ualberta.ca*).

Pollinators are declining at an alarming rate worldwide. In the boreal forest, pollinators are responsible for the reproduction of many understory shrub and flower species. However, many forms of disturbance may threaten pollinator assemblages and little work has been carried out on pollination in the boreal forest. We examined the effects of variable retention harvesting on bee (Apiformes) and hoverfly (Syrphidae) assemblages at the Ecosystem Management Emulating Natural Disturbance (EMEND) project site in northern Alberta, Canada, in 2012 and 2013. Pollinators were collected using pan traps and net capture in control stands of four different forest cover types (deciduous dominant, deciduous dominant with spruce understory, mixed wood, and coniferous dominant) as well as clearcuts and stands harvested to 20 and 50% retention in the deciduous dominant and coniferous dominant forest cover. Pollinators were more abundant in high retention stands in deciduous dominant forest and in low retention stands in coniferous dominant forest. Pollinators were also sampled along roadsides in forested and agricultural areas. Pollinators were more abundant along roadsides than in forested stands.

Ecosystem services of native trees: experiences from two traditional agroforestry systems in Karnataka, southern India. Bhaskar, D., Sathish, B. (*University of Agricultural Sciences, India; krupaias@gmail.com; satibn@gmail.com*), Viswanath, S. (*Institute of Wood Science and Technology, India; sviswanath@icfre.org*), Purushothaman, S. (*Azim Premji University, India; seema.purushothaman@gmail.com*).

Land-use decisions intended to maximize a single output such as agricultural production or timber production are likely to generate an accompanying decline in the provision of other ecosystem services. But we demonstrate that native-tree-based agroforestry systems (AFS) can create a win-win situation where a sustained flow of provisioning services can be maintained without compromising supporting and regulatory services, by comparing and contrasting two traditional AFS in Karnataka state of southern India. The two AFS were 1) coffee-based shaded perennial systems in Kodagu district of tropical humid zone, and 2) dryland agroecosystems with *Ficus* trees in Mandya district of semi-arid zone. Assessment of ecosystem services as per field data collected and farmers' perceptions in both the systems revealed that when compared to exotic species, native trees provide more direct and indirect benefits, irrespective of the differences in type, location, scope, and management of these systems. The role of native trees in supporting the overall sustainability of these AFS is highlighted in the study. It is also emphasized that the long term sustenance of traditional agroforestry systems depends on appreciation of their indirect and intangible benefits.

Forest edges as sources of ecosystem services for landscape agroecology. Deconchat, M., Alignier, A., Andrieu, E., Giffard, B., Ladet, S. (*National Institute for Agricultural Research (INRA), France, marc.deconchat@toulouse.inra.fr; audrey.alignier@rennes.inra.fr; emilie.andrieu@toulouse.inra.fr; brice.giffard@gmail.com; sylvie.ladet@toulouse.inra.fr*), Ouin, A. (*Université de Toulouse, France; annie.ouin@ensat.fr*), Roume, A. (*National Institute for Agricultural Research (INRA), France; anthony.roume@gmail.com*), Sourdril, A. (*Université de Paris X, France; asourdril@gmail.com*).

Forest edges are very common components of most of temperate landscapes. They are the interfaces between forest and agriculture. Many species are able to live in both habitats and benefit from the structure of edges. Some parts of this biodiversity provide ecosystem services for agriculture, such as pollination and pest regulation. We present several examples of such type of edge-related ecosystem services and we show how edge management can be an efficient way to improve some of them in a landscape agroecology perspective. The management of edges usually implies several stakeholders (managers of the two adjacent habitats). Forest managers may be asked by the farmers to adapt his practices in order to create the best conditions in edges for the organisms involved in the ecosystem services. A better understanding of the ecological processes important for biodiversity in forest edge, but also of the social and technical links between habitats managers, is necessary. We provide some research directions and key questions related to this challenge.

Recovering the biodiversity in cacao plantations south of Maracaibo Lake, Mérida, Venezuela. Gutierrez, N., Mazon, M. (*Universidad de Los Andes, Venezuela; nestorgutierrez@ula.ve; marinamazonmor@gmail.com*).

The common agronomic practices tend to reduce the overall biodiversity in the agroecosystems which consequently impact ecosystem functions and resilience. It is even occurring in traditionally highly biodiverse agroecosystems, such as cacao plantations. With the objective of reversing this situation in cacao plantations, we designed a strategy to include communities of cacao producers in the recovery of the ecosystems using two techniques. First we developed a restoration ecology plan within and surrounding plantations, and second we increased the diversity of shade trees, with problematic areas within the plantations selected by the communities. There are good indications of a success initial recovery of abundance and richness of tree species in restored areas. The selection of planted shade trees was done by communities using mainly native species. The cacao producers were motivated mainly by the protection of water sources and the possibility of harvesting wood in the future. However, there was reluctance to assign large areas to recovery using restoration ecology techniques because these areas were considered unproductive and possibly a refuge for snakes. This project had very good results integrating biodiversity recovery with cacao production, and has potential to be applied in other crops.

Agroforestry for ecosystem services: a North American perspective. Jose, S. (*University of Missouri, USA; joses@missouri.edu*).

Recent trends in the agriculture sector necessitate farm diversification as an essential strategy for economic competitiveness in a global market. Agroforestry systems offer great promise for the production of biomass for biofuel, specialty and organic crops, pasture-based dairy and beef, among others. Agroforestry also offers strategies for carbon sequestration, soil enrichment, biodiversity conservation, and air and water quality improvement for not only the landowners or farmers, but for society at large. Evidence in the agroforestry literature supporting these perceived ecosystem benefits has been lacking until recently. This paper builds on a number of recent studies from North America to provide quantitative evidence in support of ecosystem services provided by major temperate agroforestry systems. It examines four major ecosystem services of agroforestry: (1) carbon sequestration, (2) air and water quality, (3) soil enrichment, and (4) biodiversity conservation. The available data clearly indicate that agroforestry, as part of a multifunctional working landscape, can be a viable land-use option that, in addition to providing food security, offers a number of ecosystem services and environmental benefits. This realization should help promote agroforestry and its role as an integral part of a multifunctional working landscape not only in North America, but the world over.

Strengthening the provision of ecosystem services in agricultural landscapes in Costa Rica. Louman, B., Gutierrez, I. (*CATIE, Costa Rica; blouman@catie.ac.cr; igutie@catie.ac.cr*), Wulfhorst, J. (*University of Idaho, USA; jd@uidaho.edu*), LeCoq, J. (*CIRAD, Costa Rica; jflecoq@cirad.fr*).

The forest transition in Costa Rica is mainly due to increased forest areas in agricultural landscapes, providing a variety of ecosystem services. Stimulated by an environmental and economic crisis, the transition was strengthened through policy measures such as forest legislation and a scheme of payment for environmental services. The effectiveness and efficiency of the latter has been questioned, suggesting that other factors also influence decision making of farmers. To better understand this decision making, we interviewed 163 farmers in three agricultural landscapes in Costa Rica, using the Community Capitals frameworks. We analyzed tree cover change on their farms using remote sensing images for a 20-year timespan. We compared these data using multivariate analyses to identify characteristics that differentiate farmers with increased tree cover from those without. In five local workshops, we validated our findings. Since the 1996 ban on land use change, the combination of assets and ecosystem services that influence decision making varies from one farmer to another, reducing the effectiveness of conservation strategies oriented towards income increase alone. Although trees are considered important by all farmers, strengthening ecosystem services in agricultural landscapes will require strategies that improve financial assets, as well as information services, education and local governance.

Economic valuation of pollination service in coffee, Risaralda, Colombia. Plata Fajardo, A. (*Federal University of Paraná, Brazil; aplatafa@gmail.com*).

The value of pollination derives from its contribution to the ecosystems maintenance, as well as its contribution to agriculture. This paper shows the economic role of pollination services to support the production of coffee crops in Risaralda, Colombia. The main aim is to estimate the marginal economic value of the pollination service in the coffee crop. The production function approach seems to be the best model since it is particularly useful for ecosystem services that support economic activities. Using a spatial regression model, the study estimated the value of pollination as well as other environment services for Risaralda production coffee. Using Ricketts and coworkers' 2004 equation, I estimated the economic benefits of the pollination services at the scale of the farm. The results show a loss of farm income of around $140/year (USD). Hence, at the farm level there is evidence of income loss due to the decrease of the pollination service in coffee crops. The results shed light on the establishment of current market prices for commercial pollination in coffee crops. Also, the study contributes to the knowledge of spatial econometrics in the valuation of ecosystem services.

B-16 Contribution of genetics and genomics to conservation and sustainable management of forests under changing environmental conditions

Organizers: Om Rajora (University of New Brunswick, Canada) & Wickneswari Ratnam (Universiti Kebangsaan Malaysia)

Assessing the adaptive portfolio of reforestation stocks for future climates. Aitken, S., Yeaman, S., Hodgins, K. (*University of British Columbia, Canada; Sally.Aitken@ubc.ca; yeaman@zoology.ubc.ca; hodgins@zoology.ubc.ca*), Hamann, A. (*University of Alberta, Canada; andreas.hamann@ualberta.ca*), Whitlock, M. (*University of British Columbia, Canada; whitlock@zoology.ubc.ca*), Liepe, K. (*University of Alberta, Canada; liepe@ualberta.ca*), Rieseberg, L., Nurkowski, K., MacLachlan, I., Mellway, R., Smets, P. (*University of British Columbia, Canada; lriesebe@interchange.ubc.ca; kristin.nurkowski@gmail.com; ianrmaclachlan@gmail.com; rmellway@mail.ubc.ca; pia.smets@ubc.ca*).

Climate change is creating a mismatch between tree populations and the climates they inhabit. Assisted gene flow between populations has the potential to mitigate this maladaptation. To better plan for reforestation for new climates, the AdapTree project is characterizing the extent of local adaptation in two widespread conifers in western Canada, lodgepole pine (*Pinus contorta*) and the interior spruce species complex (*Picea engelmannii, P. glauca,* and their hybrids). Seedlings from more than 250 populations per species have been phenotyped for climate-related traits including growth, bud phenology, cold hardiness, and heat and drought stress responses under a range of simulated climatic conditions. These individuals have also been genotyped either through resequencing more than 28 000 genes in lodgepole pine and more than 35 000 genes in interior spruce, or through genotyping using a 50 000 single nucleotide polymorphism (SNP) array. Relationships between provenance climate and both phenotypes and SNP genotypes are being used to characterize the extent of, and climatic drivers of, local adaptation in both species. Results will be used to design climate-based seed transfer policies for future climates, and to evaluate the capacity of natural populations to rapidly adapt to new climatic conditions.

Using case studies for enhancing capacity for managing forest genetic resources. Boshier, D. (*Bioversity International, UK; david.boshier@plants.ox.ac.uk*), Bozzano, M., Loo, J., Rudebjer, P. (*Bioversity International, Italy; m.bozzano@cgiar.org; j.loo@cgiar.org; p.rudebjer@cgiar.org*).

Forest trees are long-lived species with high genetic diversity that is central to their survival, regeneration, and adaptation to climate change. However, forest managers and conservationists are often not well informed about genetic aspects of population viability. Lack of understanding of forest genetic resources (FGR), therefore, constrains sustainable forest management and adaptation to climate change. Tertiary education curricula cover FGR issues poorly or not at all. A vicious cycle is looming in which teaching and understanding of FGR and its importance to sustainable forest management becomes increasingly marginalized. We describe a case-study-based approach to teaching and learning about FGR use and conservation. Designed to promote FGR-friendly decision-making, the Training Guide covers practical issues in forest and tree management of both global and local relevance. Each case study provides genetic, ecological, and socioeconomic information as a basis for students' analysis. Teacher's notes, PowerPoint presentations, and videos give background information for each case. The guide targets both tertiary education and on-the-job training. It is or will soon be available in English, Spanish, French, Russian, and Chinese. The material has proved popular with trainees and is flexible and easy to use in a range of formal and informal learning situations.

Bioprospecting for novel genes through characterization of leaf transcriptome of *Withania somnifera*, a valued medicinal plant. Dasgupta, M., George, B. (*Institute of Forest Genetics and Tree Breeding, India; modhumitaghosh@hotmail.com; blessan.orion@gmail.com*).

In the present era of "-omics," rapid sequencing and analysis of genomes of non-model species is constantly increasing. Studies have revealed that these uncharacterized genomes are hidden treasures of gene clusters potentially coding for biologically active peptide/compounds. The present study was undertaken to identify novel pathogenesis-related (PR) genes from *Withania somnifera*, a valued medicinal plant with pharmaceutical and nutraceutical applications. The global transcriptome of salicylic acid treated leaves was sequenced using an Illumina Genome Analyzer IIx sequencer. The de novo assembly, gene ontology (GO) mapping, functional annotation, and pathway analysis of transcript contigs were conducted using different computational pipelines. The assembly generated 73 523 transcript contigs and 71 062 were annotated using BLASTx against the non-redundant (nr) database for Viridiplantae. The annotated transcript contigs were mapped on GO database and 53 424 sequences were assigned GO terms. The metabolic process and the cellular process constituted the main biological processes and 182 functional pathways were identified from the sequence data. Further, the transcriptome data was mined for PR genes and 18 genes from 12 families were identified and their expression during signal amplification was analyzed using quantitative real time polymerase chain reaction (qRT-PCR) technology. This study provides a repertoire of functional PR gene pools for future transformation programs in diverse genotypes.

Range-wide geographic variation in *Prunus africana* at the molecular and chemical level. Geburek, T., Schueler, S., Konrad, H., Kadu, C. (*Federal Research Centre for Forests, Austria; thomas.geburek@bfw.gv.at; silvio.schuler@bfw.gv.at; heino.konrad@bfw.gv.at; cheledikadu@gmail.com*), Vinceti, B. (*Bioversity International, Italy; b.vinceti@cgiar.org*), Miretie, Z. (*Federal Research Centre for Forests, Austria; ziyinm@yahoo.com*).

This paper describes the molecular and chemical variation of *Prunus africana*, an important Afromontane medicinal tree species. Genetic variation and differentiation at both chloroplast and nuclear DNA microsatellites were high. The highest molecular richness was detected in the northern distribution area, especially in Ethiopia. Genetic variants detected in the far north were only shared in the southeastern, but not in the western lineage, questioning the immigration routes accepted so far. For both marker types a distinct phylogeographic pattern was detected. Eventually six main regions were differentiated: 1) Ethiopia, 2) West Africa, 3) East Africa west of the Eastern Rift Valley (ERV), 4) East Africa east of the ERV, 5) southern Africa, and

6) Madagascar. The strongest divergence was evident between Madagascar and continental Africa both for chloroplast as well as nuclear microsatellites. Estimates of gene flow based on chloroplast and nuclear markers were slightly different indicating a shift of gene flow barrier in the ERV over time. Bark extracts were analyzed by gas chromatography. Variation among populations was high. However, contrasting to the DNA data, the populations were only weakly differentiated on a geographic level. The results will be discussed in view of the biography and conservation of this species.

Population and landscape genomics to study local adaptation in loblolly pine (*Pinus taeda*) populations and to breed more climate change resilient trees. Krutovsky, K. (*University of Göttingen, Germany; kkrutov@gwdg.de*), Chhatre, V. (*U.S. Forest Service, USA; crypticlineage@gmail.com*), Lu, M., Byram, T. (*Texas A&M University, USA; mira0501@tamu.edu; tbyram@tfs.tamu.edu*), Wegrzyn, J., Neale, D. (*University of California at Davis, USA; jlwegrzyn@ucdavis.edu; dbneale@ucdavis.edu*), Loopstra, C. (*Texas A&M University, USA; c-loopstra@tamu.edu*).

Population and landscape genomics help us better understand local adaptation and develop sustainable management of forests to mitigate climate change and to breed more drought and disease resilient trees. Loblolly pine (*Pinus taeda* L.) has great economic importance and also a wide geographic distribution occupying a variety of environmental conditions, which makes it a good system to address these issues. We used genotypic data based on a genome-wide set of 4 264 single nucleotide polymorphisms (SNPs) representing expressed loci to study association of SNPs with adaptive and breeding value related traits and environmental variables in more than 1 450 loblolly pine trees from the Western Gulf Forest Tree Improvement Program. Numerous significant associations were found between various phenotypic traits, environmental variables and SNPs. We also tested the genome target sequencing techniques for re-sequencing exome regions and for high-throughput SNP discovery and genotyping by sequencing (GBS). More than 6.5 million SNPs were detected that we plan to use for genotyping the entire exome in more than 400 individual trees to link allelic variation with phenotypic variation in important economic, adaptive, and breeding traits. Implications of our results for breeding, genomic selection, genetic conservation and towards understanding local adaptation will be discussed.

Development of a DNA-based timber-tracking system for *Koompassia malaccensis* in Malaysia. Lee, C., Tnah, L., Lee, S., Ng, K., Ng, C. (*Forest Research Institute Malaysia; leechait@frim.gov.my; leehong@frim.gov.my; leesl@frim.gov.my; kevin@frim.gov.my; chinhong@frim.gov.my*), Diway, B. (*Sarawak Forestry Corporation, Malaysia; bibian@sarawakforestry.com*), Eyen, K. (*Sabah Forestry Department, Malaysia; eyen.khoo@sabah.gov.my*).

Illegal logging jeopardizes sustainable forest management. It is a global issue that needs to be addressed urgently. This project aimed to establish an individual and population database for *Koompassia malaccensis* in Malaysia, in order to develop a DNA-based timber-tracking system for this widespread and commonly traded timber species. A total of 1 467 *K. malaccensis* samples collected from 56 locations throughout Malaysia were genotyped using nine short tandem repeat (STR) loci. Forensic parameters and allele frequencies for each locus were estimated, with the minimum allele frequency adjusted to 5/2n. Assuming independence between alleles and loci, the theoretical 9-locus STR profile estimates can range from 7.8631×10^{-9} to 7.5240×10^{-48}, implying that individual identification is feasible in forensic casework. Results also showed that the individual identification database could be further divided into three subgroups (East Malaysia, West Malaysia, and Peat Swamp Ecotype). From the assignment tests, the mean proportion of baseline individuals correctly assigned to the respective subgroups was 99.2%. The chloroplast DNA analysis was carried out using 395 samples to establish a population identification database, yielding a region specific haplotype distribution map. In the case when DNA extraction is feasible, the combined usage of STR and chloroplast markers will enable geographic traceability *K. malaccensis* timber in Malaysia.

Genetic diversity of central and peripheral populations of *Toona ciliata* var. *pubescens*, an endangered tree species endemic to China. Liu, J., Jiang, J. (*Chinese Academy of Forestry, China; ywliu2005@163.com; jiang_jingmin@163.com*).

Our objective was to examine the genetic diversity of central and peripheral populations of *Toona ciliata* var. *pubescens*, to elucidate whether the central-peripheral hypothesis applies to these populations. We analyzed 384 individuals from nine natural populations using eight pairs of polymorphic simple-sequence-repeat (SSR) primers. The results showed that the mean numbers of observed and expected alleles in peripheral populations were higher than in central populations. Both the observed and expected heterozygosities were higher in peripheral populations compared with the central populations. The coefficient of gene differentiation of the peripheral populations was 0.3045, which was significantly higher than that of the central populations. The gene flow between central populations was greater than one, but less than one between peripheral populations. This indicates that frequent gene flow exists between central populations, while terrain and habitat fragmentation prevent gene flow among peripheral populations. A Mantel test indicated there is no relationship between genetic and geographical distance of *T. ciliata* var. *pubescens*.

Identifying site characteristics that explain variation in Douglas-fir productivity, stem form, and adaptability. Magalska, L., Howe, G., Maguire, D., Jayawickrama, K. (*Oregon State University, USA; lauren.magalska@oregonstate.edu; glenn.howe@oregonstate.edu; doug.maguire@oregonstate.edu; keith.jayawickrama@oregonstate.edu*).

The ability to project the value of Douglas-fir plantations is limited by 1) how stand growth, stem quality, and adaptability (e.g., cold hardiness, budburst, survival) are influenced by site characteristics; 2) the effects of seed source and genotype transfer among sites; and 3) the effects of near-term climate change. Our objectives were to understand how plantation site characteristics are related to growth, stem form, and adaptability. Differences in productivity among sites result from genetic and environmental variation. To separate these effects, we used progeny tests in which the same genetic materials were planted on multiple sites. The site characteristics that we focused on included climate, soils, and topography. Measures of site productivity, stem form, and adaptability were explained using correlation, random forest, and linear regression analyses. These analyses identified important site characteristics related to summer drought, cold season temperatures, and precipitation interactions with soil properties. These results will form the foundation of future studies to understand how parental site characteristics are related to the performance of their progeny at each test location, the extent to which seed sources and families can be successfully moved among sites, and the near-term effects of climate change.

Visualising the environmental responses of forest tree populations. Meder, A., Brawner, J. (*Commonwealth Scientific and Industrial Research Organisation, Australia; roger.meder@csiro.au; jeremy.brawner@csiro.au*), Dvorak, W., Hodge, G. (*North Carolina State University, USA; dvorak@ncsu.edu; grh@ncsu.edu*).

A novel methodology for describing genotype by environment interactions estimated from multi-environment field trials is described and empirical examples using trial networks of pines and eucalypts is presented. The network of experiments consists of replicated field trials of eucalypts across the subtropics of eastern Australia, or across the southern hemisphere in the case of pines. To apply the results across broad landscapes rather than a specific environment, species' productivity is classified simultaneously by the differential in species' productivity across a range of sites and the differential in site environmental variables, and their effect on productivity, by site. An important feature of the method is that it abstracts performance away from the specific trials that have sampled the target planting environment so that changes in productivity are associated with the environmental variables classifying the trials. This facilitates the visualisation of changes in productivity (GxE) across the climatic variables that classify the landscape rather than changes in productivity among specific sets of trials and facilitates an alternative display of GxE which obviates reference back to the trials used to evaluate sets of germplasm.

Genetic structuring and triploidy in North American aspen (*Populus tremuloides*). Mock, K. (*Utah State University, USA; karen.mock@usu.edu*).

Trembling aspen (*Populus tremuloides*) is the most broadly distributed native tree species in North America, and the species is known for its ability to form large clones through root suckering. Rangewide genetic patterns indicate that there are two major genetic groups of aspen: one in the western United States and one across Canada, Alaska, and parts of the northern United States. This structure, along with rangewide patterns of genetic diversity, suggests that aspen in the western United States are a distinct lineage and did not participate in the post-glacial expansion across Canada. Aspen populations in the western United States are more distinct from each other, but within-population diversity is lower, compared to aspen in the rest of the species range. This pattern is likely a result of topography and isolation among western United States populations. Furthermore, western North American aspen populations have higher rates of triploidy than in the rest of the range and the proportion of triploidy correlates roughly with drier climates. The data underlying these patterns, and corresponding ecological and management implications, will be discussed.

Karyological studies on *Picea* spp. Muratova, E. (*Sukachev Institute of Forest, Russia; elena-muratova@ksc.krasn.ru*).

Species from the genera *Picea* are stable diploids and contain 24 A-chromosomes (2n=24). In the morphological type *Picea*, eight pairs are long metacentrics and four pairs are short meta- or submetacentrics. In *P. schrenkiana, P. jezoensis, P. pungens, P. x fennica*, and *P. breweriana*, one B-chromosome occurs (2n=24+1B); *P. koyamae*, and *P. engelmannii* have one to two (2n=24+1-2B), *P. ajanensis* and *P. meyeri* have one to three (2n=24+1-3B) *P. obovata* has one to four (2n=24+1-4B), and *P. glehnii* has one to five B-chromosomes (2n=24+1-5B). This is the first study case occurrence of B-chromosomes in four species: *P. breweriana, P. pungens*, *P. koyamae*, and *P. schrenkiana*. At present, B-chromosomes are found in 19 *Picea* species including interspecies hybrid *P. x fennica*. Sizes of A-chromosomes *Picea* are from 9 to 15 mm. Lengths of B-chromosomes of these species compose 25–30% of the A-chromosomes (4–6 mm). In their morphology, B-chromosomes can be metacentric (B1 type) and submetacentric B2 type. It is supposed that submetacentric B-chromosomes originated as the result of pericentric inversion of metacentric ones. The number of B-chromosomes in conifers varies from one to six. The highest number (six) was registered in *Picea glauca* and *P. albertiana*; *P. glehnii* and *P. sitchensis* had five, and *P. obovata* had four. Other researchers found that the presence of B-chromosomes can be connected with unfavourable ecological factors. Effects of B-chromosomes can have adaptive characteristics. The results obtained allow us to consider that this system is a general phenomenon and B-chromosomes are of importance for populations and species and may possibly play a role in their adaptations.

The evolutionary history and genetic diversity of ponderosa pine: management implications for an important species of western North America. Potter, K. (*North Carolina State University, USA; kpotter@ncsu.edu*), Means, R. (*Bureau of Land Management, USA; rmeans@blm.gov*), Hipkins, V., Mahalovich, M. (*U.S. Forest Service, USA; vhipkins@fs.fed.us; mmahalovich@fs.fed.us*).

Ponderosa pine (*Pinus ponderosa*) is the most broadly distributed pine species of the Western Hemisphere, where it has considerable ecological and economic importance. It exhibits complicated patterns of morphological and genetic variation, suggesting that it may be in the process of differentiating into multiple species. These patterns have created confusion about evolutionary relationships within the ponderosa pine complex, while the near absence of paleoecological data during the Pleistocene ice age obscures phylogeographic processes that influenced the evolutionary history of the complex. This study offers some surprising insights into ponderosa pine evolutionary history and phylogeography using three genetic marker systems: a highly polymorphic mitochondrial minisatellite DNA region, nuclear microsatellites, and allozymes. The results from this study, which encompasses 3 100 trees from 104 populations across the species range, should assist in management decision-making and conservation planning relating to ponderosa pine sub-taxa and populations. For example, mtDNA haplotypes may represent evolutionarily distinct units that may respond differently to climate change because of differences in adaptation to climatic conditions. Measures such as seed archiving, silvicultural treatments, and prescribed fires should consider whether populations possess rare haplotypes and alleles and high haplotypic or allelic diversity.

The role of genomics research in understanding responses and adaptation of forest trees to changing climate and environmental conditions. Rajora, O. (*University of New Brunswick, Canada; Om.Rajora@unb.ca*).

Recent climate and environment changes are subjecting our forests to significant abiotic stresses, which can negatively impact their adaptation, health, productivity, and fitness. Therefore, it is essential to understand the genetic/genomic basis of responses and adaptation of forest trees to these changed conditions so that measures to mitigate the negative impacts of climate and environment change can be developed by selecting, creating, conserving, and sustainably managing well-adapted, genetically

diverse, and healthy forest resources. Genomics research and applications provide excellent opportunities to address these crucial research needs. I will discuss how structural, functional, and population genomics and bioinformatics research and applications can contribute to decode responses and adaptation of forest trees to climate and environment change, and will present highlights of our own research on these aspects. We have identified and characterized genes expressed differentially in response to elevated CO_2, drought, and co-stressed conditions, their metabolic pathways and relationships with physiological traits in black spruce (*Picea mariana*), and mapped quantitative trait loci for phenotypic and ecophysiologic traits related to growth and adaptation to climate change. We have also identified genes under natural selection in response to air pollution and involved in adaptation of red spruce (*Picea rubens).*

Genetic diversity of introduced species facing climate change: *Eucalyptus robusta* in eastern Madagascar. Ramananantoandro, T., Andriambelo R., R. (*University of Antananarivo, Madagascar; ramananantoandro@gmail.com; andriambelo.radonirina@yahoo.fr*), Daniel, V. (*CIRAD, Madagascar; daniel.verhaegen@cirad.fr*), Chaix, G. (*CIRAD, France; gilles.chaix@cirad.fr*).

Eucalyptus is the most widely planted species in Madagascar. *Eucalyptus robusta* is the most common species (225 000 ha) because it is well adapted and has multipurpose wood uses (energy, pole, and timber). Although this species has been naturalized for more than a century, little is known about the introduced genetic diversity. Previous research leads us to assume that it has a narrow genetic base. A study of genetic variability and genotype by environment interaction for *E. robusta* growth was therefore conducted. This study concerns two provenance trials (24 provenances from Australia, 1 from Madagascar) and three progeny trials established in two bioclimatic regions, regularly monitored for >10 years. In both sites, results showed strong provenance effects and genotype by environment interactions for growth. However, the Malagasy provenance was the poorer performer for growth, compared to the Australian. This could be attributed to its origin, mainly to inbreeding depressions due to the narrow genetic base introduced. Due to climate change, this low diversity, which will be confirmed by ongoing molecular genetic studies, may represent biological and economical risks. These will help forest managers to capitalize on the genetic resources existing in Madagascar for a better future.

Gene dispersal inference across multiple forest patches in an endangered medicinal tree. Tariku, H. (*Griffith University, Ethiopia; h.tariku@griffith.edu.au*), Schmidt, D. (*Griffith University, Australia; d.schmidt@griffith.edu.au*), Teketay, D. (*Botswana College of Agriculture, Botswana; dteketay@bca.bw*), Zalucki, J., Hughes, J. (*Griffith University, Australia; j.zalucki@griffith.edu.au; jane.hughes@griffith.edu.au*).

Gene dispersal in forest trees is a fundamental mechanism for colonizing new sites and adapting to changing climates. It determines the spatial patterns of tree regeneration, which in conjunction with other evolutionary, demographic, and environmental forces can shape the spatial genetic structure of tree populations. Under limited gene dispersal, significant spatial genetic structuring can be observed in tree populations. Thus analyzing fine-scale spatial genetic structure can provide information critical for understanding the level of historical gene dispersal among forest patches. Knowledge about gene dispersal can be useful in understanding tree populations' ability to survive under changing conditions. In particular, contrasting past and current gene dispersal can provide useful insights to gauge the extent of recent human disturbances and guide management strategies. Dispersal study within this context, especially seed dispersal inference across multiple sites is, however, very limited. This study is the first to compare historical and contemporary gene dispersal within and between multiple forest patches in the endangered tree, *Prunus africana*. We employ eight highly polymorphic microsatellite markers and several approaches to estimate gene dispersal distance. We show limited current dispersal compared to dispersal in past few generations. We also show shorter dispersal distance in small-isolated than large-less-isolated forest patches.

Timber identification of CITES-listed species *Dalbergia retusa* and non-CITES-listed species *Dalbergia tucurensis*: wood anatomy or DNA barcoding? Yin, Y., Jiao, L., Jiang, X. (*Chinese Academy of Forestry, China; yafang@caf.ac.cn; jiaolichao@126.com; xiaomei@caf.ac.cn*).

Dalbergia retusa Hesml. is a valuable timber species mainly distributed in tropical South America. Currently, the natural forest resources of *D. retusa* are in danger of disappearing due to illegal and excessive logging. Thus, it has been moved to Appendix II from Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since 2013. For these reasons, the protection and identification of *D. retusa* is crucial and significant. However, it is very difficult to impossible to distinguish *D. retusa* from its closely related wood species, especially *Dalbergia tucurensis*, which is non-regulated in CITES, when only considering wood anatomical characteristics. DNA barcoding, a newly developed molecular marker approach, might provide an improvement in species identification. In this study, dried timber specimens of *D. retusa* and *D. tucurensis* were selected for wood identification using DNA barcoding technology. Moreover, chloroplast DNA regions and the nuclear ribosomal DNA were considered as DNA barcodes for polymerase chain reaction (PCR) amplification. The results indicated that dried wood obtained from *D. retusa* and *D. tucurensis* could be identified by the DNA barcoding method to improve the timber identification at the species level and reduce the illegal logging worldwide.

B-17 Salamanders: world icons of aquatic biodiversity in forests

Organizer: Deanna Olson (U.S. Forest Service)

Population structure and shelter characteristics of hellbender salamanders in an eastern Tennessee stream. Hecht, K., Nickerson, M. (*University of Florida, USA; kirstenhecht@ufl.edu; maxn@flmnh.ufl.edu*), Freake, M. (*Lee University, USA; mfreake@leeuniversity.edu*), Colclough, P. (*Knoxville Zoological Gardens, USA; pcolclough@knoxville-zoo.org*).

The hellbender (*Cryptobranchus alleganiensis*), a giant aquatic salamander found in mountainous regions of the eastern United States, has experienced population declines and extirpations in many sites presumably due to anthropomorphic activity. Viable populations remain in forested portions of the Blue Ridge Physiographic Region. Tennessee's Little River is known for large

numbers of immature hellbenders. From 2000 to 2010, we conducted skin-diving surveys in Little River to examine hellbender population structure and to quantify hellbender shelter characteristics within the Great Smoky Mountains National Park (GSMNP). In 2013, we also began a study of hellbender populations downstream of the park. Hellbender populations within GSMNP appeared stable over time, with larvae representing 25% of captured individuals. Catch per unit effort and abundance of hellbenders decreased downstream from the protected forest area. On average, larval hellbenders utilized significantly smaller rock shelters than sub-adults and adults. Hellbender presence at shelter rocks was positively associated with very coarse gravel, and negatively associated with fine gravel suggesting that hellbenders may exhibit specific stream substrate preferences. Based on the potential importance of stream substrate to hellbenders, we recommend that the effects of upland land use and stream activities on streambed particles be considered when managing watersheds associated with hellbenders.

Relationships of salamanders with downed wood in managed forests of the United States. Homyack, J., Kroll, A. (*Weyerhaeuser Company, USA; jessica.homyack@weyerhaeuser.com; aj.kroll@weyerhaeuser.com*).

Downed wood provides critical ecological services to forest ecosystems, including soil formation and retention, and serves as habitat for a wide range of invertebrate and vertebrate species. Salamanders, often considered to be indicators of ecological integrity or sentinels of environmental change, are a diverse and abundant suite of organisms that are often associated with large and/or well-decayed pieces of downed wood. Although retention of downed wood is recommended to ameliorate negative effects of forest harvesting on salamanders, intensification of forest management and increasing demand for forest-based biofuels may reduce spatial and temporal availability of large logs and stumps on managed landscapes. However, relationships among salamanders, downed wood, and forest management vary regionally and across species because of operational differences in silvicultural regimes, diverse salamander life-history strategies, and/or whether a species is a downed wood obligate or associate. Herein, we use a case-study approach to examine within and across region differences in occupancy, energetic, and demographic responses of salamanders to downed wood in managed forests of the United States. We report results from experimental manipulations of forest stands or downed wood to increase understanding of multi-scale and cross-regional habitat relationships of salamanders with structural elements of the forest floor.

In-river habitat changes following riparian and upland deforestation correlate with the decline of Ozark hellbender salamander health and populations. Nickerson, M. (*University of Florida, USA; maxn@flmnh.ufl.edu*), Pitt, A. (*Bloomsburg University of Pennsylvania, USA; apitt@bloomu.edu*), Tavano, J. (*Clemson University, USA; jtavano@clemson.edu*), Hecht, K. (*University of Florida, USA; kirstenkardasz@gmail.com*).

Populations of the endangered Ozark hellbender salamander (*Cryptobranchus alleganiensis bishopi*) have declined precipitously in recent decades. We evaluated the Ozark hellbender population and habitat in the North Fork of the White River, Ozark County, Missouri, from 1968 to 2007, the longest study of an Ozark hellbender population. The hellbender population declined significantly and hellbenders became typified by non-regenerating wounds. In-river habitat changes included benthic microhabitat alterations associated with redistribution of gravel, siltation, and sedimentation. Nuisance vegetation, including periphyton had greatly increased by 2004 and increased distribution through 2007. Water quality declines included high levels of total coliform bacteria and *Escherichia coli* that surpassed concentrations deemed safe for full body contact. In-river habitat changes corresponded with increased deforestation of the surrounding oak-hickory and oak-pine riparian and upland habitats. We place these results in the context of climatic variation, flooding events, human activity (including increased recreational use of the river and illegal and scientific harvesting of hellbenders), and introduced and reintroduced species. Interacting stressors including deforestation and the resulting in-river habitat changes corresponded with the precipitous decline of the hellbender population.

Utility of riparian buffers to retain salamanders in and along streams of Pacific Northwest moist coniferous forests, USA. Olson, D. (*U.S. Forest Service, USA; dedeolson@fs.fed.us*).

Streamside riparian buffers are mitigation measures in Pacific Northwest forests to address aquatic conservation in areas subject to upslope timber harvest. Aquatic conservation objectives include retention or restoration of instream and streamside conditions for the persistence of aquatic-associated fauna, including amphibians that use both aquatic and terrestrial habitats such as regionally endemic salamander species of the genera *Dicamptodon*, *Rhyacotriton*, and *Plethodon*. In a long-term study initiated in 1994, using a before-after-control-impact approach, the responses of in-stream and stream-bank salamanders to streamside riparian buffer widths with upland thinning were examined in headwater drainages. Instream and streamside animal counts were assessed post-treatment for 10 years after the initial upland thinning treatment, and again after a second-entry thinning harvest was conducted during about year 12 of the experiment. Initially, four widths of riparian buffers were installed for comparison, and during the second thinning, three of these buffers were retained. In addition, during the second entry, several streams were used as a case study of thinning throughout the riparian area with no buffers, yet with greater tree retention in streamside zones compared to uplands. Results show a mix of treatment responses among species over time. This complex study provides insights to managing for retention of salamanders in forest stands with alternative riparian-and-upland management approaches.

The importance of forest habitat connectivity for species of ambystomid salamanders, focusing on the eastern tiger salamander. Titus, V. (*Green Mountain College, USA; vtitus7@mac.com*), Zamudio, K., Bell, R., Becker, C. (*Cornell University, USA; kelly.zamudio@cornell.edu; rcb269@cornell.edu; cgb58@cornell.edu*), Madison, D. (*Binghamton University, USA; dmadison@binghamton.edu*), Green, T. (*Brookhaven National Laboratory, USA; tgreen@bnl.gov*).

Most amphibians use both wetland and upland habitats, but the extent of their movements in upland habitat is poorly known. Fragmented landscapes resulting from anthropogenic habitat modification can have significant impacts on dispersal, gene flow, and persistence of wildlife populations. Therefore, quantifying population connectivity across a mosaic of habitats in highly modified landscapes is critical for the development of conservation management plans for threatened populations. We used radiotelemetry to observe the movements of eastern tiger salamanders, as well as population genetics and GIS to examine regional genetic population structures and potential barriers to migration among remaining populations. Individuals strictly chose refugia in pitch pine/oak forested habitat. We found low genetic diversity and high relatedness within populations. Nonetheless,

landscape connectivity analyses revealed habitat corridors among remaining breeding ponds and molecular estimates of population connectivity among ponds indicate that gene flow still occurs. Further fragmentation of remaining forested habitat will potentially restrict dispersal among breeding ponds, cause the erosion of genetic diversity, and exacerbate already high levels of inbreeding. We recommend the continued management and maintenance of forested habitat corridors to ensure long-term viability of these endangered populations.

Woodland salamanders as metrics of forest ecosystem recovery: a case study from California's redwoods. Welsh, H., Hodgson, G. (*U.S. Forest Service, USA; hwelsh@fs.fed.us; ghdogson@fs.fed.us*).

Woodland salamanders occur in huge numbers in healthy forests in North America where their high abundance and trophic role as apex predators on decomposer arthropods influence nutrient and carbon pathways at the leaf litter/soil interface. Their extreme niche conservatism and low vagility make them uniquely suitable metrics of forest ecosystem recovery. Mill Creek is a 103-km^2 commercially logged redwood watershed where primary forest is being restored. We examined salamanders as metrics of recovery by comparing surface counts and body condition across early seral, mature, and primary forest (never harvested old-growth) stands. We used analysis of covariance with a principal components analysis (PCA)-derived composite landscape covariate to distinguish effects of coastal proximity and advancing succession. Both effects increased California slender salamanders (*Batrachoseps attenuatus*); advancing succession alone increased ensatina (*Ensatina eschscholtzii*). However, means and variances of body condition indices (BCI) were lower for both in older stands. Del Norte salamanders (*Plethodon elongatus*) showed higher BCIs inland but lower BCIs on late seral stands. Modeling of counts and BCIs along environmental gradients associated with succession indicated that increased structural complexity supported larger populations of two of three species, with greater competition within (intraspecific) and among (interspecific) species suggesting greater population fitness directly related to advanced succession.

B-18 Ecology and dynamics of dead wood dependent species at multiple trophic levels – promoting natural pest control in managed forests or increasing hazards?

Organizers: Stephen Pawson (Scion, New Zealand), Kimiko Okabe (Forestry and Forest Products Research Institute, Japan) & Antoine Brin (University of Toulouse, France)

Wood-inhabiting fungi diversity response to management abandonment: a spatiotemporal perspective. Gosselin, F. (*National Research Institute of Science and Technology for Environment and Agriculture, France; frederic.gosselin@irstea.fr*), Voiry, H. (*Office National des Forêts, France; hubert.voiry@onf.fr*), Delabye, S. (*Université Rouen, France; delabyes@gmail.com*), Debaive, N. (*Reserves Naturelle de France, France; nicolas.debaive-rnf@espaces-naturels.fr*), Paillet, Y. (*National Research Institute of Science and Technology for Environment and Agriculture, France; yoan.paillet@irstea.fr*).

One of the important anthropogenic pressures on forest biodiversity comes with harvesting for wood. This is, therefore, no surprise that networks of more or less strict forest reserves have developed worldwide. Saproxylic fungi are known as an ecological group that is sensitive to forest management and that benefits from management abandonment. Little is known however on this relationship in Western Europe, as well as on the strength of this relationship. Based on a nation-wide project comparing the biodiversity of seven ecological groups in managed and unmanaged forest stands, we analyzed the relationship of saproxylic fungi diversity to management cessation based on a quantitative spatiotemporal approach. Management cessation is here analyzed both in time (duration since management abandonment) and in space (distance to the closest stand). Saproxylic fungi diversity showed a strong response to duration since abandonment. We studied the shape of the relationship; in particular, is there a form of long-term stabilization? And is there a space-duration interaction that shapes saproxylic biodiversity?

An early evaluation of restoring natural disturbances in boreal forest landscapes: flat bugs (*Aradus* spp.) as indicators of success. Hägglund, R. (*Swedish University of Agricultural Sciences, Sweden; ruaridh.hagglund@slu.se*).

Industrial forestry and fire suppression has led to reduced structural heterogeneity with subsequent declines of biodiversity in boreal forests. To achieve environmental certification forest companies implement environmental considerations such as tree retention and leaving buffer zones against waters. It would be desirable to practice more active restoration such as prescribed burns and creating artificial gaps in order to improve prerequisites for biodiversity. By using replicated prescribed burns, artificial gap cuts and forest set asides as experimental controls, we tested the efficacy of restoration efforts in maintaining biodiversity. Fungivorous flat bugs, within the poorly studied *Aradus* genus were positively affected by forest fire. *Aradus corticalis*, *A. betulae*, and *A. brevicollis*, which previously were not considered pyrophilous, were exclusively found in burned sites. We suggest that more species of *Aradus* are strongly favored by forest fire than previously known. In contrast to the fire-favored species, *Aradus depressus* was primarily found in stands with artificially created gaps. To maintain multiple *Aradus* species in the landscape our recommendation to forest managers is the use of a diverse restoration toolbox, including prescribed fire and artificial gap creation as part of their management practices.

Combining of aggregated and dispersed retention is effective for conserving deadwood-associated beetles on managed landscapes. Lee, S., Spence, J. (*University of Alberta, Canada; seungil1@ualberta.ca; john.spence@ales.ualberta.ca*), Langor, D. (*Canadian Forest Service, Canada; dlangor@nrcan.gc.ca*).

Deadwood-associated beetles (saproxylic beetles) are a diverse group of organisms known to be vulnerable to traditional forestry activities. Retention of living trees in harvested landscapes has been strongly promoted as a way to conserve forest biodiversity; however, it is not known whether managing the amount and distribution of residual trees in harvest blocks can also meet conservation goals for saproxylic beetles. We sought to understand how dead wood characteristics and variable retention harvesting influence the composition and diversity of saproxylic beetle assemblages in white spruce coarse woody debris in boreal

forests. We compared saproxylic beetle assemblages among two sizes of aggregated retention patches (0.20 and 0.46 ha) within matrices of different dispersed retention levels (clear-cut, 20%, 50%) on the Ecosystem Management Emulating Natural Disturbance (EMEND) experiment, using window and emergence traps. Aggregated patches alone were insufficient to conserve saproxylic beetle assemblages 10 years post-harvest, given blow-down in retention patches with loss of advanced decay stages of dead wood. However, the matrix mattered to some extent, and the combination of aggregated and dispersed retention maintained saproxylic beetle assemblages similar to those in unharvested forest.

Effects of structural and deadwood attributes on the abundance of saproxylic beetles and microhabitats in a silver fir forest, Italy. Lombardi, F., Andrea, S., Tognetti, R., Trematerra, P., (*University of Molise, Italy; fabio.lombardi@unimol.it; sciarretta@unimol.it; tognetti@unimol.it; trema@unimol.it*), Marchetti, M. (*Italian Academy of Forest Sciences, Italy; marchettimarco@unimol.it*), Parisi, F., Chirici, G. (*University of Molise, Italy; francesco.parisi@unimol.it; gherardo.chirici@unimol.it*), Campanaro, A. (*Centro Nazionale Biodiversità Forestale "Bosco Fontana" di Verona, Italy; ale.naro@gmail.com*).

We described forest structural attributes, deadwood characteristics, and microhabitats occurrence, evaluating their role on the abundance, diversity, and distribution of saproxylic beetle fauna. The study was done in Central Apennines (Italy), in a silver fir stand that has been unmanaged for several decades. A systematically aligned sampling method was done on 240 ha, using 50 plots. Data were collected to assess forest structural parameters, microhabitats, deadwood volumes, and decay classes. Saproxylic beetles were sampled using window flight traps and emergence traps; the link between structure-based indicators and saproxylic species was then analyzed. Geostatistical analyses were conducted for highlighting the spatial variability of the parameters investigated and the beetle pattern distributions. With the aim of describing the complex saproxylic ecological network, the species of beetles were classified according to the type of interactions with wood and other insects and to trophic levels. Results showed how the saproxylics are influenced by the deadwood amounts, size and decay, but also by the forest complexity and microhabitats. The results implied the importance of deadwood traits and microhabitat amounts as monitoring tools for preserving biodiversity. New indicators, such as microhabitats, should be implemented in the traditional forest inventory approaches as a measure of nature conservation.

Exploring the connection between arthropod-accelerated wood decay and forest productivity. Ulyshen, M. (*U.S. Forest Service, USA; mulyshen@fs.fed.us*).

Efforts to quantify the ecosystem services provided by arthropods associated with dead wood are surprisingly few given the diversity of these organisms and their threatened status in some parts of the world. I conducted two field studies aimed at 1) quantifying the contributions of termites (*Reticulitermes* spp.) and other insects to wood decomposition in seasonally flooded and unflooded forests, and 2) exploring the relationship between insect-accelerated wood decay and tree growth in young loblolly pine (*Pinus taeda* L.) plantations in the southeastern United States. The findings from the first study indicate that insects accelerated wood decay significantly and to a similar extent in both flooded and unflooded forests, with approximately 20.5 and 13.7% of specific gravity loss after 31 months being attributable to insect activity in the respective forest types. The rationale and methodology for the second study will be discussed and the results from the first 2 years of data collection will be presented. Finally, the implications of these findings with respect to the value of woody debris and associated insect biodiversity to forest productivity will be considered.

Effect of climate change and wood properties on fungal decomposition: comparison between kelo (old growth) and managed boreal Scots pine. Venugopal, P., Kouki, J. (*University of Eastern Finland, Finland; venugopa@student.uef.fi; jari.kouki@uef.fi*), Junninen, K. (*Metsähallitus Natural Heritage Services, Finland; kaisa.junninen@uef.fi*), Linnakoski, R. (*University of Helsinki, Finland; riikka.linnakoski@helsinki.fi*), Edman, M. (*Mid-Sweden University, Sweden; Mattias.Edman@miun.se*).

Boreal forests, particularly old growth forests, which are key global carbon stores, are not carbon neutral as previously presumed, but carbon sinks. Boreal organic decomposition, chiefly carried out by fungal decomposers, has the ability to produce feedback between climate and global carbon cycle. However, the impact of environmental changes and underlying ecological mechanisms on carbon storages in boreal forests are still largely unknown. The primary objective of the study was to investigate the effect of climate and wood properties on coarse woody decomposition in boreal forests. Heartwood samples from kelo (very old standing dead pine) and managed Scots pine trees were decayed in climate chambers, using saprotrophic polypore fungi, at four different high-low combinations of temperature and humidity values, based on predicted boreal climate. Initial results measured using mass-loss method indicates that climate change and wood quality have an impact on fungal wood decomposition. These topics will be discussed in detail and results will be presented for the final paper. The results are crucial to understand the role of boreal forests in mitigation and adaptation to the predicted climate change and also to understand the poorly explored relationships between climate change, biodiversity, dead woody biomass, and carbon and nutrient dynamics.

Colonization and extinction rates in deadwood substrates and their role in conservation and restoration. Work, T. (*Université de Québec à Montréal, Canada; work.timothy@uqam.ca*).

Loss of downed deadwood poses significant risks for saproxylic organisms and can lead to significant long-term impacts such as extinction debts. We calculated colonization and extinction rates for 931 beetle species collected from six types of spruce deadwood that were placed in clearcuts, managed forests, and old-growth forest reserves in northern Sweden. We found that extinction rates were generally higher than colonization rates, which we expected in decomposing substrates. Inoculation of spruce deadwood with brown rot reduced overall colonization rates while extinction rates were generally lower in substrates placed within clearcuts. While we initially expected to see trophic differences in colonization and extinction rates; with fungivores having increased colonization versus extinction rates, particularly within inoculated logs, and cambium feeders having reciprocal responses, we observed no consistent patterns among these trophic groups. We interpreted species whose extinction rate equaled or exceeded colonization rates to be declining species which may be lost in the future as part of an extinction debt.

B-19 Forests, roots and soil carbon

Organizers: Cindy Prescott (University of British Columbia, Canada), Douglas Godbold (University of Natural Resources and Life Sciences, Austria), Heljä-Sisko Helmisaari (University of Helsinki) & Shalom Daniel Addo-Danso (Forestry Research Institute of Ghana & University of British Columbia, Canada)

The relationship between fine root and litterfall dynamics across various types of temperate deciduous and coniferous forests. An, J. (*Kyoto University, Japan; jiyoung.an.63c@st.kyoto-u.ac.jp*), Park, B. (*Chungnam National University, Republic of Korea; bbpark@cnu.ac.kr*), Osawa, A. (*Kyoto University, Japan; aosawa@kais.kyoto-u.ac.jp*), Park, G. (*Korea Forest Research Institute, Republic of Korea; graceh03@snu.ac.kr*).

We have little understanding of the relationship between litterfall and fine root dynamics in temperate forest ecosystems, even though these are major components in carbon and nutrient cycling. We studied litterfall, fine root biomass, and production in five deciduous and four coniferous forests at the Gwangneung Long Term Ecological Research Site in Korea. We used ingrowth cores to measure fine root turnover for 2 years. Collected roots were divided into living and dead roots of <0.5, 0.5–1, 1–2, and 2–5 mm in diameter. Litterfall was separated into leaves, twig, bark, seed, and others and all leaves were further separated by species. Our preliminary results show that fine root turnover rate was 1.68/year for deciduous forests and 2.07/year for coniferous forests. Annual fine root (<2 mm) production ranged from 47 to 335 g/m^2 in the first year and from 138 to 490 g/m^2 in the second year. The annual litterfall production ranged from 340 to 597 g/m^2. For further research, we will test the relationships between the fine root production, litterfall production, and environmental variables and the contribution of fine root and litterfall to nutrient dynamics by forest types.

Tree root systems and nutrient mobilization: mineral weathering by rhizospheres and deep roots. Boyle, J. (*Oregon State University, USA; forsol40@comcast.net*), Harrison, R. (*University of Washington, USA; robh@uw.edu*), Raulund-Rasmussen, K. (*University of Copenhagen, Denmark; krr@life.ku.dk*), Zabowski, D. (*University of Washington, USA; zabow@u.washington.edu*), Stupak, I., Callesen, I. (*University of Copenhagen, Denmark; ism@ign.ku.dk; ica@ign.ku.dk*), Hatten, J. (*Oregon State University, USA; Jeff.Hatten@oregonstate.edu*).

Roots mobilize nutrients via deep penetration and rhizosphere processes inducing weathering of primary minerals. These contribute to C transfer to soils and to tree nutrition. Assessments of these characteristics and processes of root systems are important for understanding long-term supplies of nutrient elements essential for forest growth and resilience. Research and techniques have significantly advanced since Olof Tamm's 1934 base mineral index for Swedish forest soils, and basic nutrient budget estimates for whole-tree harvesting systems of the 1970s. Recent research in areas that include some of the world's most productive intensively managed forests, including Brazil and the Southeast and Pacific Northwest regions of the United States, have shown that root systems are often several meters in depth, and often extend deeper than soil is sampled. Large amounts of carbon are also sometimes stored at depth. Other recent studies on potential release of nutrients due to chemical weathering indicate the importance of root access to deep soil layers. Release profiles clearly indicate depletion in the top layers and a much higher potential in B and C horizons. Review of evaluations of potential sustainability of nutrient supplies for biomass harvesting and other intensive forest management systems will advance understanding of these important ecosystem properties, processes, and services.

Tree species identity influences the accumulation of recalcitrant deep soil carbon. Godbold, D., Ahmed, I. (*University of Natural Resources and Life Sciences, Austria; douglas.godbold@boku.ac.at; iua@dhaka.net*), Smith, A. (*Bangor University, UK; a.r.smith@bangor.ac.uk*).

Using an acid hydrolysis approach, easily degradable labile and recalcitrant C pools in soils from single and mixed tree stands of *Betula pendula*, *Alnus glutinosa*, and *Fagus sylvatica* and adjacent grassland were determined, in relation to leaf litter inputs and fine root distribution and turnover. The vertical distribution and turnover of fine roots did not differ between species planted in monoculture or polyculture. In the upper layers, no significant differences in C storage or fractionation pools were found between the treatments; however, in the deeper soil layers, the greatest storage of recalcitrant C was found in the polyculture. The C storage in the polyculture soil at depth was significantly greater compared to the *B. pendula*, *A. glutinosa*, and grassland soil, but not statistically different compared to *F. sylvatica*. In the lower soil profile, both *F. sylvatica* and the polyculture had a statistically higher C storage in the recalcitrant pool compared to under grass. In the grassland soil, only 17% of the total recalcitrant C pool was accumulated within the 40- to100-cm layer, whereas in *F. sylvatica* and the polyculture soils, 53% of the total recalcitrant C pool was determined.

Revaluating the role of roots and mycorrhizal hyphae in belowground carbon and nutrient cycling in forests. Guo, D. (*Chinese Academy of Sciences, China; guodl@igsnrr.ac.cn*).

Fine roots of trees are complex branching structures composed of multiple branch orders. The two to three finest branch orders confined to primary development are truly absorptive roots that turn over quickly. These absorptive roots have much less biomass that that of the entire fine root pool, thus previous estimates of fine root mortality and turnover treating all fine roots as one dynamic unit may have substantially overestimated total absorptive root turnover. Moreover, these absorptive roots contain high concentrations of C and N, contributing to their slow decomposition. The absorptive roots of many tree species also bear abundant root hairs and/or mycorrhizal hyphae, which turn over more rapidly than absorptive roots. These microscopic structures also influence total C and nutrient input into the soil and subsequent soil C sequestration. Reevaluating turnover for absorptive roots and including mycorrhizal and root hair turnover would significantly improve the accuracy of total belowground C and nutrient turnover and subsequent C storage in the soil.

Carbon input into forest soil from below- and aboveground litter in climatically contrasting Norway spruce forests. Helmisaari, H., Leppälammi-Kujansuu, J. (*University of Helsinki, Finland; helja-sisko.helmisaari@helsinki.fi; jaana.leppalammi-kujansuu@helsinki.fi*), Hansson, K. (*Swedish University of Agricultural Sciences, Sweden; karna.hansson@slu.se*), Salemaa, M., Aro, L. (*Finnish Forest Research Institute, Finland; maija.salemaa@metla.fi; lasse.aro@metla.fi*).

Boreal forests are known to store a great amount of global C both in vegetation and in soils, but the contribution of different sources to soil C is poorly known. We determined fine-root and aboveground litter C flux of Norway spruce stands located in a climate gradient from southern Sweden to northern Finland, and related it to climate as well as stand and site characteristics. Tree and understory fine root litter was estimated using soil coring for biomass and minirhizotrons for longevity. Aboveground litterfall was estimated from litter traps and understory litter production from the annual biomass production. Spruce and understory fine root (<1 mm in diameter) litter C inputs were high in the northern sites. The contribution of understory vegetation litter, both below- and aboveground, to the C input into the forest soil was also substantial in the northern sites. Ignoring these C fluxes in ecosystem studies or models leads to serious underestimations of soil C inputs.

The quantity and storage mechanisms of carbon in deep soil horizons of the Pacific Northwest. James, J., Harrison, R. (*University of Washington, USA; jajames@uw.edu; robh@uw.edu*), Devine, W. (*Joint Base Lewis-McChord, USA; wdevine27@yahoo.com*).

Carbon storage has become a major objective in forest management, and soil is the largest sink for C in forest ecosystems. Nonetheless, soil C is overlooked in ecosystem C budgets and underreported in the literature. This has led to a lack of understanding about mechanisms for soil C storage, particularly in subsurface horizons. This paper examines the quantity of soil C to 2.5 m depth in the Pacific Northwest Douglas-fir zone, and investigates mineral-surface adsorption, occlusion in aggregates, and inherent chemical recalcitrance as mechanisms for soil C storage. We demonstrate that 1) on average, 66% of soil C can be found below 0.2 m and >20% below 1.0 m in these soils; 2) mathematical models can help us estimate soil C in deep layers given sampling depths of 1.0 m; and 3) adsorption reactions are the major mechanism for stabilizing soil C in deep layers, especially in soils dominated by noncrystalline minerals such as allophane, imogolite, and ferrihydrite. Whether C enters the soil system via decomposition of forest litter or through root exudates and turnover, a thorough mechanistic understanding of soil C storage is necessary to understand belowground C dynamics and potential for C sequestration.

Relation of fine root vertical distribution to soil carbon in *Cunninghamia lanceolata* forest in subtropical China. Liao, Y., Wang, H. (*Chinese Academy of Sciences, China; liaoyingc@163.com; wanghm@igsnrr.ac.cn*).

The objective of the study was to assess the root mass density (RMD) and root carbon density (RCD), and the relation of their distribution to soil C, in *Cunninghamia lanceolata* forest in subtropical region of China. The vertical root distribution and soil bulk in the 0- to 40-cm soil profile were investigated by a soil excavating method. The roots were classified into non-woody short-lived roots, woody long-lived roots, dead roots, live herb roots, and gross roots. The results showed that soil C content, RMD, and RCD of short-lived roots, dead roots, and herb roots peaked in the 0- to 10-cm soil layer and decreased with soil depth, while RMD and RCD of long-lived roots peaked in the 10- to 20-cm soil layer. Soil C and soil N had strong correlation with each other ($P < 0.01$) in the three soil layers. RMD and RCD of herb roots and dead roots were positively correlated with soil C in the 0- to 10- and 10- to 20-cm soil layers ($P < 0.1$), while RMD and RCD of short-lived roots and long-lived roots had strong correlations to soil C in the 10- to 20-cm soil layer. However, the distribution of RMD and RCD of gross roots had a strong correlation with soil C in each soil layer.

Estimates of forest fine root productivity based on functional classification of fine roots and root traits. McCormack, M., Guo, D., Tian, J., Jingyuan, W. (*Chinese Academy of Sciences, China; mltmcc@gmail.com; guodl@igsnrr.ac.cn; tianj@igsnrr.ac.cn; wangj@igsnrr.ac.cn*).

Carbon flow into soil through the turnover of fine root biomass in most forest ecosystems is thought to range from 10 to 60%, with 33% serving as a de facto best guess in many cases. Most previous estimates have been based on the assumption that fine roots consist of a single class of roots with relatively fast turnover times of a few months to a few years. However, recent studies have highlighted a clear functional divide within traditionally defined fine roots with the most distal roots being active in resource acquisition and having fast turnover times and more proximal fine roots functioning more as storage and transport structures with slower turnover times. We conducted a rigorous characterization of ephemeral and persistent fine root biomass and estimated the total flow of carbon through fine root turnover on a species-specific basis in a diverse, northern temperate forest in northeastern China. Our results generally indicate lower estimates of annual carbon loss through fine root turnover than previously expected. We discuss these findings and their implications for leftover carbon and carbon allocation to root exudation and mycorrhizal fungi.

Applicability of mesh methods to the estimates of fine root production in forest ecosystems. Ohashi, M. (*University of Hyogo, Japan; ohashi@shse.u-hyogo.ac.jp*), Hirano, Y. (*Nagoya University, Japan; yhirano@nagoya-u.jp*), Noguchi, K. (*Forestry and Forest Products Research Institute, Japan; kyotaro@affrc.go.jp*), Ikeno, H. (*University of Hyogo, Japan; ikeno@shse.u-hyogo.ac.jp*), Finér, L. (*Finnish Forest Research Institute, Finland; leena.finer@metla.fi*), Nakano, A. (*University of Hyogo, Japan; aiko.na0518@gmail.com*).

Determination of fine root production is important for estimation of carbon storage and understanding the mechanisms of carbon cycling in forest ecosystems. The mesh sheet method is one of the most recent techniques for measuring fine root production. However, the methodological protocol is still uncertain; for example, no study examined the effects of mesh materials and physical properties on the results. In this study, therefore, we aimed to compare fine root production estimated by mesh methods using different mesh materials with different mesh sizes and hardness in forest ecosystems. We prepared four different mesh materials (stainless, polyamide, polyethylene, polyester) whose hardness was separated into two classes (soft, hard). Two different sizes (2 and 4 mm) were used for the mesh sheet made by polyester. The estimated value of fine root production was 7 ± 7 g/m^2/year in a Japanese cedar forest in Japan and 71 ± 65 g/m^2/year in a tropical rainforest in Malaysia. We could not find

any clear impact of mesh material, size, and hardness on the estimates. This suggests that mesh sheet method is widely applicable, which would make the comparison of fine root production estimated by this method comparable among different forest ecosystems in future.

The burial of aboveground woody debris: an important source of soil carbon. Stokland, J. (*Norwegian Forest and Landscape Institute, Norway; jogeir.stokland@skogoglandskap.no*), Moroni, M. (*Forestry Tasmania, Australia; Martin.Moroni@forestrytas.com.au*), Okabe, K. (*Forestry and Forest Products Research Institute, Japan; kimikook@ffpri.affrc.go.jp*), Hagemann, U. (*Leibniz Centre for Agricultural Landscape Research, Germany; Ulrike.Hagemann@zalf.de*), Morris, D. (*Ministry of Natural Resources, Canada; Dave.M.Morris@ontario.ca*), Shaw, C. (*Canadian Forest Service, Canada; Cindy.Shaw@NRCan-RNCan.gc.ca*), Harmon, M. (*Oregon State University, USA; mark.harmon@oregonstate.edu*), Merganic, J., Merganicova, K. (*Technical University Zvolen, Slovakia; j.merganic@forim.sk; merganicova@tuzvo.sk*), Fenton, N. (*Université du Québec en Abitibi-Témiscamingue, Canada; nicole.fenton@uqat.ca*).

Buried wood from aboveground parts of trees is a common, yet poorly studied source of soil carbon. Downed trunks are frequently overgrown by ground vegetation before complete decomposition and they become incorporated into forest soils. This study gives an overview of published and unpublished buried wood studies from 11 countries across North America, Europe, Asia, and Australia. Buried wood is particularly common in boreal coniferous forests. The probability of wood burial is affected by wood dimension, decay stage, rot type, ground vegetation, and soil type. Coniferous forests with a dominant and active bryophyte layer represent conditions where large amounts of buried wood have been recorded (20–935 m^3/ha). The bryophyte layer and bryophyte-derived organic soils lower soil temperature and enhance soil moisture to the extent that below-ground wood decay rates are significantly reduced as compared with aboveground decay rates. Wood decomposition is further slowed down by paludified (poorly drained) soil. The long-term preservation can accumulate subterranean dead wood amounts that greatly exceed those above ground. The widespread occurrence of bryophyte-dominated as well as paludified forests, especially in the boreal zone, suggests that carbon dynamics of dead wood should be revised and updated to include below-ground decomposition rates.

Posters

Methods for quantifying root dynamics for forest carbon studies: a review. Addo-Danso, S. (*Forestry Research Institute of Ghana and University of British Columbia, Canada; shalomdanso@hotmail.com*), Prescott, C. (*University of British Columbia, Canada; cindy.prescott@ubc.ca*).

Belowground components including coarse (>2 mm) and fine (≤2 mm) roots are key components of forest biomass and productivity, as well as the biogeochemical cycle. Despite the critical roles they play, roots and other belowground components have been understudied compared to the aboveground components due mainly to technical difficulties and methodological challenges. There is no consensus regarding fine roots about how root dynamics (biomass, production, turnover, and mortality) can be estimated, and which method is the most suitable. Critical evaluations of the assumptions, strengths, and inherent limitations associated with the various methods are required to inform investigators about the conditions for which a particular method should be preferred. From literature the use of indirect methods such as allometric equations are widely accepted as a cost-effective and reliable means to estimate coarse root biomass and production, although most are not validated. The use of the ground-penetrating radar (GPR) to quantify root biomass looks very promising for future carbon studies. The sequential coring and ingrowth methods still remain the preferred choices for estimating fine root biomass, production, and turnover. Indirect methods like the stable or isotopic radiocarbon are becoming very important due to their increased use in global carbon models.

Response of autotrophic and heterotrophic soil respiration to long-term management in tree-based and treeless grassland ecosystems. Adewopo, J. (*University of Florida, USA; adewopo@ufl.edu*).

We assessed changes in total soil respiration (R_S) and its components (autotrophic, R_A and heterotrophic, R_H), after >22 years of managing a gradient of pine-bahiagrass silvopasture, bahiagrass-pasture, and reference native-rangeland ecosystems. Using an EGM-2 soil respiration chamber, we measured in-situ R_S, R_A, R_H, and critical control factors (soil temperature and moisture) for 12 weeks in winter (January to March) and summer (May to August). Relative to baseline native-rangeland, R_S, R_A, and R_H did not change in silvopasture during the winter and summer (difference ~0.02–0.04 g $CO_2/m^2/h$; $P > 0.05$), but a significant increase (up to 0.68 g $CO_2/m^2/h$ in R_S) was observed in bahiagrass-pasture during the summer. Similar to R_S and R_A, temperature-sensitivity (Q10) of R_H generally decreased from native-rangeland to bahiagrass-pasture (1.65 to 1.44) during winter, but increased in the same order during the summer (1.48 to 2.29). However, compared to reference native-rangeland, bahiagrass-pasture became less sensitive to the joint effects of temperature and moisture during winter ($r^2 = 0.71$ and 0.95), while silvopasture became less sensitive in the summer ($r^2 = 0.23$ and 0.51). Overall, our findings suggest that tree-grass integrated silvopastures may reduce soil C loss through respiration during warmer period, but loss may be accelerated in bahiagrass-pastures.

Soil respiration across different scales and successional time scales in boreal mixedwood forests. Akande, O. (*University of Alberta, Canada; oluwabun@ualberta.ca*).

Carbon dioxide (CO_2) is a major greenhouse gas that is rapidly increasing in the atmosphere, mostly as a result of anthropogenic emissions. The second largest store of carbon in the world is the soil, surpassed by that of the deep ocean. Boreal forests have the ability to capture and store large quantities of carbon dioxide. The first objective of this research is to compare the spatial variability of large-scale soil respiration to that of fine-scale soil respiration. The second objective is to partition soil respiration in the field into autotrophic and heterotrophic respiration, determining how scale affects the partitions individually. The third objective is to determine the relationship between biodiversity and soil respiration. The total soil respiration along with its heterotrophic and autotrophic partitions was measured during the growing seasons from 2012 to 2014. These results will be useful in climate change studies to understand how soils respire with various scales and timelines. We need to understand how CO_2 is cycled through the ecosystem to create adaptation and mitigation plans by offsetting soil-CO_2 efflux through anthropogenic global warming.

Temporal and spatial variability of soil carbon flux in longleaf pine forests in the southeastern United States. ArchMiller, A., Samuelson, L. (*Auburn University, USA; aaa0013@auburn.edu; samuelj@auburn.edu*).

Longleaf pine (*Pinus palustris* Mill.) is being restored in the southeastern United States for many ecosystem services. Little is known about longleaf pine soil respiration (R_S), the largest flux of carbon dioxide from forests. This research included three studies that together aimed to 1) quantify and predict soil carbon flux (R_S) in longleaf pine forests; 2) determine factors controlling temporal and spatial variability in R_S, such as litter biomass, vegetative cover, forest structure, soil characteristics, and root biomass; and 3) partition R_S into its heterotrophic component. Soil respiration ranged from 12.1 to 14.2 Mg C per hectare per year in longleaf pine forests ranging in age from 5 to 87 years old. Soil temperature accounted for 63 to 81% of the temporal variation in R_S over an annual cycle but demonstrated little to no effect on R_S spatial variation. More than 70% of the spatial variation in longleaf pine R_S was accounted for by soil carbon and moisture, buried coarse woody debris, basal area, and litter biomass. The heterotrophic component of soil respiration was estimated to be 76–84% of R_S. This presentation will also discuss the implications of this research for longleaf pine carbon sequestration.

Foliage and root contribution to SOC pools in Utah forest soils. Boca, A., Van Miegroet, H. (*Utah State University, USA; ntr@inbox.lv; helga.vanmiegroet@usu.edu*).

Prior research has shown that in semi-arid montane sites in Utah, soils under aspen store more soil organic carbon (SOC) than those under adjacent conifer stands, and that the SOC under aspen is more stable. Some authors have suggested that root-derived C is more stable in soils, in part the result of intrinsic chemistry and protection of in situ rhizodeposition. However, foliage-derived dissolved organic carbon (DOC) can be stabilized through adsorption to mineral surfaces. To investigate whether foliage or root C is preferentially stored in soils under both overstory types, we compare the presence of foliage and root biomarkers (plant biopolymers representative for foliage and roots) in SOC from mineral soil (0–50 cm) sampled under adjacent aspen and conifer stands. We hypothesized that in Utah forests, foliage C would move downward as DOC during snowmelt causing a decline in foliage C biomarkers with depth, whereas the relative abundance of root C biomarkers was more likely to follow root distribution. In supplementary laboratory study, we investigated differences in adsorption between root- vs foliage-derived DOC in surface and deep soils. Results from ongoing experiments will be presented.

Morphological plasticity and biomass allocation in two provenances of *Abies holophylla* seedlings under different nitrogen fertilization regimes. Chai, Y., Xu, C. (*Beijing Forestry University, China; chinacacy@163.com; cyxu@bjfu.edu.cn*).

Under the greenhouse conditions, the effects of different fertilization regimes on root and shoot morphological plasticity and biomass production of two provenances of *Abies holophylla* Maxim. (Fengcheng and Xinbin) seedlings were examined for one growing season. Seedlings were raised under three fertilizer rates (30, 60, or 90 mg N/seedling/season) and two application schedules (conventional fertilization, C, and exponential fertilization, E) for 10 weeks. The results showed that both provenances with seedlings fertilized in the conventional way developed significantly longer stems and more secondary lateral roots. The value increased as the nitrogen rate increased. We expected that for both provenances, roots would contribute more carbon to growing media when more fertilizer was provided. However, for Fengcheng seedlings with different fertilizer rates, the trend decreased to the 90E treatment. The root mass ratio increased in the early stage, but decreased in the late growing season. For Xinbin seedlings with different fertilizer rates, the total biomass increased from 30E to 90E, but there was no significant difference between 60E and 90E. Root mass ratio continued to increase during the whole growing season. The value of root mass ratio and coefficient of variation were higher for Xinbin than Fengcheng seedlings. In conclusion, roots were more sensitive to fertilizer rate. Xinbin seedlings showed stronger adaptability when fertilized in the range of 30–90 mg N and additional fertilizer contributed to the soil carbon.

Spatial distribution of root biomass of *Pinus massoniana* plantation in Three Gorges Reservoir Area, China. Cheng, R., Xiao, W., Xiao, W. (*Chinese Academy of Forestry, China; chengrm@caf.ac.cn; xiaowenf@caf.ac.cn; chengrm@yeah.net*).

The horizontal and vertical distribution of root (0–10 mm diameter) biomass for three *Pinus massoniana* plantations of different ages (20, 30, and 46 years old) in the Three Gorges Reservoir area, Hubei Province, China, was studied. Ten-centimeter-diameter soil cores were collected at different horizontal distances (0.5, 1.0, 1.5, and 2.0 m) from the stem. Each soil core was separated into five sections at depths of 0–10, 10–20, 20–30, 30–40, and 40–60 cm. Roots (0–10 mm) were first separated into living and dead roots, then were classified into two categories: fine roots (0–1 mm and 1–2 mm) and coarse roots (2–5 mm and 5–10 mm). Our results indicated that the total root biomass (≤10 mm diameter) for *P. massoniana* forest for the 20-, 30-, and 46-year-old stands was 2.40, 4.72, and 2.94 t/ha, respectively, and differences between them were statistically significant ($P < 0.05$). However, the fine root biomass (0–2 mm diameter) declined insignificantly with an increase in forest age ($P > 0.05$). Spatial distribution of fine root biomass was very significantly influenced by soil depth ($P < 0.01$), but effects of stand age and horizontal distance from the tree stem were not significant ($P > 0.05$).

Estimating fine root biomass of *Pinus densiflora* using soil core sampling and minirhizotron techniques. Han, S., Yoon, T., Han, S., Yun, S., Son, Y. (*Korea University, Republic of Korea; aryian@naver.com; bluemirror_@hanmail.net; saerom.han@gmail.com; lucksal7@naver.com; yson@korea.ac.kr*).

This study was conducted to estimate fine root biomass of *Pinus densiflora* using soil core sampling and minirhizotron techniques in Gwangneung, Korea, from May to August, 2013. Conversion factors (g/m^2) between fine root surface area from minirhizotrons and fine root biomass from soil core sampling were developed for the total 0- to 30-cm soil depth (Cal 1: 2 756) and for the three soil depths (Cal 2: 3 242 for 0–10 cm, 2 361 for 10–20 cm, and 2 395 for 20–30 cm, respectively). The relationship between the predicted fine root biomass and the measured fine root biomass was stronger using a single conversion factor (Cal 1, R^2=0.64) than using conversion factors for the three soil depths (Cal 2, R^2=0.81). The predicted fine root biomass data using the conversion factors of Cal 2 was, in general, close to the measured fine root biomass at soil depth on each sampling date. However, the predicted fine root biomass data using a single conversion factor by Cal 1 was underestimated at the top 10-cm soil layer and overestimated at the lower soil layers. The predicted fine root biomass (kg/ha) at the 0- to 30-cm soil depth using the conversion factors of Cal 2 ranged from 3 175.7 (May) to 4 054.4 (July) during the study period.

454 pyrosequencing analyses of mountain forest soils reveal a high fungal diversity and a rapid response to successional stages. La Porta, N. (*European Forest Institute and Edmund Mach Foundation, Italy; nicola.laporta@fmach.it*), Sablok, G., Pindo, M. (*Edmund Mach Foundation, Italy; gaurav.sablok@fmach.it; massimo.pindo@fmach.it*), Squartini, A. (*University of Padova, Italy; andrea.squartini@fmach.it*).

A broad range fungal metagenomics study, using a Roche 454 pyrosequencing platform, was undertaken targeting internal transcribed spacer (ITS) fungal amplicons from six Norway spruce (*Picea abies*) forest soils in the northeastern Italian Alps. In our study, several stands having different bedrock composition (acid, basic, and intermediate) types, facing northern or southern slope exposure, and being in one of four stand age classes such as: gap, innovation, aggradation, and biostatic were investigated to examine the effect of these factors and their combinations on the associated fungal communities. The aim of the project was to assess the overall fungal diversity across a range of different conditions and to rank the shaping forces of different environmental factors over soil fungal community composition. In particular, the analysis determined the extent of conserved taxa and their site specificities across a given geographic range and through a gradient of environmental conditions. More than 330 fungal taxa were identified. Results indicated patterns highly guided by pH as shown by a highly diverse community of acid/north spruce forest in which evenness was higher and successional stages were less evident and did not lead to emerging dominances at mature stages as instead occurred in each of the south-facing forests.

Effects of stand structure regulation on soil labile organic carbon under *Pinus elliottii* plantations. Liu, Y., Tan, G., Li, X., Huo, B., He, M. (*Jiangxi Agricultural University, China; liuyq404@163.com; tgx98101225@163.com; 908319985@qq.com; 540418011@qq.com; 274264518@qq.com*).

This study was conducted in Taihe County, a degraded red soil region in Jiangxi Province. We focused on how plantation type and stand structure affected the contents of soil labile organic carbon (SLOC), by comparing the contents of SLOC analyzed under pure forest of *Pinus elliottii* (I), pure forest of *Pinus massoniana* (II), mixed forest of *P. elliottii-L. formosana* (III), and pure forest of *Liquidambar formosana* (IV). The ranges of the content of dissolved organic carbon (DOC), readily oxidizable organic carbon (ROC), and microbial biomass carbon (MBC) were 52.67–105.17, 6.68–13.33, and 57.70–154.21 mg/kg, respectively. DOC decreased in the following order: IV > III > II ≈ I. The decreasing order of MBC and ROC was IV ≈ III > II ≈ I. The soil DOC, ROC, and MBC significantly increased after structure adjustment in the sixth and ninth years with thinning and planting of broadleaf on the *P. elliottii* plantation compared with the pure *Pinus elliottii* plantation. The results suggest that transformation of conifer monocultures into mixed conifer-broadleaved plantations is an effective means to improve the ecological function of artificial pure coniferous forest.

Different allocation patterns of 18 chemical elements in leaves, branches, and different root branch orders across 18 species in the Gurbantünggüt Desert in China. Ma, Z., Guo, D. (*Chinese Academy of Sciences, China; mazeqing@gmail.com; guodl@igsnrr.ac.cn*).

Plant chemical traits play a vital role in plant functioning, such as growth and defense, and are tightly related to carbon and nutrient cycling in ecosystems. However, little is known about how different chemical traits are allocated across different plant organs. Here, we examined plant organ-chemical traits relationships by analyzing 18 chemical traits (C, N, P, K, Mg, Ca, etc.) in leaves, branches, and different orders of roots across 18 species of different life forms (including spring ephemerals, herbs, shrubs, and trees) in the Gurbantünggüt Desert. We found that plant chemical traits, including plant essential mineral elements (e.g., N, P) and soil-derived metals (e.g., Fe, Al, Pb) showed different allocation patterns in leaves, branches, and different orders of roots across 18 species. Tissue N and P were highest in the distal organs such as leaves and first order roots, but tissue Fe, Al, and Pb were concentrated in roots and diluted in leaves. Plants accumulated some elements in leaves and others in roots. Moreover, these patterns differed systematically between ephemerals, herbs, and trees. These findings suggest that roots play an important role in filtering and selecting nutrients from soil, and different life forms differ in predictable manners in the filtering process.

Fine root turnover within land-use change from primary forest to degraded forest and oil palm plantation on tropical peat. Persch, S., Hergoualc'h, K., Verchot, L. (*Center for International Forestry Research, Indonesia;* s.*persch@cgiar.org; k.hergoualch@cgiar.org; l.verchot@cgiar.org*), Hoelscher, D. (*University of Goettingen, Germany; d.hoelsc@gwdg.de*), Dawson, L. (*James Hutton Institute, UK; lorna.dawson@hutton.ac.uk*), Jourdan, C. (*CIRAD, France; christophe.jourdan@cirad.fr*).

Root turnover is a crucial component of ecosystem and nutrient cycling. However, our current knowledge and understanding is still very limited, especially in regard to tropical forests, which are degraded and deforested at an increasing rate. Among the most vulnerable forest ecosystems to land-use change in the tropics are peat swamp forests. We studied root turnover on tropical peat in Jambi, Sumatra, from October 2012 to September 2013 in a land-use trajectory from primary peat swamp forest (PF) to degraded forest (DF) and oil palm plantation (OP). We used the sequential coring technique, ingrowth nets, and minirhizotrons to estimate root turnover rates. Preliminary results from the sequential coring with the min-max approach suggested that the root turnover rates differed (0.82 ± 0.07/year, 1.32 ± 0.37/year, and 1.01 ± 0.14/year, for the PF, DF, and OP, respectively). These preliminary results indicate that the change of land use from waterlogged conditions to drained soil has an effect on root turnover and carbon input into the soil.

Lateral root distribution of *Eucalyptus camaldulensis* and *Eucalyptus pellita* under different tree spatial arrangements. Reis, G., Ferreira Reis, M. (*Universidade Federal de Viçosa, Brazil; greis@ufv.br; mgfreis@ufv.br*), Contreras-Marquez, C. (*Universidad Centroccidental Lisandro Alvarado, Venezuela; carloscontreras@ucla.edu.ve*), Faria, R., Lopes, E., Baiero, D. (*Universidade Federal de Viçosa, Brazil; ronan.faria@ufv.br; emerson.lopes@ufv.br; diogo.baiero@ufv.br*).

Eucalypt has been planted in Brazil in low tree density stands to produce large diameter logs in consortium with crop or pasture. Tree root distribution is an important variable to be considered in agroforestry systems. Lateral roots were excavated to a depth of 40 cm in 0.5 m × 0.5 m sampling units distributed systematically in one quarter of the area occupied by each tree, in 7-year-old

Eucalyptus camaldulensis and *Eucalyptus pellita* stands, in the savannah region, in Brazil, in several tree spatial arrangements. Root dry matter for every quadrat of 0.5 m × 0.5 m in this area was obtained through interpolation. Coarse roots (diameter >2 mm) decreased sharply with the distance from the tree in all spatial arrangements, being this difference greater for *E. pellita* than for *E. camaldulensis.* Fine roots (diameter <2 mm) distribution was more uniform than for coarse roots for both species in all tree arrangements studied. Average fine roots dry matter was 80 and 136 g/m^2 in the largest (9 m × 9 m) arrangement studied for *E. camaldulensis* and *E. pellita*, respectively. These results indicate that the distance between tree rows in agroforestry systems should be large enough to maintain reduced competition for growth resources with crops or pasture allowing higher production of all components of the system.

Behavior of roots of savanna species in the Pantanal wetlands, Brazil. Salis, S. (*EMBRAPA, Brazil; salis_sm@yahoo.com.br*), Lehn, C. (*Instituto Federal de Educação, Ciência e Tecnologia Farroupilha, Brazil; crlehn@gmail.com*), Mattos, P., Bergier, I., Crispim, S. (*EMBRAPA, Brazil; patricia.mattos@embrapa.br; ivan.bergier@embrapa.br; sandra.crispim@embrapa.br*).

The objective of this study was to determine the maximum depth variation, structure, diameter, and biomass of the roots of common woody species in two savanna physiognomies in the Pantanal wetland, Brazil. The root systems of 37 trees and 34 shrubs were excavated for measurements and estimating the root biomass through the allometric relationship with diameter at soil level. Regression equations to estimate root biomass of the common species were also developed. The root systems of savanna woody species usually range from 3 to 19 m in depth. However, it was observed that these savanna species in the wetland have different behavior. The average length of rooting system in savanna woodland was 0.8 ± 0.3 m and 0.7 ± 0.2 m in open woody savanna. All the regression analyses showed a level of significance of $P < 0.05$ and R^2 values close to or above 0.8. Shorter root systems of lower biomass were observed in comparison to those recorded in well-drained savannas. This was regarded as a response to the water table effect, particularly during the wet season. This effect is important when considering the biomass and carbon stocks of wetland savannas in national and global carbon inventories.

Mycorrhizal communities in *Imperata cylindrical* invaded and non-invaded commercial *Pinus taeda* stands. Trautwig, A., Eckhardt, L. (*Auburn University, USA; antrautw@gmail.com; eckhalg@auburn.edu*), Hoeksema, J. (*University of Mississippi, USA; hoeksema@olemss.edu*).

Pinus taeda comprises >50% of the growing stock in commercial forests, totaling more than 1.2 billion seedlings. *Imperata cylindrica*, a highly noxious weed, has been shown to reduce tree vigor in *P. taeda* plantations. This species is known to produce allelopathic exudates that may influence the community dynamics of *P. taeda* symbionts like mycorrhizal fungi and which have to date not been adequately quantified. In November 2013 and May 2014, roots were sampled at an intensively managed site in Greene County, Mississippi, on Westervelt property in *I. cylindrica* invaded and non-invaded plots. Roots were measured for percent colonization, and then separated by morphotype for molecular analysis of the internal transcribed space (ITS) region. Spatial analyses allowed quantification of the patchiness that is often present in mycorrhizal networks and normalization of data across stands. We will provide a baseline for assessing ectomycorrhizal fungal community dynamics during the stages of invasion, and quantify differences between invaded and non-invaded plots and the ecological effects of some of the absent species in invaded plots (i.e., as it pertains to disease, nutrition, and second degree invasion). We hypothesize that there will be less species diversity in *I. cylindrica* invaded plots due to fewer plant species and allelopathic exudates.

Free air humidity manipulation (FAHM) experiment in Estonia provides new knowledge of climate change effects on northern forests. Tullus, A., Sellin, A., Ostonen-Märtin, I., Kukumägi, M., Hansen, R. (*University of Tartu, Estonia; arvo.tullus@ut.ee; arne.sellin@ut.ee; ivika.ostonen@ut.ee; mai.kukumagi@ut.ee; raili.hansen@ut.ee*), Lutter, R., Tullus, T., Tullus, H. (*Estonian University of Life Sciences, Estonia; reimo.lutter@emu.ee; tea.tullus@emu.ee; hardi.tullus@emu.ee*), Lõhmus, K., Sõber, A., Kupper, P. (*University of Tartu, Estonia; krista.lohmus@ut.ee; anu.sober@ut.ee; priit.kupper@ut.ee*).

Global warming will bring more precipitation in northern latitudes and warmer air can hold more water vapour, meaning that air humidity will increase. The free air humidity manipulation (FAHM) research facility was established in Estonia (58°14′N, 27°18′E) in 2006–2007 to study effects of elevated (*about* 7% over the ambient) atmospheric humidity on the growth and functioning of silver birch (*Betula pendula* Roth) and hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) forests. As expected, under elevated humidity conditions transpiration flux through the trees decreased, which in turn affected soil water potential and mineral nutrient supply to the leaves. Responses to elevated humidity interacted with other climate variables and varied among the studied tree species. Mainly due to differences in belowground production and soil respiration, young forest stands under elevated humidity acted as C sinks, while control plots were C sources after the first 2 experimental years. To conclude, the expected climate-change-induced increase in the growth rate of trees at northern latitudes (boreal areas) due to the earlier start of growing season in spring or higher carbon assimilation rate could be smaller than expected if temperature rise is accompanied by a rise in atmospheric humidity.

Precipitation frequency controls interannual variation of soil respiration in a subtropical forest. Wang, H. (*Chinese Academy of Sciences, China; wanghm@igsnrr.ac.cn*), Wang, Y. (*Tianjin Normal University, China; wangyidong58@gmail.com*).

Forest carbon pool is generally affected by environment fluctuations on an annual scale. However, factors that control the interannual variation of soil respiration (R_S) have not been sufficiently investigated. Interannual variation of R_S was studied using a 6-year data set in a subtropical plantation in China. The results showed that seasonal variation of R_S was significantly affected by soil temperature and soil water content (SWC). R_S in the dry season (July–October) was constrained by seasonal drought. Mean annual R_S was estimated to be 736 ± 30 g C/m^2/year, with a range of 706–790 g C/m^2/year. Although this forest was characterized by a humid climate with high precipitation (1 469 mm/year), the interannual variation of R_S was attributed to the changes of annual mean SWC (R^2= 0.66, P = 0.03), which was affected by annual rainfall frequency (R^2= 0.80, $P < 0.01$) and not rainfall amount (P = 0.84). Consequently, the precipitation pattern indirectly controlled the interannual variation of R_S by affecting soil moisture in this subtropical forest. In the context of climate change, interannual variation of R_S in subtropical ecosystems is expected to increase because of the predicted changes of precipitation regime.

B-20 Radioactive contamination in forest ecosystems and safe uses of forest products

Organizers: Masamichi Takahashi (Forestry and Forest Products Research Institute, Japan), Frédéric Coppin (Institut de Radioprotection et de Sûreté Nucléaire, France) & George Shaw (Nottingham University, UK)

Modelling of radionuclide transfer and ambient dose rates in the Fukushima forest ecosystem: a preliminary study. Gonze, M., Calmon, P., Mourlon, C., Hurtevent, P., Coppin, F., Simon-Cornu, M., Debayle, C., Gurriaran, R. (*Institut de Radioprotection et de Sûreté Nucléaire, France; marc-andre.gonze@irsn.fr; philippe.calmon@irsn.fr; christophe.mourlon@irsn.fr; pierre.hurtevent@irsn.fr; frederic.coppin@irsn.fr; marie.simon-cornu@irsn.fr; christophe.debayle@irsn.fr; rodolfo.gurriaran@irsn.fr*), Thiry, Y. (*National Agency for Radioactive Waste Management (Andra), France; yves.thiry@andra.fr*), Yuichi, O. (*University of Tsukuba, Japan; onda@geoenv.tsukuba.ac.jp*).

The Fukushima nuclear accident in northeastern Japan led to high atmospheric depositions of volatile fission products, such as cesium, iodine, and tellurium isotopes. The radioactive concentrations and ambient radiation levels are particularly high in forest ecosystems, due to the efficient interception of airborne radionuclides by forest canopies. In the next decades, the contamination is likely to be dominated by cesium-137, given its long physical half-life (i.e., 30 years) and its long-term recycling between the abiotic/biotic forest compartments. Accordingly, the long-term management of contaminated forest areas is of great environmental, economic, and social concerns for Japanese authorities. In 2013, French and Japanese researchers launched an integrated environmental project which aimed to better understand and predict the fate and transport of gamma-emitting radionuclides in the forested Fukushima landscape. A special emphasis was put on the long-term processes controlling the cesium-137 cycle within forest ecosystems, and the possible exportation to freshwaters through watershed run-off. The project combines field measurements, from meter to regional scales, in addition to mechanistic modelling of long-term cesium dynamics and ambient dose rates. The overall objectives, modelling approaches, and preliminary results will be presented.

Distribution and migration of radiocesium in the forest ecosystem after the Fukushima Daiichi Nuclear Power Plant accident. Kaneko, S., Akama, A., Ikeda, S., Miura, S., Kiyono, Y., Tanaka, H., Kajimoto, T., Saito, S., Tonosaki, M., Kuroda, K., Takano, T., Takahashi, M. (*Forestry and Forest Products Research Institute, Japan; kanekos@ffpri.affrc.go.jp; akama@ffpri.affrc.go.jp; ikedas@ffpri.affrc.go.jp; miura@ffpri.affrc.go.jp; kiono@ffpri.affrc.go.jp; hirop@ffpri.affrc.go.jp; tkaji@ffpri.affrc.go.jp; stetsu@ffpri.affrc.go.jp; tonosaki@ffpri.affrc.go.jp; kurodak@ffpri.affrc.go.jp; ttakano@ffpri.affrc.go.jp; masamiti@ffpri.affrc.go.jp*).

Forests have been widely contaminated by radiocesium due to the accident at the Fukushima Daiichi Nuclear Power Plant in eastern Japan. To recognize the distribution and behavior of radiocesium in forest ecosystems, we established five plots in three areas with different contamination levels ($^{134}Cs+^{137}Cs$: 10–30, 100–300, and 1 000–3 000 kBq/m^2) in Fukushima prefecture. In summer 2011, radiocesium was distributed at levels of 25–45, 30–43, and 19–28% for tree, litter layer, and surface soil (0–5 cm depth), respectively, for Japanese cedar (*Cryptomeria japonica*) forests, while for Japanese red pine (*Pinus densiflora*) and deciduous hardwood forests, radiocesium was distributed at levels of 18–19, 47–50, and 22–26% for tree, litter layer, and surface soil (0–5 cm depth), respectively. Changes in distribution from 2011 to 2012 involved a decline in radiocesium in the tree and litter layer, while radiocesium in surface soil increased in every forest type. Consequently, more than half the radiocesium was distributed in surface soil at a depth of 0–5 cm in summer 2012. These results suggested that radiocesium was highly captured by the canopy of Japanese cedar forests due to the high leaf biomass, while radiocesium migrated rapidly from the tree canopy and litter layer to the surface soil in 2 years due to washout, litter fall, and decomposition of organic matter.

Managing the irradiated forest of the Chernobyl Exclusion Zone for nature conservation, fire protection, and biomass fuel production. Oliver, C. (*Yale University, USA; chad.oliver@yale.edu*), Zibtsev, S. (*National University of Life and Environmental Sciences of Ukraine, Ukraine; sergiy.zibtsev@nauu.kiev.ua*), LaRoche, D. (*United Nations Environmental Programme, USA; dal1727@gaw.com*), Goldammer, J. (*University of Freiburg, Germany; johann.goldammer@fire.uni-freiburg.de*).

The 260 000 ha of irradiated landscape designated as the Chernobyl Exclusion Zone (CEZ) will remain a health threat even after Confinement II of the failed reactor is completed in 2015. Most of the CEZ contains pine forests on sandy soils that are in imminent danger of burning, creating further problems downwind for crops and inhalation. There are conflicting and controversial future visions for the CEZ. At one extreme is a proposal for intensive harvesting and use of the timber for bioenergy and at the other extreme, a vision of a biodiversity reserve with no management. A balanced approach is being developed by the Global Environmental Facility of the United Nations Environmental Programme using a triad approach. It proposes to combine reserve areas, areas of active management for fire reduction and habitat restoration, and other areas where biomass fuel can be grown intensively and used to produce energy in a safe manner. The approach is expected to accomplish the combined goals of irradiated fire risk reduction, biodiversity protection, carbon sequestration in the forest and, through the use of wood energy, commodity production to pay for the proactive management.

Biogeochemical cycling of radiocaesium in contaminated forest area: an overview. Thiry, Y. (*National Agency for Radioactive Waste Management (Andra), France; yves.thiry@andra.fr*).

Following atmospheric deposition of radiocaesium from the Chernobyl and Fukushima plume, a primary source of forest tree contamination was direct dry or wet interception of aerosol-derived radiocaesium by the canopy, followed by translocation from foliar surfaces to structural components of the tree. Further changes in tree and soil contamination after the initial fallout were due to two main processes. The first was a dominant self-decontamination process of the tree canopy, affected by throughfall and litterfall. This process was rapidly followed by root uptake which continued over time. The long-term radiocaesium cycling in a forest ecosystem is, however, far from a simple formula between soil and tree. Our study aimed to document different forest

peculiarities and influential processes by addressing a series of scientific questions. How significant is the capacity of a forest to recycle radiocaesium? Why is the initial interception of radiocaesium by forest canopy so important? What is the role of forest soil horizons as a sink or source of radiocaesium? What are the natural processes and associated fluxes which control the radiocaesium biological cycling? These different aspects will be illustrated with data gained through complementary field studies (Chernobyl remote zone, Fukushima area, Red Forest) or experimental approaches.

Inside contamination of Japanese cedar tree by radiocesium from the Fukushima Nuclear Power Plant accident. Yoshida, H. (*Tokyo Metropolitan University, Japan; yoshida-hirohisa@tmu.ac.jp*), Ogawa, H. (*Fukushima Forestry Research Center, Japan; ogawa_hideki_01@pref.fukushima.jp*), Hirano, Y., Igei, S., Yokota, K. (*Tokyo Metropolitan University, Japan; hirano-yurika@ed.tmu.ac.jp; igei-shigemitsu@ed.tmu.ac.jp; kahori-yokota@ed.tmu.ac.jp*), Murakami, K., Kumata, A (*Fukushima Forestry Research Center, Japan; murakami_kaori_02@pref.fukushima.jp; kumata_atsushi_01@pref.fukushima.lg.jp*).

The objective of the study was to evaluate the transportation mechanism of radioactive cesium in the ecosystem at Yamakiya, Kawamata, Fukushima prefecture, from 2011 to 2013. The estimated initial radiocesium deposition was 1 568 000 Bq/m^2 (^{134}Cs + ^{137}Cs) in the study area. The sample species from the bark to the pith was obtained by increment borers (12 mm diameter) from the living tree and the sample was cut every 1–2 cm. The concentration of radiocesium in samples under dry states were evaluated by Ge conductor-ray spectrometer SEG-EMS (Seiko EG&G Co. Ltd.). The contamination of the inside of the cedar tree was 100 times lower than that of the bark, and was dependent on the direction and height in 2011. The first stage of inside contamination of the cedar tree was caused by the foliar and bark absorptions. The level of radiocesium in the inner tree was highest in heartwood and phloem in cedar. The radiocesium concentration in heartwood was related to height; however, concentration in the phloem and sapwood was only slightly related to height. In 2012 and 2013, the concentration profile in the horizontal direction of sapwood was similar; however, concentration in heartwood was homogeneous.

Posters

Radiocesium contamination in Satoyama forests in Kashiwa city, a suburb of the Tokyo metropolitan area. Fukuda, K., Kutsuna, N., Terada, T., Mansournia, M. (*University of Tokyo, Japan; fukuda@k.u-tokyo.ac.jp; kutsuna@k.u-tokyo.ac.jp; terada@nenv.k.u-tokyo.ac.jp; mrmansournia@yahoo.com*), Uddin, M. (*Government of Bangladesh, Bangladesh; nz_post@yahoo.com*), Jimbo, K., Shibuya, S., Fujieda, J., Yamamoto, H., Yokohari, M (*University of Tokyo, Japan; jimbo@nenv.k.u-tokyo.ac.jp; sshibuya@nenv.k.u-tokyo.ac.jp; juri09a@nenv.k.u-tokyo.ac.jp; yama@k.u-tokyo.ac.jp; myoko@k.u-tokyo.ac.jp*).

Radioactive cesium contamination caused by the Fukushima nuclear disaster was investigated in forest patches in Kashiwa city, Chiba prefecture, a suburb of the Tokyo metropolitan area. The forest patches we studied were former S*atoyama* woodland, which was historically maintained to provide firewood and other organic materials. Restoration of *Satoyama* can enhance its ecological functions, but radiocesium contamination is a barrier. Air dose rate at 1 m above ground in summer to winter of 2011 was 0.3–0.4 μSv/h, both inside and outside the forest patches. The radiocesium concentration was highest in old leaves of conifers and the outer bark of both conifers and deciduous broadleaves and least in wood tissues; however, radiocesium concentration in some part of the stem wood was above the limit for firewood (40 Bq/kg). Deposition of radiocesium on the aboveground parts of forests was estimated as 5.7 kBq/m^2 in a mixed forest of hinoki and deciduous broadleaves and 3.7 kBq/m^2 in a deciduous oak forest. The total amount of radiocesium above- and belowground was estimated as 60–90 kBq/m^2, which was much higher than the estimation by government through aircraft measurements.

Transportation of radiocesium from forest to agricultural fields. Hirano, Y., Yokota, K. (*Tokyo Metropolitan University, Japan; hirano-yurika@ed.tmu.ac.jp; kahori-yokota@ed.tmu.ac.jp*), Ogawa, H., Kumata, A. (*Fukushima Forestry Research Center, Japan; ogawa_hideki_01@pref.fukushima.jp; kumata_atsushi_01@pref.fukushima.lg.jp*), Yoshida, H. (*Tokyo Metropolitan University, Japan; yoshida-hirohisa@tmu.ac.jp*).

The objective of this study was to evaluate the transportation of radioactive cesium from forest to paddy fields in the ecosystems at Ogami, Kawamata, Fukushima prefecture, where mushroom cultivation was carried out. The dispersion of radiocesium in the forest (24 ha) and the paddy field close to the forest (40 ha) was evaluated. The forest area consisted of two ridges and one ravine with two irrigation ponds. Comparing the depth profile of radiocesium concentration on the ridges and the ravine revealed that the transportation of radiocesium from the ridge to the ravine was mainly caused by the transportation of fallen leaves. The depth profile of radiocesium concentration in the ravine, the irrigation ponds, and the paddy fields indicated that radiocesium existed in the litter layer of post-fallout expanded leaves; water-soluble radiocesium was scarcely observed in the soil and the litter in 2013. The decontamination trial of bark from *Quercus serrate* for mushroom cultivation was also reported.

Seasonal change of radiocesium in different age needles and male flowers of Japanese cedar (*Cryptomeria japonica*) in Fukushima. Kanasashi, T., Takenaka, C. (*Nagoya University, Japan; kanasashi.tsutomu@g.nagoya-u.jp; chisato@agr.nagoya-u.ac.jp*).

Decontamination of radioactive substances from forests is required to recover forestry and to promote residents coming back home to eastern Fukushima. *Cryptomeria japonica* is an evergreen needle-leaved tree and one of the main plantation species distributed widely in the Fukushima region. The needles grow every year from the top of the previous year's needles and the male flowers develop at the top parts of current growth needles. To elucidate accumulation and transportation of radiocesium in trees, we studied the seasonal change of ^{137}Cs in needles of different ages and the male flowers at four sites in middle and north-eastern Fukushima, beginning in 2011. Radiocesium was detected by gamma ray spectrometry using a high purity germanium radiation detector. The specific radioactivity of ^{137}Cs in each part has been obtained from September 2011 and the total activity in each part from December 2012. Because ^{137}Cs was detected in the needles and male flowers grown after the Fukushima accident, radiocesium was transported from the older needles. Needles grown before the accident showed higher specific radioactivity and total activity through all seasons, suggesting that the effects of the direct deposited radiocesium and its absorption had continued.

Radiocesium inventory of forested land in Japan just before the Fukushima Daiichi Nuclear Power Plant accident. Miura, S., Shichi, K., Ito, E., Kaneko, S. (*Forestry and Forest Products Research Institute, Japan; miura@ffpri.affrc.go.jp; shichi@ffpri.affrc.go.jp; iter@affrc.go.jp; kanekos@affrc.go.jp*).

Fallout from nuclear weapon tests in the atmosphere in the 1950s and 1960s dispersed ^{137}Cs across the globe and deposited it on soils. Because ^{137}Cs was deposited at the soil surface, it has been used as a tracer for soil erosion studies. Cesium deposited onto forested land in Japan was expected to be redistributed because of steep mountainous landforms and frequent heavy rains. We examined concentrations and amounts of ^{137}Cs in surface soils (0–5, 5–15, and 15–30 cm in depth) all over Japan just before the accident at the Fukushima Daiichi Nuclear Power Plant. Concentrations of ^{137}Cs in surface soils ranged from below detection limit to >200 Bq/kg and fit a gamma distribution. Cesium concentrations in the upper soil layers were higher than those in lower layers. Amounts of ^{137}Cs retained on forested slopes varied widely; concentrations were lower in cultivated soils. We analyzed the effects of site and environmental factors on physical movement of contaminated surface soils. This information will be valuable in predicting the long-term dynamics of ^{137}Cs derived from the Fukushima radioactive accident.

Predominant factors in the depth profile in forest soil of radiocaesium, released by the Fukushima Daiichi Nuclear Power Plant accident. Niizato, T., Abe, H., Watanabe, T., Ishii, Y., Sasaki, Y. (*Japan Atomic Energy Agency, Japan; niizato.tadafumi@jaea.go.jp; abe.hironobu@jaea.go.jp; watanabe.takayoshi@jaea.go.jp; ishii.yasuo@jaea.go.jp; sasaki.yoshito@jaea.go.jp*).

This paper discusses the predominant factors in the depth profiles of radiocaesium, released by the Fukushima Daiichi Nuclear Power Plant Accident, in forest soil under the evergreen coniferous and broadleaved deciduous forests of the valley-head of mountain area of Fukushima, northeast Japan. The samples were obtained from ridge, slope, and bottomland in the forest by drilling with a soil sampler and scraping with a scraper plate to a depth of about 40 and 20 cm, respectively. The investigation of soil horizons, a tree census, and a topographical survey were also carried out to characterize the study area. The results show that the concentration profile of radiocaesium in the uppermost soil horizon was related to the distribution of depositional and erosional area in the forest; that is, the concentration profile tended to be higher in the depositional area than in the erosional area. Additionally, the decrease in concentration rate from the ground surface to the depth was related to the soil composition, such as organic, clay minerals, and clastics of parent rock. Therefore, not only soil type but also geomorphological aspects should be taken into consideration in the elucidation of the dynamics of radiocaesium in the mountain forests of Fukushima.

Acquisition of radioactive cesium in the stems of trees in Japan. Takano, T., Fujiwara, T., Kuroda, K., Abe, H., Youki, S., Akira, K., Yoshitaka, K., Sugiyama, M., Zhang, C., Tonosaki, M. (*Forestry and Forest Products Research Institute, Japan; ttakano@ffpri.affrc.go.jp; fujiwara@ffpri.affrc.go.jp; kurodak@affrc.go.jp; abeq@affrc.go.jp; youki@ffpri.affrc.go.jp; akagawa@ffpri.affrc.go.jp; kubojima@ffpri.affrc.go.jp; sugicchi@ffpri.affrc.go.jp; chunhua@ffpri.affrc.go.jp; tonosaki@ffpri.affrc.go.jp*).

The accident at the Fukushima Daiichi Nuclear Power Plant in March 2011 caused radionuclide contamination of the surrounding forest. To determine the degree of stem contamination with radioactive cesium, samples of *Cryptomeria japonica*, *Chamaecyparis obtusa*, *Pinus densiflora* and *Quercus serrata* were collected in Fukushima Prefecture from August to November of 2011 and August to September of 2012, respectively. Concentration of radioactive cesium of the bark in 2012 was 60 to 40% of that found in 2011 in all species. This reduction may be due to rainfall and the bark peeling due to the growth of trees. In terms of radioactivity of the wood, no clear differences emerged between the 2011 and 2012 samples. However, while sapwood radioactivity declined, that of heartwood increased, which led to a more uniform concentration of radioactive cesium in wood. In other species, radioactivity was higher in sapwood. These results of radioactivity in wood suggest the radial migration of radioactive cesium toward heartwood in *C. japonica*.

Transport of cesium in Japanese bamboo: perspective on decontamination of radiocaesium from bamboo forests. Takenaka, C., Sugiura, Y., Umemura, M., Kanasashi, T. (*Nagoya University, Japan; chisato@agr.nagoya-u.ac.jp; sugiura.yuki@b.mbox.nagoya-u.ac.jp; i040013b@yahoo.co.jp; kogunkandori@yahoo.co.jp*).

Bamboo forests, important to people as areas supporting various livelihoods like bamboo shoots, were also contaminated with radiocaesium (^{137}Cs) derived from the serious accident of Fukushima Daiichi Nuclear Power Plant in 2011. The decontamination of ^{137}Cs from bamboo forests is an essential task, but is considered difficult because of the existence of a large amount of rhizomes. To propose an effective decontamination procedure for ^{137}Cs, we aimed to clarify the absorption and transport mechanisms of cesium in bamboo. Bamboo samples, such as stem, branch, leaves, and rhizomes, were collected from three moso bamboo (*Phyllostachys pubescens*) forests in Fukushima prefecture. The target bamboos were selected to include stems grown both before and after the accident. Also, we used bamboo samples collected in Aichi prefecture in order to compare the dynamics of stable cesium (^{133}Cs) together with the other elements. We found that the same level of ^{137}Cs was observed in the leaves of stems grown before and after the accident. This result indicated that the uptake ability of old and young bamboo might be similar. In addition, we discuss the difference of cesium transport to the apex of the shoot and the rhizome.

Impact of forest vegetation on long term recycling of radionuclides at polluted sites. Thiry, Y. (*National Agency for Radioactive Waste Management (Andra), France; yves.thiry@andra.fr*).

Forest ecosystems are usually long lived and over time accumulate large amounts of biomass. Forest area can thus act as a biospheric sink for numerous pollutants (atmospheric or underground). In addition, many spoils or contaminated industrial soils are afforested for a return to a better ecologically functional system. The stabilization role of forests has been illustrated from different environmental studies. Still, a remobilization of contaminants is likely in case of vegetation-site-climate equilibrium disruption. The long-term impact of perennial vegetation on pollutant biogeochemistry is usually hardly considered in standard risk assessments. In particular, the role of biota in partitioning processes needs further attention for a complete long-term assessment of the contamination dynamics. This contribution aims at deciphering the influence of forest biological cycling in the redistribution of different radioactive contaminants with emphasis on the processes involved. At least four study cases will be envisaged: 1) a vast pine forest highly contaminated with radiocaesium originating from the Chernobyl atmospheric fallout; 2) a

coniferous stand established on uranium-mining debris for stabilization purposes; 3) a new forest in the Chernobyl exclusion zone growing after burial of radioactive matter into trenches; and 4) natural pine stand used to describe and model the chlorine-36 cycle.

Radioactive contamination of aquatic animals in stream impacted by the Fukushima Nuclear Power Plant accident. Yoshimura, M., Akama, A. (*Forestry and Forest Products Research Institute, Japan; yoshi887@ffpri.affrc.go.jp; akama@affrc.go.jp*).

The Fukushima Daiichi Nuclear Power Plant accident emitted radioactive substances into the environment, contaminating a diverse range of organisms. Stream algae, litter, sand substrate, aquatic insects, and fishes are among the organisms that have been impacted. Radioactive cesium concentration in litter and sand substrate was elevated where the atmospheric dose rate in the air was high. Radioactive cesium concentration in algae and aquatic insects varied irregularly; nevertheless, radioactive cesium concentration in aquatic insects in pools was consistently higher than in stream riffles. Contamination by the radioactive cesium differed by species, location, and stream velocity. Contamination of fishes, those used by humans for food, occurred via dietary uptake, and consequently, the degree of fish contamination was diet dependent. This study was undertaken in a limited number of samples and sites, with more extensive studies planned to fully determine the impact of radionuclides on aquatic ecosystems.

Accumulation of radiocesium by higher fungi after the Chernobyl NPP accident. Zarubina, N. (*Institute for Nuclear Research of National Academy of Sciences of Ukraine, Ukraine; zarubina@kinr.kiev.ua*).

The purpose of this research is to study the accumulation of radionuclides by higher fungi after the Chernobyl Nuclear Power Plant (NPP) accident in 1986. Our research has shown that higher fungi accumulated almost all types of radionuclides originating from the accident. They accumulated the long-living ^{90}Sr in much smaller (by 3–4 orders) quantities than ^{137}Cs. One of the major factors that influenced levels of accumulation of ^{137}Cs by fungi was their nutritional type (ecological group). Fungi that belonged to ecological groups of saprotrophes and xylotrophes accumulated this radionuclide in much smaller quantities than symbiotrophic fungi. As a result of the conducted research, it has been established that symbiotrophic fungi store more ^{137}Cs than any other biological organisms in forest ecosystems. Among the symbiotrophic fungi species, species showing the highest level of ^{137}Cs contamination varied in different periods of time since the deposition. We established the existence of two stages in accumulation of ^{137}Cs by higher fungi after the accident on the Chernobyl NPP: the first stage involved the increase in the concentration, and the second involved a gradual decrease of levels of specific activity of this radionuclide.

Carrying out remediation of forest soils with the use of fruit bodies of higher fungi. Zarubina, N. (*National Academy of Science of Ukraine, Ukraine; zarubina@kinr.kiev.ua*), Kireev, S. (*Chernobyl Spetskombinat, Ukraine; kireev@ecocentre.mns.gov.ua*), Zarubin, O. (*National Academy of Science of Ukraine, Ukraine; oleg.zarubin2011@mail.ru*), Bogdan, L. (*Chernobyl Spetskombinat, Ukraine; bogdan.lm@yandex.ru*).

Fungi are the maximum concentrators of ^{137}Cs, which has polluted forest ecosystems since the accident at the Chernobyl Nuclear Power Plant (NPP) in 1986. We researched accumulation of this radionuclide by fungi at different directions and distances from the NPP. Results of our research have shown that the specific activity of ^{137}Cs in fungi, which are concentrators of this radionuclide, at testing areas in the 5-km zone around the Chernobyl NPP reached 1 million Bq/kg of fresh weight, 26 years after the accident (2012). We decided to investigate the possibility of carrying out remediation of soils in forest, using fruit bodies of higher fungi. We began testing at Kopachi, 2 km from the Chernobyl NPP, in 2013. The initial data has shown that the use of fruit bodies of higher fungi for carrying out of remediation of forest soils at Kopachi, at the present stage of development after the accident, was ineffective. Further research in areas with higher levels of pollution of soils by ^{137}Cs is necessary.

Theme C: Forests and Climate Change

C-01 Climate Change: A driver for land-use change and adaptive forest management on six continents

Organizers: J.P. Skovsgaard (Swedish University of Agricultural Sciences), Jean-Michel Carnus (National Institute for Environmental and Agricultural Science and Research, France), Ronald E. McRoberts (U.S. Forest Service), Tod Ramsfield (NRCan-Canadian Forest Service)

Impact of climate change on major forest ecosystem services in Europe. Hanewinkel, M. (*Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland; marc.hanewinkel@wsl.ch*), Nabuurs, G. (*Wageningen University, Netherlands; gert-jan.nabuurs@wur.nl*).

The paper deals with impacts of climate change to European forests. It concentrates on two major ecosystem services: the production function and carbon sequestration. In the first part of the paper, economic consequences of climate change are discussed. Based on the results of a combination of a European-wide species distribution model with a large-scale scenario model and a classical land expectation value model, it shows effects of a potential shift of major tree species on the economic productivity of Europe's forests under changing climatic conditions. The impacts of such a change of the area of productive species like Norway spruce to forest owners and the forest industry are examined. In the second part, potential effects of climate change on the future carbon sequestration of Europe's forests are investigated. Here, first signs of a carbon saturation of forests in Europe are shown, and it is discussed how this trend might further develop under changing climatic conditions. The paper examines especially the limitations of our current understanding, where we have uncertainty over climate change and its impacts, and large uncertainty over adaptive potential of tree species, or adaptive potential of the forest sector in Europe. Approaches to deal with these uncertainties are discussed as well.

Species and populations growth responses to changed climate: implications for adaptive forest management. Leites, L. (*Pennsylvania State University, USA; lpl3@psu.edu*), Rehfeldt, G. (*U.S. Forest Service, USA; jrehfeldt@gmail.com*), Beaulieu, J. (*Natural Resources Canada, Canada; Jean.Beaulieu@RNCan-NRCan.gc.ca*), Joyce, D. (*Ontario Ministry of Natural Resources (retired), Canada; dennis.joyce@vianet.ca*), Cleaves, D. (*U.S. Forest Service, USA; dcleaves@fs.fed.us*).

As climate changes, forest tree species' growth and survival will likely be affected as a result of climatic maladaption. For some species with ample intra-specific genetic variation, the response to changes in climate will be population specific. Understanding and quantifying these responses is crucial because climatically adapted forests are likely to maintain their productivity and the ecosystem services they provide. We model species- and population-level growth responses to changes in climate. To develop these models we use provenance and common garden tests data, which are experiments in spatial climate change where the climate at which the seed source has originated differs from that of the test site. When populations are tested in several sites, genetic differences in growth responses to changes in climate can be elucidated. These, in turn, can inform seed sources selection and transfer guidelines under an adaptive management plan. Our objectives are: 1) to present species- and population-specific models for three conifers, and 2) to discuss and illustrate how these models can be used in forest adaptive management.

Using 3PG to assess climate change impact on the management plan optimization of eucalyptus plantations: case study in Southern Brazil. Palma, J. (*Superior Institute of Agronomy, Portugal; joaopalma@isa.ulisboa.pt*), Lemos, C., Weber, K. (*International Paper, Brazil; Cristiane.Lemos@ipaper.com; Karla.Weber@ipaper.com*), Hakamada, R. (*University of São Paulo, Brazil; rodrigo_hakamada@yahoo.com.br*), Estraviz, L. (*, Universidade de S Paulo-ESALQ, Brazil; luiz.estraviz@esalq.usp.br*).

Management optimization of resources is a common practice in paper industry managed plantations, and new forest growth models may help to understand the impact of climate change during the decisions of the optimized processes. An assessment with the model 3PG was taken to evaluate the response of stand growth under climate change. The generated information was supplied to the management plan optimizer allowing climate change impact on the management plan interpretation. The comparison to the current optimized plan shows a variation in different strategic options of the management of this stand, as well as an overall increase of costs between 2–4% and a decrease of cumulated net present value, initially at 15%, but later stabilizing at 6–8%. Although a basic comparison for observing climate change effects, it provides insights on how the decision process may change due to a reduction in biomass production under future climate scenarios. The method used demonstrates the use of physiological models to extract information that can be merged with existing and already implemented empirical models. The methodology may be considered a preliminary alternative to using physiological models, allowing some insight of forest response to different future climate conditions which empirical models are not designed for.

A new paradigm for adaptive management. Rist, L., Felton, A. (*Swedish University of Agricultural Sciences, Sweden; lucy.rist@slu.se; adam.felton@slu.se*), Samuelsson, L., Sandström, C. (*Umeå University, Sweden; lars.samuelsson@philos.umu.se; camilla.sandstrom@pol.umu.se*), Rosvall, O. (*Rosvall Consulting, Sweden; ola.rosvall@gmail.com).*

Uncertainty is a pervasive feature in natural resource management. Adaptive management (AM), an approach that focuses on identifying critical uncertainties to be reduced via diagnostic management experiments, is one favored approach for tackling this challenge. While adaptive management is considered a key method in the environmental manager's toolbox, there remains a lack of clarity over when its use is appropriate or feasible. Its implementation is often viewed as suitable only in a limited set of circumstances. Here we restructure some of the ideas supporting this view and show why much of the pessimism around AM may be unwarranted. We present a new paradigm for adaptive management that shows that there are no categorical limitations to its appropriate use, the boundaries of appropriate application being defined by problem conception and the resources available to managers. We also separate adaptive management as a management tool from the burden of failures that result from the complex

policy, social, and institutional environment within which management occurs. Decisions about implementation however, must be made in the context of broader considerations, for example stakeholder interests or societal values. Thus we set this new paradigm in the context of broader institutional features and governance processes.

Socio-economic and policy issues of climate change for forests in Asia. Vira, B. (*University of Cambridge, United Kingdom; bv101@cam.ac.uk*).

The governance of forests in large parts of Asia, especially the Indian sub-continent and South East Asia, has undergone significant changes in the decades since the early 1990s. Most significantly, countries in the region have pioneered innovative forms of participatory and inclusive forest governance, seeking to involve a wide range of stakeholders in management regimes. These new institutional structures have been associated with greater recognition of the forest rights of the poorest and most vulnerable groups, and have responded to pressures from civil society for more equitable and just forest governance. The likely impacts of climate change on these structures of governance remain uncertain. This paper explores concerns about the ways in which greater recognition of the role of forests in carbon sequestration and storage might result in a re-centralization of control over forests, undermining the participatory regimes that have evolved over the last couple of decades, threatening the livelihoods of the forest-dependent poor. It also discusses the impacts of new structures of global monitoring, reporting, and verification, and the ways in which these will interact with existing and proposed community-level systems for forest management and control.

Posters

Scenarios of future climate for the Camagüey province, Cuba: possible influence on the forest plantations of mediterranean distribution. Acosta, L. (*Instituto de Investigaciones Agroforestales, Cuba; ccforestal@ciget.camaguey.cu*), Rivero, Z. (*Centro Meteorológico Provincial de Camagüey, Cuba; roger@cmw.insmet.cu*).

Using climatic observations taken by the six operational meteorological stations belonging to the province of Camagüey, mean monthly values of precipitation, maximum, minimum, and ordinary temperature for the period 1976–2005 were calculated for each station and used to create a reference climate dataset. Changes predicted by the HadCM3 global climate model with greenhouse gas emissions scenario SRES A2 were applied to the climate variables in the reference climate dataset in order to obtain their predicted values for two 30-year periods centered in 2050 (2036–2065) and 2100 (2085–2115). Results obtained show a trend to aridity in the province, given by an increase in mean temperature and a general decrease in precipitation for all scenarios. These conditions could imply a sizable decrease in growth and productivity of most managed species in forest plantations and, at the end of the century, the interruption of the growth period of deciduous species because of a second stage of leave falling every year given the expected increase in magnitude and length of the so-called summer drought.

Sex-related, growth-climate association of *Araucaria angustifolia* in subtropical planted forests in Argentina. Bogino, S. (*State University of San Luis, Argentina; stellabogino@gmail.com*), Montañez Valencia, R., Bravo Oviedo, F. (*University of Valladolid, Spain; colombiaforestal@gmail.com; fbravo@pvs.uva.es*), Fassola, H. (*State Institute of Agricultural Research, Argentina; hfassola@montecarlo.inta.gov.ar*).

The araucaria (*Araucaria angustifolia* (Bertoloni) O. Kuntze) is a dioecious species that dominates Araucaria forests of Brazil and Argentina. Given the critical conservation status of the species, also affected by an average increase in temperature within the context of global climate change, it is rather essential to broaden and deepen the scientific knowledge of the dynamics and relationships between growth and climate. Here, we analyzed sex-related growth climate association of *A. angustifolia* in planted forests in northeastern Argentina. Three sampling sites were established, and standard dendrochronological tests were applied to date 20, 45, and 16 individuals respectively, discriminated by sex. Results showed planting ages of 57, 58, and 38 years. Radial growth curves showed maximum growth in the 10th year being 6.26 mm, the highest average annual radial growth. The mixed linear model showed significant differences ($p<0.001$) between site and parameters (Gompertz model). The dioecy was not statistically significant in comparison to the average growth. July and August precipitation, previous to the growing season, had a significant impact on growth. Finally, these results suggest explanatory models, adding silvicultural and climate variables in the interest of acquiring new management tools in implanted stands.

Opportunities for climate change mitigation through afforestation and reforestation of degraded lands in the Sub-Saharan Africa. Daramola, T. (*University of British Columbia, Nigeria; t.daramola@yahoo.com*).

The continuous expansions of degraded lands have been a major concern in the global discussions on land use land-use change and forestry (LULUCF). Land degradation is caused by various factors, including climatic variations and human activities. The principal causes of land degradation are the unsustainable exploitation of land by pastoral farming, uncontrolled deforestation, and extensive farming activities. Other factors contributing to land degradation include deficiency of forest policy formulation and implementation, most especially in the developing tropical countries. Land is central to development in sub-Saharan Africa, as the livelihoods of about 60% of the population are dependent on agriculture (Vlek and Tamene 2003). With population pressures increasing and the low investments in land conservation, the future health of land is in question. In this study, evidence of land degradation in the sub-Saharan Africa where presented, and the opportunities available for restoration of the degraded lands for a sustainable livelihood, environmental protection, and climate change mitigation where analyzed.

Shelterbelts system of agroforestry improves microclimate, crop yields, carbon sequestration, and mitigates climate change in dry land ecosystem of peninsular India. Honnurappa, S., Palaiah, S., Chavan, R., Visveswaraiah, S. (*University of Agricultural Sciences, Dharwad, India; shivanisir59@gmail.com; psurendra63@gmail.com; rajuchavanuasr@gmail.com; suryanarayana1962@gmail.com*).

Planting of belts of trees rows on borders of farm land is practiced in peninsular India. Six tree species, *Azadirachta indica, Acacia auriculiformis, Casuarina equisetifolia, Dalbergia sissoo, Pongamia pinneta,* and *Tectona grandis* were planted in three

rows with three combinations. Ten-year-old 8 h, north–south oriented shelterbelts of 6.0 m wide and 300 m length have been planted, maintained, and managed since 2003 in the dry land ecosystem of peninsular India. The shelterbelt has improved the microclimate and enhanced crop yields. The tree species have higher carbon sequestration potential leading to mitigation of climate change. The multi benefits on the leeward side of shelterbelts include improved microclimate, increase in crop yields, improved vegetative cover, increased shelter to birds and beneficiary insects, and added aesthetic value to the area. Highest soil moisture was recorded in sheltered area, while lowest was noticed in the open (control). Crop yields increased, largely the result of increased soil moisture and availability of nutrients, lowered plant water stress because of reduced evaporation, and higher relative humidity in the protected area. The highest soil moisture content, leaf area, plant height, chlorophyll content, dry matter production were recorded in leeward side of the shelterbelt as compared to controls. An extensive shelterbelt agri-silvi sisystem is recommended for peninsular India.

Vegetation change in Boundou natural community reserve region of Tambacounda/Senegal from 1974 to 2010. Laurice Codou, F. (*Kwame Nkrumah University of Science and Technology, Senegal; queenlaurice19@yahoo.fr*), Mbow, C. (*World Agroforestry Center* (*ICRAF), Kenya; C.Mbow@cgiar.org*).

Natural community reserves which are the main sources of income for local populations are facing two major constraints: climatic and demographic. The natural reserve of Boundou located in southeast of Senegal is a good illustration of this situation because of its vegetation that is undergoing extreme changes. The main aim of this study is to characterize the land cover dynamic through human activities and climate. The study is based on the exploitation of data from Landsat images from January 1974 (MSS sensor), January 1986 (ETM sensor), and December 2010 (ETM+ sensor). The methodology used is the supervised classification. The mapping of the land cover evolution reveals a dynamic of the different areas. The farm lands and the gallery forest-savannah trees occupied respectively 1 638.76 ha and 38 641.08 ha while savannah shrub and grasses are experiencing a reduction. Household surveys combined with rainfall data were used to determine the major factors of this dynamic correlated with human activities and climate which are tied. The negative changes in the climate are causing adaptation strategies with an unsustainable use of natural resources. Therefore, these adaptation strategies result from the situation of land which itself, is dictated by climate.

C-02 From understanding drivers to gaining leverage at the tropical forest margins: 20 years of ASB Partnership

Organizers: Peter Akong Minang & Elizabeth Kahurani (World Agroforestry Centre, Kenya)

Identifying policy levers of deforestation and recovery of tree cover from the driver analyses: a case study from Indonesia. Dewi, S., Ekadinata, A., Johana, F., Widayati, A. (*World Agroforestry Centre (ICRAF), Indonesia; Sdewi@cgiar.org; aekadinata@cgiar.org; fjohana@cgiar.org; awidayati@cgiar.org*), Minang, P. (*ICRAF, World Agroforestry Centre, Kenya; pminang@cgiar.org*).

Concerns over natural forest cover loss in the tropics have led to enormous volumes of academic researches of drivers of deforestation and various local to global initiatives such as REDD+ strategies. Trajectories and drivers of forest loss and recovery are interconnected and are both crucial in shaping future deforestation and tree cover recovery, but only deforestation is usually addressed. We study three provinces in Indonesia: (i) South Sumatra, with highest gain in area of tree cover recovery, as tree crops, in 2005–2010 compared to the deforested area in 2000–2005; (ii) Jambi, where area of tree cover recovery, mostly as agroforestry system, surpasses the area of natural forest loss; and (iii) Papua, who recently joined the top ten deforesting provinces. Using analytic network process, we studied the importance and interdependencies of predisposing environmental factors, five capitals, demographic, economic, policy and institutional, technological, and cultural driving factors and events that trigger deforestation and tree cover recovery. We collected the data through a series of discussions and interviews with multiple stakeholders, guided by spatial analysis on land use/cover maps. Drivers and levers of deforestation and recovery are compared across the three provinces, and policy recommendations at local, national, and global levels are formulated.

Farmers' learning of private and common values of conservation contracts as determinant for performance-based landscape rehabilitation. Hairu, B. (*World Agroforestry Center, Indonesia; L.Beria@cgiar.org*).

Farmers' willingness and ability to accomplish conservation contracts will ensure achievement of conservation goals. Reverse conservation auction is one of environmental policy tools to reveal farmers' willingness to accept values to rehabilitate their landscape. The design of this auction, by allowing farmers to bid in multiple rounds, enable farmers to experience learning feedback at each round. This learning includes both the process of the auction and farmers' private and common values of performance-based contracts offered by external agents. The hypothesis of this paper was that farmers who have better learning feedback will accomplish the contracts more successfully compared to their peers who do not perform during the auction. This study will contribute to the understanding of how learning and contract value as part of economic incentive will determine an effectiveness of a conservation effort.

Theories of change and change in theory of managing landscapes within the past twenty years. Kanninen, M. (*University of Helsinki, Finland; markku.kanninen@helsinki.fi*).

The 20 years since the 1992 Rio Earth Summit has been characterized by a fight to reverse the development path of the human kind leading to global climate change and loss of biodiversity and other natural resources. In forestry and natural resources sectors, the main focus has been in the fight against forest loss and degradation and in promoting sustainable forest management. However, now we see that wood consumption per capita is decreasing. Is it due to increased efficiency of forest use? It may also be that official statistics don't reveal the whole truth. We are witnessing an ongoing transformation process of landscapes where trees are increasingly grown on farms and small wood lots to meet the market demands for construction wood and fuelwood. This has led to a regreening of landscapes and increased carbon sequestration. Now it is time to revisit our assumptions and theories of

change and analyze if they need to be reoriented. Maybe we need to promote more positive change and focus less in preventing negative change, but are our institutions ready for the task? For instance, in many countries tree farming is still not recognized by forest or agricultural authorities, and both of them have different reasons for not promoting it.

Assessing the drivers of forest degradation and forest change in tropical dry forest landscapes: a case study in Western Mexico. Morales, L. (*Bangor University, Costa Rica; moralesluciacr@gmail.com*), Borrego, A., Skutsch, M. (*Universidad Nacional Autónoma de México, Mexico; armoniab@gmail.com; mskutsch@ciga.unam.mx*).

Understanding the causes of forest degradation along with landowner's decisions on land use is of particular interest for the design of effective forest management that can both benefit people and avoid forest resources depletion. However, our knowledge of the processes and patterns that cause forest degradation and where they are occurring is extremely limited, especially for tropical dry forest. In this study we examined the likelihood of forest cover change and forest losing biomass by combining spatial with social economic data. For this, 300 interviews were undertaken in 30 communal lands within the Ayuquila Basin, Jalisco, which is a typical mosaic forest landscape dominated by shifting cultivation. Through the questionnaires we obtained data on the use of forest areas and forest resources. Detailed forest cover maps using high resolution data for 2004 and 2010 were developed, and ancillary geographical data were used to derived spatial variables. Possible factors influencing forest degradation were combined using a multiple regression model to obtain the probability of change in forest cover and in forest cover density. Preliminary results showed that distance to road, the parcel size, and its location are important factors determining the probability of forest degradation.

Potential for reducing deforestation through agricultural intensification in landscape mosaics in sub-Saharan Africa. Namirembe, S. (*World Agroforestry Centre (ICRAF), Kenya; S.Namirembe@cgiar.org*), van Noordwijk, M. (*World Agroforestry Centre (ICRAF), Indonesia; m.vannoordwijk@cgiar.org*), Minang, P. (*ICRAF, Kenya; p.minang@cgiar.org*).

Expansion of agricultural land has been established as the major driver of deforestation in sub-Saharan Africa. It is likely to intensify with the escalation of demand for agricultural land to produce food for the growing population and to satisfy the rapidly emerging global demand for biofuels. One way of addressing this according to the Borlaug hypothesis is "increasing the productivity of agriculture on the best farmland to control deforestation by reducing the demand for new farmland." Segregation of agriculture and biodiversity conservation therefore can lead to a win-win situation where benefits from both land uses are maximized. It has been established that this rarely holds true on its own and may result in inequitable distribution of resources. Where agricultural landholding is fragmented into small-scale units, as is most often the case, forest loss is mainly diffuse, through the removal of forest patches from the landscape. We compare literature on agriculture intensification initiatives to that of landscape-based initiatives in sub-Saharan Africa between the 1980s and 2010 to assess their potential to reduce forest conversion and overall impact on livelihoods of multiple stakeholders in mosaic landscapes. The objective is to identify approaches that take into consideration other deforestation drivers and underlying causes, leading to overall increase in agricultural productivity without loss of forest mosaics.

Theories of change and change in theory within 20 years of ASB partnership for the tropical forest margins. van Noordwijk, M. (*World Agroforestry Centre (ICRAF), Indonesia; m.vannoordwijk@cgiar.org*), Tomich, T. (*University of California, Davis, USA; tptomich@ucdavis.edu*), Swallow, B. (*University of Alberta, Canada; bswallow@ualberta.ca*), Minang, P. (*World Agroforestry Centre (ICRAF) and ASB Partnership for the Tropical Forest Margins, Kenya; a.minang@cgiar.org*).

With current interest in theories of change as guidance of research and development efforts, we note that during its 20 years of partnership in the tropical forest margins, ASB has changed its overarching theory of change a number of times. Initially framed within the Borlaug hypothesis that intensifying agriculture from its shifting cultivation roots would lead to reduced pressure on forests and lower actual deforestation, the characterization and diagnostic phase in a number of landscapes showed that profitable land use systems, where they emerged could speed up rather than slow down deforestation. Focus shifted to analysis of multiple attributes (trade-off and synergy) of the main land use systems involved in local tree cover transitions. A number of medium-intensity agroforest management systems were found to combine profitability and the provision of environmental services at levels close to natural forest, but required additional incentives (regulatory, economic, recognition) to compete with tree crop monocultures. The opportunity cost to do so might be attractively low in terms of carbon stock. Lessons learned on conflict reduction and incentive mechanism helped subsequently frame approaches to the emerging REDD+ discussion, where ASB pioneered landscape approaches based on reduced emissions from all land uses (REALU).

Assessing sustainability of swidden systems in the tropical forest margins. Yemefack, M. (*International Institute of Tropical Agriculture, Cameroon; myemefack@yahoo.fr*), Porro, R. (*EMBRAPA, Brazil; roberto.porro@embrapa.br*), Niomgang, R. (*Institute of Agricultural Research for Development, Cameroon; rnjomgang@yahoo.fr*), Minang, P. (*World Agroforestry Centre (ICRAF), & ASB Partnership for the Tropical Forest Margins, Kenya; a.minang@cgiar.org*).

Tropical forest margins comprise shifting agricultural landscape mosaics where diverse swidden (slash-and-burn, shifting cultivation) systems provide food and cash crops. These systems sustainability implies that they simultaneously comply with economic, environmental, social, and cultural objectives with a protagonist role of households and communities in adjusting to drivers from proximate to larger contexts along time. With increasing concerns for food security, environmental services, and improved livelihoods, knowledge on the sustainability of each system is key to identifying development objectives and pathways for swidden improvement. Despite recent advances in social and environmental assessment used in the REDD+ framework, methods for providing systematic sustainability for swidden systems are not always readily available. This study presents an analytical framework for suitable assessment of swidden sustainability. The framework is adjusted and adapted from AMBITEC-AGRO, a nested multi-criteria impact assessment platform developed by EMBRAPA through specific applications to traditional and smallholder communities in southern Cameroon and eastern Brazilian Amazon. The framework for social assessment includes 5 aspects, 13 indicators, and 78 components. The procedure was robust to stratified social groups in the studied communities, with reproducible results. This method is expected to work well for studying swidden dynamics in various communities in the tropical forest margins.

C-03 Understanding the relationships among biodiversity, carbon, and people for REDD+ forests: The importance of environmental and social safeguards

Organizers: Ian Thompson (NRCan-Canadian Forest Service), Kimiko Okabe (Forestry and Forest Products Research Institute, Japan), Jae Soo Bae (Korea Forest Research Institute, Republic of Korea) & John Parrotta (U.S. Forest Service)

Analyses of potential livelihood outcomes, farming practices and conflicts in natural resource use under a REDD+ implementation in Ghana. Damnyag, L., Oduro, K., Foli, E. (*Forestry Research Institute of Ghana, Ghana; ldamnyag@yahoo.com; kwameoduro@gmail.com; efoli@hotmail.com*).

Reducing emissions from deforestation and forest degradation (REDD+) mechanism is an important international effort to mitigate climate change effects. REDD+ incentives aim to support forest conservation, help to secure services provided by forests as well as carbon storage and sequestration. However, potential social impacts, risks, conflicts and required changes in farming practices under REDD+ implementation is not fully understood. This paper posits that success or failure of REDD+, at any scale, depends on the possibility of designing interventions that do not harm local populations, and at best lead to favorable joint outcomes of reduced net carbon emissions and improved rural livelihoods. Data, analyzed using frequency, graphs, and averages, was collected from three communities each from three administrative districts in Ghana using questionnaire surveys and focus group discussions. The paper highlights the potential effects of REDD+ implementation on local people's existing land use practices and their control over natural resources, and discusses important strategies to overcome potential negative effects of REDD+ implementation. It concludes by discussing the implications for policy, thus providing valuable inputs to support ongoing national policy debates to halt deforestation, particularly Ghana's policy efforts on reducing emissions from deforestation and forest degradation (REDD+).

Local participation in global conservation: villagers' knowledge and perceptions of incipient REDD+ initiatives. Duchelle, A., Resosudarmo, I., Ekaputri, A., Sunderlin, W. (Center for International Forestry Research*, Brazil; a.duchelle@cgiar.org; d.resosudarmo@cgiar.org; a.desita@cgiar.org; w.sunderlin@cgiar.org*), Jagger, P. (*University of North Carolina, USA; pjagger@unc.edu*).

REDD+ has been proposed as a win-win tool for mitigating global climate change and bolstering local livelihoods. Broadly-accepted REDD+ social safeguards, which focus on doing no harm, promoting good governance and enhancing local benefits, hinge upon local peoples' access to information and meaningful participation in REDD+ design and implementation. In this study, we ask: 1) What determines local knowledge and perceptions of REDD+; and 2) Are REDD+ intervention strategies aligned with local needs? We assessed villagers' knowledge and perceptions of 16 incipient REDD+ initiatives in Brazil, Peru, Cameroon, Tanzania, Indonesia, and Vietnam through structured surveys in 133 villages and 4 275 households. Our results highlight that villagers' knowledge of local REDD+ initiatives was generally low (23%) at the initial stage of design and implementation, yet more knowledgeable households were located closer to village centers and had benefitted from other outside interventions. Villagers' primary hopes and recommendations for REDD+ were focused on income/welfare improvement, which is reflected in the livelihood enhancement activities that have become a centerpiece intervention of many of these initiatives. Based on our analyses, we provide recommendations for ways to genuinely involve local people in global conservation initiatives, such as REDD+, to promote both equity and effectiveness.

Collaborative forest management with effective REDD+ social safeguards: an experience from a national park in East Java, Indonesia. Harada, K. (Nagoya University*, Japan; harada@agr.nagoya-u.ac.jp*), Aliadi, A. (*LATIN, Indonesia; aaliadi@yahoo.com*), Ma, H. (*The International Tropical Timber Organization (ITTO), Japan; ma@itto.or.jp*).

This study investigated inner/outer factors for successful collaborative forest management in a national park and their implications for REDD+ social safeguards such as local participation and benefit sharing. While REDD+ debates primarily focus on national parks owing to forest conservation and plantation, many national parks in Indonesia have been confronting conflicts between governments and communities associated with land/forest resource use and have been experiencing deforestation and forest degradation. The following case from Meru Betiri National Park is a good example of collaborative forest management for REDD+. The national park experienced illegal logging and subsequent land encroachment by local people adjacent to the park in 1998–1999. The park authority in collaboration with an NGO started a rehabilitation program in the bare land with local participation. The local people were allowed to use lands inside the national park for cultivating annual crops, along with the planting of medicinal and fruit trees. The produced crops and fruits could contribute to increase their incomes. Outstanding issues that should be highlighted include 1) how third parties such as NGOs can have constructive dialog and establish collaborative relationships with governments and communities, and 2) how alternative livelihoods can provide economic motivations and a sense of safety.

REDD+ and community adaptive capacity in the Central Highlands of Vietnam. Huynh, T., Keenan, R. (*University of Melbourne, Australia; thubahuynh@gmail.com; rkeenan@unimelb.edu.au*).

The study assesses social vulnerability and how REDD+ interventions could influence resilience and adaptive capacity of communities in Lam Dong province of Vietnam. Survey data from 120 households, four village surveys, and interviews with government officials collected over 3 years (2010–2013) was used to generate livelihood profiles of the local people who are vulnerable to climate related events and to assess the adaptation practices adopted in response to these events. This study also documented REDD+ related activities, especially the benefit distribution systems (BDS), and considered potential links between REDD+ implementation and vulnerability of local communities. The paper concluded that if REDD+ projects and payments are to contribute to reducing social vulnerability and building adaptive capacity of local communities, a focus on poverty and ethnicity in the design of the BDS is important, but not sufficient. In the way it has been implemented in this location, the BDS design may run the risk of increasing vulnerability of some non-indigenous groups and fail to achieve REDD+ goals of reducing emissions from deforestation and. Results are used to offer policy recommendations on the improved design of REDD+ interventions to achieve its objectives as a climate change mitigation option while facilitating longer-term community adaptation.

An assessment of the impacts of the REDD+ pilot project on community forests user groups (CFUGs) and their community forests in Nepal. Maraseni, T. (*University of Southern Queensland, Australia; tnmaraseni@hotmail.com*), Neupare, P. (*Nepal; prem10@hotmail.com*), Casero, F. (*Institute for Global Environmental Strategies (IGES), Japan; Federico@yahoo.com*), Cadman, T. (University of Southern Queensland*, Australia; tim.cadman@usq.edu.au*).

REDD+ has been identified for its potential to reduce greenhouse gas emissions, meet climate stabilization targets and protect biological diversity. Consequently, millions of dollars are being channeled into developing countries that are rich in forests for pilot projects that will provide data for the design of incentive-and performance-based REDD+ projects. This paper evaluates the impacts of REDD+ pilot projects on community forests and associated user groups (CFUGs) in Nepal. An in-depth field study targeted eight CFUGs that participated in a REDD+ pilot project funded by the Forest Carbon Trust Fund in Nepal. Analysis showed that the pilot project enhanced the participation of Dalit, indigenous people, women, and the poor, and could provide some social safeguards. However, it also showed that, if all of the additional costs and foregone benefits of the project are considered, REDD+ is not an attractive market-based option for Nepalese CFUGs. A better approach would be a bi-or-multilateral approach that is not market based but provides incentives beyond environmental and social safeguards. The results of this study will be useful for community forest-based REDD+ stakeholders in developing countries when designing REDD+ policies and programs.

Integrating REDD+ governance: lessons at global, national, and local scales. McDermott, C. (University of Oxford*, United Kingdom; constance.mcdermott@ouce.ox.ac.uk*).

This talk will provide a multi-level assessment of REDD+ governance to date, drawing on developments at international, national, and local scales to assess the relative prioritization of forest carbon emissions reductions and environmental and social safeguards. It will consider how the source of authority (i.e., state-based, fund-based, or market-based) and the scale of the institution influence incentives to adopt a more integrative approach to REDD+ that affords attention to multiple forest values. It will then reflect on the implications of this analysis for future REDD+ governance.

Improved understanding of the role of biodiversity in ecosystem services leads to better REDD forest management. Thompson, I. (*Canadian Forest Service, Canada; ian.thompson@nrcan.gc.ca*), Parrotta, J. (U.S. Forest Service*, USA; jparrotta@fs.fed.us*), Okabe, K. (*Forestry and Forest Products Research Institute, Japan; kimikook@ffpri.affrc.go.jp*), Brockerhoff, E. (*New Zealand Forest Research Institute, New Zealand; eckehard.brockerhoff@scionresearch.com*).

The evidence for the key role that biodiversity plays in the provision of many ecosystem services and its mechanisms is becoming clearer as the body of scientific information increases. Some ecosystem services appear to be more closely related to biodiversity than others, although the relationships are influenced by multiple factors and feedback mechanisms often including the functional relationships. A main objective of REDD is carbon sequestration, which is strongly tied to biodiversity. Mechanisms include facilitation, complementarity, and sampling effect that improve forest productivity. These functional relationships may be altered, however, by many factors including competition (including from invasive species), pests and diseases, and herbivory. Understanding these key relationships is important in the planning of REDD forests for reforestation and n recovering degraded forests. This paper reviews the evidence for the importance of biodiversity in providing some of the key ecosystem services that need to be considered in planning for sustainable REDD forests. Attention to these functional relationships can improve the capacity for success in REDD forest activities.

Social and economic considerations relevant to REDD+. Vira, B. (*University of Cambridge, United Kingdom; bv101@cam.ac.uk*), Strassburg, B. (*International Institute for Sustainability, Brazil; b.strassburg@iis-rio.org*).

While REDD+ has the potential to generate substantial positive impacts for climate mitigation and biodiversity, the way in which it is implemented will determine the extent to which it is associated with positive social and economic outcomes. The primary objectives of REDD+, avoiding deforestation and forest degradation, can benefit poor people who are often disproportionately impacted by the loss of forests and the services they provide. On the other hand, the poor are also most vulnerable to changes in regimes for resource management and access that may be associated with REDD+, with severe negative consequences for their already marginal livelihoods. If REDD+ is to address the social, political, and economic factors that produce inequitable outcomes, it must give parity to socio-economic objectives alongside carbon and biodiversity goals. Pursuing these social objectives alongside REDD+ is likely to not only make the process more equitable but also increase the likelihood of achieving carbon and biodiversity goals. However, it is important to recognize that win-win outcomes are not always possible, and there are sometimes difficult trade-offs to be negotiated between carbon, biodiversity, and social objectives. Careful and inclusive (participatory) spatial planning can positively influence the distribution of winners and losers across the landscape so that REDD+ acts in the interests of the most vulnerable groups, thereby resulting in positive impacts on both equity and environmental effectiveness.

C-04 Addressing the drivers of deforestation: Exploring synergies between REDD+ and forest policy

Organizers: Michael Obersteiner (International Institute for Applied Systems Analysis), Austria), Gilberto Camara (National Instititute for Space Research-INPE, Brazil); Martin Tadoum (The Central African Forestry Commission-COMIFAC, Cameroun) & Valarie Kapos (UNEP World Conservation Monitoring Centre, UK)

Potentials of REDD-plus in conserving and protecting the remaining Philippine forests. Bugayong, L., Dolom, P., Villanueva, M., Carandang, A. (*University of the Philippines Los Banos, Philippines; lenlab82@gmail.com; predolom@yahoo.com; lyn_bvillanueva@yahoo.com; papcarandang@yahoo.com*).

In the line with the call for countries to identify the drivers of deforestation and forest degradation (DD) in the development of REDD-plus national strategies and action plans, the study assessed key activities that threaten the Philippines remaining natural forests. The study reviewed relevant forest policies, secondary data, and studies as well as conducted key informant interviews and focus group discussions with relevant stakeholders to identify and validate past and current drivers of DD in four sites of the country. Key drivers include forest products extraction (logging/timber poaching, charcoal production, fuelwood gathering), agricultural expansion (kaingin making, forest conversion to settlements and plantations,), and infrastructure expansion (mining, road construction, tourism facilities construction). Fishbone analysis shows indirect causes of these key drivers include weak policies and governance, poverty and population pressure, market demand and economic, and technological and biophysical factors. The paper explores the potentials of developing and implementing national REDD-plus strategies, action plans and policies in addressing these drivers that would lead to the conservation and protection of the country's remaining forests.

Comparing the effectiveness of national level forest policies across Central America. Fleischman, F. (*Texas A&M University and Texas Agrilife Research, USA; blackspruce@gmail.com*), Tucker, C., Upton, C., Sanchez, S., Epstein, G. (*Indiana University, USA; tuckerc@indiana.edu; jupton@indiana.edu; sesanche@umail.iu.edu; gepstein@umail.iu.edu*), Rodriguez, C., Cox, M., Garcia-Lopez, G., Villamayor-Tomas, S., Petriello, M.

While a great deal of attention has been focused on understanding the drivers of land use change in the tropics, we still know little about what policies can be pursued by national governments to conserve forests within their borders. This question is becoming increasingly important as the development of international regimes for trade and carbon sequestration alter domestic forest policies. This paper aims to address this knowledge gap through a systematic comparison of the effects of policies on forest cover, as measured using remotely sensed data, in the Central American countries of Costa Rica, Honduras, Guatemala, and Nicaragua, as well as Mexico. We draw on a broader synthetic framework, the social-ecological systems meta-analysis database (SESMAD), which is designed to facilitate the comparison of governance systems for large scale social-ecological systems. Within this framework, we examine how the influence of variables that have been emphasized in literature on deforestation and local forest management, such as agricultural technologies, remoteness, and local governance, with the influence of national level policy frameworks. We examine both the influence of direct forest policies and the influence of other policies, such as agricultural and trade policies, that may have indirect influences on forest cover change.

Assessing potential biodiversity impacts of policies that address drivers of deforestation to achieve REDD+ objectives. Kapos, V., Mant, R. (*UNEP-World Conservation Monitoring Centre, United Kingdom; val.kapos@unep-wcmc.org; Rebecca.mant@unep-wcmc.org*).

To achieve REDD+ goals, policies will be needed that address drivers of deforestation, while safeguarding biodiversity and other environmental benefits. It is therefore essential to understand how policy options addressing particular drivers might affect land use change and ultimately biodiversity. The REDD-PAC project uses a global economic and land use model (GLOBIOM) to project future land use and resulting changes in land cover that may result from different policy options under specified scenarios, focusing on Brazil and the Congo Basin. We use the model results to investigate the biodiversity impact of the predicted land cover change using two broad approaches. Firstly, potential changes in land use and land cover are assessed spatially in relation to areas identified through national and regional processes as priorities for biodiversity conservation. Secondly, impacts on biodiversity of potential future land cover change are assessed in terms of habitat changes within current species ranges. Assessing such changes across species provides a combined assessment of the amount of range species may lose as a result of particular drivers and under different policy scenarios.

Forest fragmentation in Mexico: an evaluation of the theory of collective action. Perez-Verdin, G. (*Instituto Politecnico Nacional, Mexico; guperezv@ipn.mx*), Silva-Flores, R., Wehenkel, C. (*Universidad Juarez Estado Durango, Mexico; rsilvaf@prodigy.net.mx; wehenkel@ujed.mx*).

The objective of this study is to emphasize the critical role of Mexican ejido communities and private ownerships in the conservation of forest resources. The study was conducted in Durango, which is the fourth largest state in Mexico and accounts for the largest forest inventories in the country. Using remote sensing and three time scenes, we quantified fragmented areas across a sample of 66 ownerships which included 31 common-based and 35 private properties. We also identified the main factors driving forest fragmentation—defined here as the reduction of forest cover that eventually leads to small and isolated patches of natural areas—and compared the results across the two types of property. We found that a large amount of ejido communities in the state of Durango present moderate rates of forest fragmentation. Factors driving fragmentation included the occurrence of frequent and low intensity fires, distance to agricultural areas, population, and size of the ownership. Results showed that, regardless of the property type, economically diverse ownerships are more likely to have lower fragmentation rates. High fragmentation rates were observed in the south, an area mostly habited by indigenous communities. These results have great potential to analyze the impact of human disturbance on forest ecosystems and the role of landowners in the management of forest resources.

Carbon offsetting by small holder farmers in the Congo basin : economic and policy constraints. Pietsch, S., Niedermayr, J., Schmid, C. (*University of Natural Resources and Life Sciences, Austria; stephan.pietsch@boku.ac.at; julia.niedermayr@gmail.com; carmen_schmid@gmx.at*), Stanzl, P. (*VMS, Gabon; stanzl225@aon.at*).

Demographic pressure and agricultural expansion are increasing threats to Central African rainforests. Traditional agriculture is small holder shifting cultivation without use of fertilizers or pesticides. Today, traditional agricultural land use is more and more replaced by high input permanent plantations of medium to large scale. As a result, formerly independent small holder farmers are becoming day laborers. An alternative scenario may be based on carbon offsetting mechanisms. High transaction costs of offsetting projects along with low CO_2 prices and related risks and uncertainties are major obstacles to smallholder project implementation. Here we present the results of a case study from Gabon linking smallholder low-input agroforestry with forest preservation and small scale carbon offsetting. Results indicate that in the long run, higher initial costs of agroforestry implementation are covered by revenues from agroforestry production, but also that carbon offsetting payments at current market prices are

too low to overcome investment barriers. Based on the single farmer's carbon offsetting potential and net present value of agroforestry revenues, we calculate offsetting costs of 0.4–2.5 €/t CO^2-eq. We discuss macroeconomic benefits and policy options for the promotion of sustainable smallholder land use scenarios.

Evolution of drivers of deforestation and forest degradation in Central African forests: exploring possible policy options to address forest loss. Tegegne, Y. (*European Forest Institute, Finland; yitagesu.tekle@efi.int*), Fobissie, K. (*University of Helsinki, Cameroon; fobissie.kalame@helsinki.fi*), Lindner, M. (*European Forest Institute, Finland; marcus.lindner@efi.int*).

This paper analyzes the drivers of deforestation and forest degradation (DFD) in Cameroon and the Republic of Congo and discusses the implications for the national REDD+ strategy in both countries. This study draws on two types of data: literature review and questionnaire-guided interviews with 42 experts from various organizations. Our analysis shows that agricultural expansion, predominately subsistence agriculture, and wood extractions are leading drivers of DFD, both historically and currently. Expansion of agro-industrial plantation and mining operations in forest areas are among anticipated emerging threat of forest cover in both countries. The direct drivers of DFD in Cameroon are driven by the full interplay of institutional, demographic, economic, technological, and cultural variables rather than by single-factor causation. Finally, poor governance in forest sector, low level of law enforcement, lack of inter-ministerial integrity, and insufficient capacities create barriers to coherent country-wide approaches to reduce DFD in Cameroon and Congo. These issues are further hampered by government's policies for economic development and poverty reduction. The barriers to address the causes of DFD and possible policy options/responses to reduce forest loss are also discusses in the paper.

Analyzing the perception of deforestation drivers by African policy makers in the perspective of possible REDD+ policy responses. Wehkamp, J. (*Mercator Research Institute on Global Commons and Climate Change, Germany; wehkamp@mcc-berlin.net*), Rodrigues de Aquino, A., W. Reed, E. (*World Bank, USA; adeaquino@worldbank.org; ereed1@worldbank.org*), Fuss, S. (*Mercator Research Institute on Global Commons and Climate Change, Germany; fuss@mcc-berlin.net*), Fukuda, K. (*UN-REDD, Kenya; koji.fukuda@undp.org*).

In the context of REDD+ (reducing emissions from deforestation and forest degradation) many scholars increasingly emphasize the role of institutions and policies as drivers of deforestation. Others argue that the complex nature of such issues makes it difficult to actually address them with a single policy tool such as REDD+ alone. A too strong focus on such issues is considered to put the carbon-effectiveness of REDD+ at risk, especially during the result-based payments phase. In an attempt to move beyond a purely theoretical debate, this paper analyzes the perception of drivers of deforestation by African policy makers through content analysis. The results show that all African policy makers do not only emphasize the role of institutional and policy drivers of deforestation, but also that many of these complex issues can actually be narrowed down to very concrete problems. In the light of these findings, it will be argued in a discussion part that mechanisms and standards have to be found to allow addressing institutional and policy drivers of deforestation in the result-based payments phase.

Building consensus on REDD activities at a jurisdictional scale: case study in Huila, Colombia. Zeender, G., Van Vliet, N. (*ONF Andina, Colombia; gzeender@onfandina.com; nvanvliet@onfandina.com*), Sandker, M. (*FAO, Italy; mariekesandker@hotmail.com*), Agudelo, C., Sierra, A., González, N. (*ONF Andina, Colombia; cagudelo@onfandina.com; asierra@onfandina.com; NGonzalez@onfandina.com*).

As part of a unique pilot pre-feasibility study of REDD at a regional level in Colombia, we took a participatory approach that allows us to visualize and discuss different scenarios under different REDD activities at the level of a department (state) called Huila. We first identified and described the main drivers of deforestation and quantify historical deforestation. Then, we used STELLA 8.0 (High Performance Systems 1996) to model the landscape and the main drivers of deforestation. The model was built in a participatory manner with the experience of relevant experts from different sectors (agriculture, conservation, development). A workshop was organized to list and prioritize potential REDD+ activities. The effect of the three first prioritized activities (Payment for Environmental Services, agriculture intensification and enhanced wood use by rural families) was modeled in order to analyze impacts and discuss trade-offs between carbon stock protection and rural families' economy. Our study shows how participatory modeling approaches can help decisionmaking and bring consensus as to which activities to prioritize at the jurisdictional scale to reduce deforestation where complex interactions exist between direct and indirect drivers of deforestation and degradation.

C-05 Gender, participation and climate change

Organizers: Bimbika Sijapati Basnett, Esther Mwangi (CIFOR, Indonesia), Peter Cronkleton (CIFOR, Peru) & Terry Sunderland (CIFOR, Indonesia)

Challenges, opportunities and outcomes of women's participation in forest governance: lessons from CIFOR's Research. Basnett, B., Mwangi, E., Purnomo, H. (*Center for International Forestry Research, Indonesia; b.basnett@cgiar.org; e.mwangi@cgiar.org; h.purnomo@cgiar.org*).

The language of forest policies, laws, projects and programs are increasingly peppered with provisions for strengthening greater participation of women in decision-making and benefit-sharing mechanisms. But research on the specific challenges, opportunities and outcomes of women's participation in forest governance is lagging behind. Drawing on CIFOR's research on NTFP value chains, REDD+ projects, and forest use and management, this paper considers gendered participation from different lenses including: a) the determinants of women's participation in forestry use and management decisions; b) governance sub-outcomes of women's vs. men's groups' participation in forestry decisions; c) women vs. men's participation in value chains and benefits distribution of such activities; and d) women vs men's participation in REDD+ projects. The findings underscore the multiple

domains under which participation takes place and multiple ways in which participation can be characterized. Structural considerations (such as norms and values, institutional rules, credit, education, skills, project design) can facilitate or impede women's participation and thus need to be addressed and accounted for in fostering gender equitable outcomes.

Developing strategies for REDDES activities in selected pilot areas in Cameroon, Ghana and Nigeria. Foli, E., (*Forestry Research Institute of Ghana, Ghana; efoli@hotmail.com*), Kleine, M. (*International Union of Forest Research Organizations (IUFRO), Austria; kleine@iufro.org*), Louis Bernard, C. (*Institute of Agricultural Research for Development (IRAD), Cameroon; lbcheteu@yahoo.fr*), Addo-Danso, S., Damnyag, L. (*Forestry Research Institute of Ghana, Ghana; shalomdanso@yahoo.com; ldamnyag@yahoo.com*), Britwum Acquah, S., Adejoba, O.

Global warming and climate change are often attributed to the burning fossil fuels in developed countries; even so, deforestation and forest degradation (DFD) in developing countries are known to contribute significantly to climate change effects. The present work contributes to the control of DFD in selected pilot sites in Cameroon, Ghana, and Nigeria, the specific objective being to devise strategies for the implementation of activities for Reducing Emissions from Deforestation and Forest Degradation and enhancing Ecosystem Services (REDDES). The study was carried out by means of structured questionnaires designed for identified stakeholders in each country, preceded by stakeholder workshops on REDDES, followed by focus group discussions to identify the drivers of DFD and to determine appropriate strategies for REDDES activities. Follow-up workshops were held to adopt the strategies developed for the implementation of REDDES activities. The drivers of DFD identified were similar across countries. We present the key strategies developed, the corresponding activities identified by the stakeholders, along with the roles and responsibilities of the various stakeholders in implementing REDDES activities. We conclude that stakeholders are enthusiastic in contributing to activities that would reverse DFD and enhance ecosystem services for the benefit of the communities in the pilot areas.

Forest governance, gender and social inclusion and REDD+ in Nepal. Ghimire, M. (*Ministry of Forests and Soil Consertation, Nepal; ghimire.madhu@gmail.com*).

Despite the intense efforts on REDD+, there is little empirical evidence on how it interacts with existing governance mechanisms and impacts people. Community forests (CFs) of Nepal provide an interesting insight into this interaction. This study was conducted to: provide some reflections and insights on the level of awareness and understandings; investigate to what extent and how the gender and social inclusion (GESI) perspective is addressed in policy-making and implementation; explore the barriers to women's participation in forest governance; examine gender equity issues on REDD+ activities; and identify possible strategies to overcome barriers based on literature reviews, field visits, and interviews. Data were collected using both an e-survey and face-to-face interviews. Climate change places demand on existing governance structures to reform based on GESI and work more effectively. Despite an increasing trend in CFs on decentralized forest governance and empowering local stakeholders, this study have shown a significant difference on GESI. There is limited awareness and emphasis on governance and GESI on issues of climate change in general and REDD+ in particular resulting to appear REDD+ as a gender-blind institution. Further empirical analyses are needed on strategies that could help trigger the existing mind-set and organizational culture change.

Response to climate change in Canadian forest-based communities: Does gender matter? Reed, M. (*University of Saskatchewan, Canada; m.reed@usask.ca*), Johnston, M. (*Saskatchewan Research Council, Canada; johnston@src.sk.ca*), Natcher, D. (*University of Saskatchewan, Canada; david.natcher@usask.ca*).

Canadian forest-based communities face a range of ecological, social, and economic changes, in part because of a changing climate. Research and planning have been directed to enhancing their adaptive capacity defined as the ability of individuals and groups to access, mobilize and deploy assets and endowments to facilitate adaptation without degrading those resources. Despite a community level focus, there is no work in North America that considers how gender influences adaptive capacity for climate change forest-based communities. This gap is curious, given the heightened interest in the links among gender, forestry, and climate change in developing countries. This paper offers insights from a workshop in 2014 that brought academics and community members together to examine how gender influences how forest-dependent communities articulate and address concerns related to climate change. Contributions from indigenous and non-indigenous participants explicitly introduced gender as a key relation through which adaptive responses are conceived and implemented. Participants considered how men and women access and mobilize resources, how forest management policies and practices reinforce gendered norms and expectations, and how we can target and harness social differences to establish effective and equitable strategies for adaptive capacity in forest-based communities.

Are women more vulnerable to climate change and other interacting stressors in the rural Eastern Cape, South Africa? Shackleton, S. (*Rhodes University & Center For International Forestry Research, South Africa; s.shackleton@ru.ac.za*), Cobban, L. (*Rhodes University, United Kingdom; l.t.stadler@gmail.com*).

Rapid global environmental change combined with other stressors is increasing the vulnerability of natural resource dependent people worldwide. In South Africa, HIV/AIDS and climate variability, interacting with other localized risks, are having differential impacts across communities, households, and individuals. In this paper we explore gender-differentiated vulnerability to these linked livelihood stressors. We reflect on the ways in which households with different gender compositions are vulnerable, and question whether female-headed households are worse off, as well as explore local perspectives of vulnerability amongst men and women. We find that female-headed households have lower access to land and income, but are generally higher in social capital and food security. Moreover, women demonstrate greater innovation in terms of responding to multiple stressors which includes increased use of forest and other natural products, various other forms of self-employment, and the adoption of collective activities such as the formation of gardening and home care groups. Gender-based violence, however, adds to women's vulnerability. Our results illustrate the complexity and heterogeneity of vulnerability in local places and the consequences of this for adaptation.

Challenging perceptions about men, women and forest product use: A global comparative study. Sunderland, T. (*Center for International Forestry Research, Indonesia; t.sunderland@cgiar.org*).

This study uses a multi-case dataset to question current assumptions about the gender differentiation of forest product use. We test some of the commonly held ideas on how men and women access, manage, and use different forest products. Overall, we found significant gender differentiation in the collection of forest products, which seems to support the claim that there are distinctive male and female roles associated with the collection of forest products. However, we also found that men play a much more important and diverse role in the contribution of forest products to rural livelihoods than previously reported, with strong differences across tropical Asia, Africa, and Latin America.

Does forest decentralization strengthen women's adaptive capacity to climate change in the Congo Basin? insight from Cameroon. Tiani, AM., Perez Teran, A., Eugene, C. (*Center For International Forestry Research, Cameroon; a.tiani@cgiar.org; a.perezteran@cgiar.org; e.chia@cgiar.org*).

The post 1990 forest decentralization policy in Cameroon transferred statutory rights, authority, and responsibilities of managing a share of forests and forest revenues to local collectives and communities. Responsibilities and decisionmaking processes on the management of forest royalties and conservation depend practically on the powers of mayors. However, the transfer of management power had a limited vision for gender equity, with women poorly represented in decisionmaking related to distribution of resources. Local women as compared to men invest time and resources in activities such as slash and burn agriculture, which is sensitive to climate variability and change. Increasing farm sizes is an adaptation option for women, which is detrimental to forest conservation. Furthermore, power dynamics, which do not favor women in forest resource management and distribution, influences the adaptive capacity of women. Nevertheless, efforts are being made at various levels to push gender equity in the decentralization agenda. The recent electoral processes in Cameroon have increased the inclusion of women in different political parties aiming to manage local collectives. This is a drive to implement the international ratified conventions and a deliberate policy of gender quotas in the various decision-making bodies which is relevant for climate change decisions.

C-06 Boreal at risk: Integrative science as a strong foundation for public policy development

Organizers: Deepa Pureswaran, Werner A. Kurz, Louis De Grandpré (NRCan-Canadian Forest Service) & Philip G. Comeau (University of Alberta, Canada)

Report from the global frontlines: Does climate change during this century imperil all historic forests across planet earth? Allen, C. (*U.S. Geological Survey, USA; craig_allen@usgs.gov*).

Recent global warming, along with episodic droughts, drive elevated levels of chronic and acute forest water stress across large regions and also increase the incidence and severity of many significant forest disturbances, including wildfire, drought-induced tree mortality, and insect/disease outbreaks. Although many mesic forest regions currently appear robust, emerging changes in global-scale patterns and trends of drought-amplified forest die-off and high-severity wildfire illustrate growing risks to historic forests in all biomes. An overview of new empirical and process-based research on tree stress physiology, insects/pathogens, forest plots, remote-sensing of forest health/disturbances, and forest-climate modeling further highlights potentials for extensive tipping point tree mortality responses to increased drought/heat stress, along with many countervailing compensatory and resilience-enhancing forest processes. Despite the essential Earth-system roles of forests, amazingly large scientific information gaps and uncertainties constrain our ability to realistically project region-specific probabilities of forest turnover from mortality processes with expected climate changes this century. Which forests are most at risk, and when? This presentation targets what forest scientists, managers, and policy makers need to know with a synthesis of recent progress on tree mortality research across diverse disciplinary approaches, highlighting both worrisome and hopeful findings and key challenges, regarding the future of the world's forests.

How much dead wood is enough in Canadian forests? a review of the science and policy. Arsenault, A. (*Canadian Forest Service, Canada; andre.j.arsenault@nrcan-rncan.gc.ca*), Chapman, B. (*British Columbia Ministry of Forests, Lands and Natural Resource Operations, Canada; bill.chapman@gov.bc.ca).*

From the moment a tree seed germinates on the ground, it is engaged in the dance of life that consists of concentrating and dispersing energy and nutrients. Through its life, a tree accumulates a significant proportion of its lifetime's photosynthesis and nutrient uptake into persistent woody structures. In natural forests, each individual tree is destined to die and rot into the forest floor, and in the process, the released energy and nutrients contribute to endless ecosystem services until the tree becomes a persistent ghost of its former self. Canada is blessed with a variety of forest types which each have their individual deadwood signatures. Deadwood signatures can be characterized by the amounts of wood in various decay categories, but perhaps more importantly, as the variety of ecosystem services associated with each deadwood life stage. Understanding these stages and ecosystem services and how they transition from one stage into another in dynamic forest ecosystems is critical to inform forest policy, planning, and operations. We review what we have learned on the science of deadwood ecosystem services in Canada and examine the opportunities and challenges to integrate this information into policy and best management practices.

Can mixed wood management mitigate climate change impacts on spruce in western Canada's boreal forests? Comeau, P., Bokalo, M. (*University of Alberta, Canada; phil.comeau@ualberta.ca; mike.bokalo@ualberta.ca).*

Substantial temperature increases are forecast for the boreal forests of western Canada, and these are expected to have significant impacts on the distribution of white spruce (*Picea glauca* (Moench) Voss). Since mixtures of aspen (*Populus tremuloides* Michx.) and white spruce are a common feature of upland sites, the potential for mixedwood management to mitigate climate change

effects is of interest. Some recent studies have shown increasing mortality of trembling aspen while some studies are showing increases in spruce and aspen growth associated with warming trends that have occurred during the past two decades. While overtopping aspen have been shown to reduce the growth of white spruce, the presence of aspen has also been shown to mitigate frost injury and winter injury that may result in substantial damage to regenerating white spruce. In addition, aspen cover reduces the impacts of grass layer competition. In this presentation we will utilize data from 10 Western Boreal Growth and Yield Association research installations established across a broad climatic gradient in western Canada to examine effects of recent climatic trends on spruce growth and survival under different levels of aspen canopy cover. We will also examine other promising approaches for mixedwood management, including underplanting and understory protection as potential approaches for mitigating effects of climate change on spruce.

Ecosystem consequences of the northward expansion of the eastern spruce budworm. De Grandpre, L., Pureswaran, D., Paré, D. (*Canadian Forest Service, Canada; louis.degrandpre@nrcan-rncan.gc.ca; dpureswa@nrcan.gc.ca; David.Pare@RNCan-NRCan.gc.ca*), Morin, H. (*Université du Québec à Chicoutimi*, *Canada; hmorin@uqac.ca*), Taylor, A. (*Canadian Forest Service, Canada; anthony.taylor@nrcan-rncan.gc.ca*), Barrette, M., Kneeshaw, D.

Climate change is causing northward shifts in species ranges. For mobile species such as insects, this means access to forest ecosystems that were only weakly affected in the past. Among the most destructive ecological disturbance agents in the boreal forests of North America is the eastern spruce budworm, which defoliates fir (*Abies* spp.) and to a lesser degree spruce (*Picea* spp.). Outbreak centers are not appearing much to the north in the black spruce forest ecosystem which was only lightly affected in the past few centuries. We are evaluating the impact of a rising spruce budworm outbreak in the north eastern boreal forest over the course of the infestation. Estimates of defoliation since 2006 reveal that pure black spruce stands currently suffer up to 50% defoliation, although they are less defoliated than pure balsam fir or mixed stands. Severe spruce budworm outbreaks could decrease black spruce stand productivity compared with their effect in more diverse, southern balsam fir forests that are better adapted to outbreaks. Changes in nutrient cycling could alter regeneration patterns, resulting in the replacement of black spruce by more productive mixedwood or balsam fir dominated forests, or in some cases by less productive open ericaceous shrublands.

Preventing damage from a southern pest in northern forests: The future of the southern pine beetle prevention program? Klepzig, K., Nowak, J. (*U.S. Forest Service, USA; kklepzig@fs.fed.us; jnowak@fs.fed.us*).

The dynamics of bark beetle outbreaks are in a state of dramatic flux. Likely driven by climate change and associated impacts, these eruptive forest pests are expanding their range and causing damage in unpredicted ways. In the West, beetles are causing unprecedented outbreaks at higher elevations. In the South, the southern pine beetle is expanding northward, causing unexpected outbreaks in New Jersey. The primary silvicultural tool for dealing with the southern pine beetle has been the reduction of stand density. In this talk, we discuss the efficacy (tested by recent outbreaks) of the southern pine beetle prevention program, implemented on over 1.2 million acres so far. We also describe the mechanisms behind this efficacy. Finally, we examine the potential impacts of climate change (and associated northward expansion of the southern pine beetle range) on this successful program and the implications to its use in no analog situations. The degree to which this program may need to be adjusted to allow success in new contexts (climate, host type, and sociopolitical) will also be discussed.

Boreal at risk: from boreal science to public policy. Kurz, W., Lempriere, T. (*Canadian Forest Service, Canada; wkurz@nrcan.gc.ca; tony.lempriere@nrcan.gc.ca*), Conard, S. (*U.S. Forest Service, USA; sgconard@aol.com*), Comeau, P. (*University of Alberta, Canada; pcomeau@ualberta.ca*), Astrup, R. (*Norwegain Forest and Landscape Institute, Norway; rasmus.astrup@skogoglandskap.no*), Bernier, P., Boyland, M., Ste-Marie, C.

The 16th conference of the International Boreal Forest Research Association (held in October 2013) focused on risks to the boreal forest arising from climate change impacts on disturbance regimes, ecosystem processes, and carbon emissions. Higher temperatures, longer growing seasons, carbon-dioxide fertilization, and changes in hydrological cycles are projected to affect growth, mortality, and decomposition rates as well as disturbances and distribution and composition of tree species. While significant progress is being made in our ability to characterize current forest conditions, predicting the complex future responses to environmental change and management remains challenging. High spatial heterogeneity, interactions between processes, nonlinear transitions to new ecosystem states triggered by disturbances, effects of changing resource demands and management, and the anticipation of tipping points, such as the loss of permafrost, with the associated impacts on carbon balance and ecosystem characteristics add to this challenge. Scientific models with a systems perspective that account for ongoing changes in the natural environment and are verified against ground plot measurements and ongoing monitoring, can support adaptive forest management and the development of mitigation and adaptation strategies. Identified risks are common among circumpolar boreal countries. Improved international scientific collaboration with a focus on policy objectives may help address risks.

Climate, adaptation, and the northward range expansion of gypsy moth. Parry, D. (*State University of New York, USA; dparry@esf.edu*), Dattelbaum, K., Johnson, D. (*Virginia Commonwealth University, USA; kdattelbaum@vcu.edu; dmjohnson@vcu.edu*).

The northern range limit for gypsy moth in North America is bounded by climatic constraints. Models have consistently predicted further northward range expansion under a variety of climate change scenarios. However, these models have been based on developmental and physiological parameters derived from standard strains of laboratory reared gypsy moth. Using a common garden approach, we compared multiple populations of field collected gypsy moth from across its current North American latitudinal distribution for traits likely important for northward expansion. Although we found little difference among populations in supercooling points of eggs, we found earlier hatch phenology and more rapid development in most of our northern populations over a range of common garden temperatures. A laboratory (Otis Strain) population differed markedly from many field-collected populations in a number of traits suggesting caution when using it to parameterize range shift models. Our data suggest that the northward distribution of gypsy moth under warming temperatures may be greater than currently predicted. We further suggest that projections about future ranges of invasive forest insects should consider the synergistic effect of adaptation and a warming climate.

Understanding the interactions between climate change, heart rot, and carbon sequestration in *Populus tremuloides* in the boreal forest. Ramsfield, T., Myrholm, C., Hogg, T. (*Canadian Forest Service, Canada; tod.ramsfield@NRCan-RNCan.gc.ca; Colin.Myrholm@NRCan-RNCan.gc.ca; ted.hogg@NRCan-RNCan.gc.ca*).

Trembling aspen (*Populus tremuloides*) is one of the most widely distributed tree species in the boreal forest of Canada and within its distribution it is affected by the heart rot fungus *Phellinus tremulae*. As the tree ages, the probability of infection by *P. tremulae* is increased and as decay progresses, infected aspen transition from a net carbon sink to a net carbon source. We are investigating climatic limitations on the geographic distribution and incidence of *P. tremulae* within the range of aspen and the relationship between decay rate and temperature *in vitro*. Through these investigations, we are developing a conceptual model of decay that can be used to evaluate changes in the distribution of *P. tremulae* under various climate scenarios. These model predictions can further be used to assess carbon sequestration and release from aspen stands in the boreal forest under a changing climate.

C-07 Forests, fire and climate change dynamics

Organizers: Bill de Groot (NRCan-Canadian Forest Service), Ainuddin Nurrudin (Univesiti Putra Malaysia), Susan Conard (International Boreal Forest Research Organization, USA) & Pieter van Lierop (UN-FAO, Italy)

Challenges and pitfalls in quantifying the interactions between fire and changing climate in the boreal zone. Conard, S. (*U.S. Forest Service, USA; sgconard@aol.com*), De Groot, W. (*Canadian Forest Service, Canada; Bill.deGroot@NRCan-RNCan.gc.ca*), Cahoon, D. (*Contractor, USA; cahoonski@gmail.com*), Hao, W. (*U.S. Forest Service, USA; whao@fs.fed.us*), Ivanova, G. (*Sukachev Institute of Forest, Russia; GAIvanava@ksc.krasn.ru*), Kukavskaya, E., Flannigan, M., Ponomarev, E., Soja, A., Stocks, B., Tchebakova, N.

Circumboreal forests contain one third of global terrestrial carbon stocks, and comprise a vast timber resource. The most rapid climate warming is projected in boreal and polar regions. Changing climate and resource use are expected to alter disturbance patterns across the boreal. Higher temperatures and retreating permafrost will likely lead to increased wildfire emissions and peat decomposition. Conversion of forest to steppe will change fire regimes, carbon stocks and albedo. Higher annual burned area and increased fire severity will decrease carbon stocks, increase emissions of CO_2 other greenhouse gases and particulates, and increase winter albedo. Increased infestations of forest pests will alter carbon storage, fire hazard, and forest composition and structure. Changes in logging practices will affect both fire regimes and carbon stocks. Quantifying the net effects of these changes on terrestrial carbon, fire emissions, and other greenhouse forces including albedo, will be a significant challenge. The wide range in current estimates of fire impacts and carbon stocks illustrate that accurate assessments require integration of field data, geospatial data and modeling. They must be based on ecosystem-specific data; on local knowledge of vegetation, carbon stocks and dynamic vegetation processes; and on detailed understanding of data sets and potential errors.

Climate change and fire influence the methane uptake capacity in Australian eucalypt forest soils. Fest, B., Arndt, S., Livesley, S. (*The University of Melbourne, Australia; bfest@unimelb.edu.au; sarndt@unimelb.edu.au; sjlive@unimelb.edu.au*), Wardlaw, T. (*Forestry Tasmania, Australia; Tim.Wardlaw@forestrytas.com.au*), Hinko-Najera, N. (*The University of Melbourne, Australia; n.hinko.najera@gmail.com*).

Soil methane (CH_4) oxidation in forest ecosystems comprise the largest soil sink for this potent greenhouse gas and climate change as well as fire can have significant impacts on this important process. We present data from a number of long-term greenhouse gas studies that investigated the potential impacts of reduced rainfall and altered fire regimes on CH_4 flux in Australian eucalypt forest systems. Long-term CH_4 flux measurements with high temporal resolution in a dry-sclerophyll and wet-sclerophyll eucalypt forests contrasting in annual precipitation (870 and 1 700 mm/year) showed that 90% of soil CH_4 uptake variability is explained by soil moisture. The application of throughfall reduction shelters that intercepted 40% of throughfall caused an average reduction of 14.6% in soil volumetric water content but an increase in soil CH_4 uptake of 38%. Consequently, the predicted climate change induced reductions in rainfall in large parts of Australia are likely to result in an increase in CH_4 uptake. Fire disturbance also altered CH_4 uptake of forest systems and here the methane uptake capacity was related to stand age related changes in stand structure and stand water use, with greater CH_4 uptake in stands that use more water resulting in on average drier soil conditions.

Climate change and wildland fires in the 21st century. Flannigan, M. (*University of Alberta, Canada; mike.flannigan@ualberta.ca*), de Groot, W. (*Canadian Forest Service, Canada; bill.degroot@nrcan.gc.ca*), Stocks, B. (*B.J. Stocks Wildfire Investigations Ltd., Canada; brianstocks@sympatico.ca*).

Wildland fires are a common occurrence in many regions of the world. These fires are the result of interactions between climate/weather, fuels, and people. Our climate and associated day-to-day weather may be changing rapidly due to human activities that may have dramatic and unexpected impacts on regional and global fire activity. Existing studies suggest a general overall increase in area burned and fire occurrence although there is a lot of spatial variability, with some areas of no change or even decreases in area burned and occurrence. Fire seasons are lengthening for temperate and boreal regions and this trend should continue in a warmer world. Future trends of fire severity and intensity have been difficult to determine due to the complex and non-linear interactions between weather, vegetation and people. Increases of fire severity could lead to a positive feedback cycle in the climate system where increased emissions from fire could reinforce human-caused climate warming. A warmer world means a longer fire season, more lightning activity, and most importantly drier fuels that mean it is easier for fires to start and spread. In terms of fire management, enhanced fire danger rating systems that accurately predict the spatial and temporal variability in fire danger can help us adapt to a warmer world. Fire management will be even more challenging in a warmer world.

Canadian boreal forest timber vulnerability to current and future fire risk. Gauthier, S., Bernier, P., Beaudoin, A., Guo, X., Boulanger, Y. (*Canadian Forest Service, Canada; sylvie.gauthier@rncan.gc.ca; pierre.bernier@rncan.gc.ca; andre.beaudoin@rncan.gc.ca; xguo@rncan.gc.ca; yan.boulanger@rncan.gc.ca*).

Forest fires are important disturbances affecting timber supply in Canada's boreal forests. It is now recognize that the omission of fire risk in forest management planning can result in important fluctuations in fiber availability. With fire risk predicted to increase with climate change, we used a simple index to explore how current and future fire risks could affect timber supply. Current and future fire risk (annual area burned) was first estimated within regions of homogeneous fire regime based on the annual 1959–1999 burn statistics. Using moderate-scale Canada-wide maps of forest properties, empirical yield functions were then used to determine the time required for stands to reach a given threshold of commercial volume, For each stand, we then estimated the probability of reaching the threshold when considering either the current and future fire risks. Stand-level evaluations were spatially smoothed to produce a median probability of reaching the threshold over a 1 000 km^2 moving window. Regionally, these median probabilities represent the degree of vulnerability of timber supply to the current and future fire risks. Our results indicate that a large portion of the Canadian boreal forest has a high vulnerability to fire under future predicted fire regime.

Climate change and tropical forest fires: impacts and adaptation. Herawati, H. (*Center for International Forestry Research, Indonesia; h.herawati@cgiar.org*), Locatelli, B. (*Coopération Internationale en Recherche Agronomique pour le Développement, France; bruno.locatelli@cirad.fr*), Martius, C. (*Center for International Forestry Research, Indonesia; c.martius@cgiar.org*).

Forest ecosystems provide essential ecosystem services, such as food for local communities and carbon sequestration for mitigating climate change. Fire is a natural part of the ecological processes of some tropical forests, but it generally represents a threat to societies, ecosystems and their services. Climate change may affect fire regimes by modifying weather patterns and long-term average climate, affecting forest composition and structure. We review literatures on factors influencing tropical forest fires and climate change impacts on these factors, and model them using iMODELER software. Finally, we identify adaptation measures that can be used to sustain tropical forests and their services under a changing climate. In general, the reviewed impact studies predict increased fire danger under future climate change in some tropical areas, but uncertainties remain for other tropical areas. The model results indicate, however, that climate change has a relatively low but slowly growing influence on wildfire, while other factors such as availability of flammable fuel are more significant in triggering wildfires. The reviewed literature also describes various adaptation approaches available to anticipate the predicted fire danger increase. These include preventing fire to spread, more fire proof nonforestry practices, enhancing fuel management, and reducing and monitoring human-caused ignitions.

Forest fires and adaptation options in Europe. Khabarov, N. (*International Institute for Applied Systems Analysis (IIASA), Austria; khabarov@iiasa.ac.at*), San-Miguel-Ayanz, J. (*European Commission Joint Research Centre, Italy; jesus.san-miguel@jrc.ec.europa.eu*), Obersteiner, M., Krasovskii, A. (*International Institute for Applied Systems Analysis (IIASA), Austria; oberstei@iiasa.ac.at; krasov@iiasa.ac.at*), Swart, R. (*Alterra, Wageningen University and Research, Netherlands; rob.swart@wur.nl*), Dosio, A., Durrant, T., Camia, A., Migliavacca, M.

In this paper we present the results of our research on adaptation options to forest fires in Europe. It is a pioneering attempt to quantify impacts of reactive and preventive adaptation strategies within one modelling framework at a regional scale. Based on the community land model with an integrated fire module, we developed a model that is less computationally expensive. The model demonstrates satisfying performance in terms of agreement of the modelled burned areas in Europe with observed data. We explore fuel removal through prescribed burnings and improved fire suppression as adaptation options and quantify impacts of climate change on forest fires informed by a set of climate model realizations. Our estimation of the potential increase of burned areas in Europe under a high-emissions, no adaptation scenario is about 200% by 2090 (compared to 2000–2008). Application of prescribed burnings has the potential to keep that increase below 50%. These results are in line with the existing literature. We provide also quantitative estimates on how improvements in active fire suppression might reduce this impact even further.

Large fires in the United States under changing climate. Liu, Y., Goodrick, S., Stanturf, J. (*U.S. Forest Service, USA; yliu@fs.fed.us; sgoodrick@fs.fed.us; drdirt48@gmail.com*).

Wildfires have been projected to increase in the United Stated this century in response to the projected climate change. This study focuses on future trends and spatial relationships of large fires, which account for a small number of total fires but contribute substantially to smoke and the air quality impact. Statistical techniques were applied to modeling the current fire events and projecting future trends. The historical large fires in the past three decades were first analyzed, and fire potential indices were calculated using dynamical downscaling of regional climate change. The relationships between the historical wildfires and fire indices were then established to estimate the probabilities of large fire occurrence and spreading in the future under changing climate conditions. The fire indices showed overall increase in the Rockies, Southeast, northern Great Plains, and Southeast. The burned areas in these regions increase accordingly. Warming was found to be a more important contributor than drying. The current concurrence probability of large fires between two geographic regions is large in the western United States. It is expected to become smaller in the future due to increased spatial variability in precipitation.

Response of wildfire to climate change and its implications in vegetation dynamics in Northeast Chinese boreal larch forests. Yang, J. (*Chinese Academy of Sciences, China; yangjian@iae.ac.cn*).

Wildfire activity is projected to increase in boreal larch forest of the Great Xing'an Mountains, Northeast China, potentially altering vegetation dynamics and carbon balance under warming climate. However, the ecological drivers that influence wildfire occurrence and post-fire landscape dynamics in this region are poorly understood. In this study, we examined influences of various drivers (biotic, abiotic, and human factors) and projected climate change effects on the distribution of fire occurrence using detailed fire ignition data and a novel statistical method (spatial point pattern analysis). We also collected tree recruitment data and used a boost regression tree (BRT) method to quantify how fire severity, interacting with site conditions, affected post-fire forest succession pathways. Our results showed that both current and future projected spatial distribution of fire occurrence

density was strongly related to human activities, with proximity to settlements and roads found to be the most important influencing factors. Higher fire severity generally decreased the seedling densities of both coniferous and broad-leaved trees, but increased the proportion of coniferous tree seedlings. Further forest landscape simulations suggested that the broadleaf tree species could increase its total coverage by 30% at the end of 21st century in response to the increase of fire activities induced by climate change in this region.

C-08 Managing forest for fire in a changing climate

Organizers: Cristina Aponte, Helen Vickers, Thomas Fairman (University of Melbourne, Australia) & William Elliot (U.S. Forest Service).

Long-term effects of repeated prescribed fires on aboveground carbon stocks in a temperate eucalypt forest. Aponte, C., Tolhurst, K., Löw, M., Baker, T., Bennett, L. (*University of Melbourne, Australia; caponte@unimelb.edu.au; kgt@unimelb.edu.au); m.loew@unimelb.edu.au; tgbaker@unimelb.edu.au; ltb@unimelb.edu.au*).

Repeated prescribed fires at regular intervals are required to maintain reduced fuel hazards and lessen wildfire risk, however the long term consequences of repeated low intensity fires on forests properties are still unclear. We investigated the effects of four different prescribed fire treatments repeated over 27 years on aboveground carbon stocks, namely standing live and dead trees, stumps and coarse woody debris (CWD), and on tree growth, in a mixed-species eucalypt forest of south-eastern Australia. Prescribed fire treatments were a factorial combination of two frequencies (3 yearly and 10 yearly) and two seasons (spring and autumn). Burning decreased total standing tree-based carbon stocks. This was consistent with the observed bark consumption, less carbon in dead stems and decreased mean annual diameter increment of the dominant Eucalyptus species over 27 years in Fire treatments. Burning also reduced CWD carbon stocks, particularly in decayed pieces. CWD carbon losses in Fire treatments were not balanced by minor increases in pyrogenic carbon (char). Tree-based carbon stocks were greater in autumn than in spring fire treatments while the opposite was observed for CWD carbon stocks. All carbon stocks were greater in low than in high frequency fire treatments. These findings suggest a potential management trade-off between sustained reductions of wildfire risk, and the consequences of changes in forest properties.

The season, severity, and frequency of prescribed fire shaping the community dynamics of heathland shrub species. Chick, M., Cohn, J., Nitschke, C., York, A. (*University of Melbourne, Australia; mchick@student.unimelb.edu.au; janet.cohn@unimelb.edu.au; craign@unimelb.edu.au; alan.york@unimelb.edu.au*).

Throughout the fire prone regions of the world the threat of wildfire is being met through increasing both the temporal and spatial components of prescribed burning; meaning the frequency increasing, and the seasonality and severity altering. Within Victoria, Australia, fire management practices are such that fire prone communities, such as heathland, will experience prescribed burning across a larger range of age classes and at higher frequencies into the future. This research will be focusing on the ecological responses of shrubs in the heathland community to time since last fire (TSLF), the season (spring versus autumn) and severity of prescribed fire, and how these responses vary geographically across a precipitation gradient. This will occur: (1) retrospectively through the assessment of TSLF shrub species dynamics; (2) presently through building predictions of community responses when prescribed fire is introduced into these different TSLF dynamics; and (3) into the future through modeling community responses to alternate seasons of prescribed fires with the use of fire scenario modeling. To obtain these objectives, data collected will parameterize the landscape dynamics model LANDIS-ii. Through this research better understanding of the relationship between climate, fire regimes and shrub dynamics in heathland will be developed.

How do recurrent disturbances change temperate forests? perspectives from the decade of megafires in Victoria, Australia and implications for forest management. Fairman, T. (*University of Melbourne, Australia; tfairman@student.unimelb.edu.au*).

In the south-eastern Australian State of Victoria, over four million hectares of forest have burned in wildfires at varying severities in the last decade (2003–2014: 4.3 million hectares), roughly equivalent to the cumulative area burned in the preceding 50 years (1952–2002: 4.4 million hectares). Despite Australian forests residing in the fire flume (where certain weather conditions promote periodic fires of extreme intensity), it has been observed that recent fires have reburned the forests that were burned within the last decade. Given that many of these highly valued eucalypt forests are obligate seeders that require an interval of at least 15–25 years before reaching sexual maturity, there are significant questions about what this new fire paradigm implies for the variety of benefits these forests provide (water, biodiversity, carbon, recreation). This new dynamic, increasingly relevant under climate change, requires the focus to be directed to recurrent fires to assess the impact on forests and forest fuel management as it is currently practiced. Here we outline the preliminary results of studies on reburned forests in Victoria, seeking to illustrate the changes in species and structure, and whether any composition changes of these ecosystems may make them more susceptible to future fire.

Mulching treatments alter understory vegetation in forested ecosystems of the western United States. Fornwalt, P., Rhoades, C., Battaglia, M. (*U.S. Forest Service, USA; pfornwalt@fs.fed.us; crhoades@fs.fed.us; mbattaglia34@gmail.com*), Rocca, M. (*Colorado State University, USA; rocca@warnercnr.colostate.edu*).

Forest mulching treatments (chipping or shredding woody biomass and broadcasting it on the forest floor) have been increasingly utilized by land managers in the last decade to restore forest structure and reduce the risk of catastrophic wildfire. Because mulching treatments are relatively novel and have no natural analog, their potential ecological impacts are poorly understood. We initiated a study in 2007 to examine the effects of mulching treatments on understory vegetation and other critical ecosystem components. We established 17 sites across Colorado, with 7 in lodgepole pine forests, 5 in ponderosa pine forests, and 5 in pinyon pine–juniper forests. Understory vegetation sampling occurred in 2007 or 2008 (2 to 4 years post-treatment) and again in

2012 (6 to 9 years post-treatment) along six transects located in mulched and adjacent untreated stands. Data are being analyzed to address several questions about the short- and long-term impacts of mulching treatments, including: (1) How do mulching treatments impact understory richness and cover? (2) Do mulching treatments influence understory composition? (3) Do mulching treatments favor nonnative species? Our findings will improve the ability of managers and others to anticipate understory dynamics following mulching treatments and to determine if additional activities are required to meet desired understory conditions.

Greek fir forests, fire and climate change. Raftoyannis, Y. (*Central Greece University of Applied Sciences, Greece; rafto@teilam.gr*), Spanos, I. (*Forest Research Institute, Greece; ispanos@fri.gr*).

The Greek fir (*Abies cephalonica* Loudon) is a dominant tree species of the mountainous Greece, where it forms extended productive and protective forests. The Greek fir is a fire-intolerant species mainly because of its thin resinous bark, shallow root system, flammable crown, and limited seed bank. In the Greek fir forests, fire was not considered a major threat, but in the last decades these forests have experienced large crown fires with subsequent ecological and economical losses. Fir forests used to have a patchy structure and fires burned in a mixed pattern, but after six decades of fire exclusion and silvicultural management, a large amount of biomass accumulation has increased the occurrence of fires of unusual size and severity. Furthermore, increasing drought incidences resulted in extended fir tree mortality with subsequent higher fire risk. Studies have shown that severe crown fires may knock succession back to herbs and shrubs or replace fir forests with the more fire tolerant oak forests. The purpose of this contribution is to present scientific information related to fires in Greek fir forests and their interrelationships with climate change and forest management. Fire prevention and post fire management measures will be also discussed.

Innovative techniques to suppress wildfires in the Black Sea region. Zibtsev, S. (*National University of Life and Environmental Sciences of Ukraine, Ukraine; sergiy.zibtsev@nubip.edu.ua*), Mitsopoulous, I. (*The Global Fire Monitoring Center (GFMC), Greece; ioanmits@gmail.com*), Mallinis, G. (*Democritus University of Thrace, Greece; gmallin@fmenr.duth.gr*), Saglam, B. (*Artvin Çoruh University, Turkey; saglambul@gmail.com*), Kucuk, O. (*Department of Forestry, Kastamonu University, Turkey; omerkucuk@kastamonu.edu.tr*), Zaimes, G., Borsuk, A., Fesenko, O.

Wildfires are major threats for all protected areas since they can cause irreversible damages to them or impacts that last for decades or even centuries. Many of the Black Sea region countries did not face major problems with fires in the past. Climate change is expected to increase the potential of large wildfires even in regions. Since most of the countries of this region have insufficient infrastructure to suppress fires it is necessary to find innovative techniques to enhance fire suppression in the region. Implementation of these techniques will take place in six pilot protected areas in six different countries of the Black Sea Region. The first action involves the accurate prediction of fire behavior and growth, considering predominantly the fuel parameters, weather conditions, and topography. Field measurements, remote sensing, along with Geographic Information Systems (GIS) will be utilized. The hydrologic model SWAT is used to estimate the water resources that are essential for the effective suppression of wildfires. Finally, specialized software will provide the optimal locations of the reservoirs and the best routes for the fire vehicles to reach the reservoirs. These innovative techniques will lead to the more cost-effective management of fires in the region.

Posters

Caloric values of species utilized in the composition of fuel breaks of Brazil. Assunção, R., Batista, A., Tetto, A. (*Federal University of Paraná, Brazil; rafa.assunc@gmail.com; batistaufpr@ufpr.br; tetto@ufpr.br*).

Among the techniques for forest fire prevention, fuel breaks stands out to be a simple and effective way to hinder the spread of forest fires. One of desired features is the heating value of the species used in the composition of the fuel breaks. This study aimed to evaluate the higher heat value (HHV) and the lower heat value (LHV) of four species with potential for use in fuel breaks: *Magnolia grandiflora*, *Psidium cattleianum, Rhododendron simsii* and *Evonymum japonica.* For this, we used the forest fuel smaller than 0.7 cm in diameter for determining the HHV in a bomb calorimeter. From the results of HHV, LHV of fuels was calculated and then compared with of HHV and LHV of *Pinus taeda* needles as a reference of forest fuel of high values of HHV and LHV. The results showed that the *Pinus taeda* needles showed higher results for both surveys. In the HHV analysis, *Rhododendron simsii* presented values nearest *Pinus taeda*, followed by *Evonymum japonica, Magnolia grandiflora,* and *Psidium cattleianum*, with values of 4 846.5, 4 754.5, 4 670, and 4 191 cal/g, respectively. The LHV showed the same trend. With the exception of azalea, all species have potential for use in fuel breaks.

Mastication effects on fuels, plants, and soils in four western U.S. ecosystems: trends with time-since-treatment. Battaglia, M., Rhoades, C. (*U.S. Forest Service, USA; mbattaglia34@gmail.com; crhoades@fs.fed.us*), Rocca, M. (*Colorado State University, USA; rocca@warnercnr.colostate.edu*), Fornwalt, P. (*U.S. Forest Service, USA; pfornwalt@fs.fed.us*).

Over the past decade, fire managers have increased their use of mastication treatments, the on-site disposal of small-diameter trees through chipping and shredding. Mastication is a relatively untested management practice that alters the chemical and physical conditions of the forest floor and may influence vegetation regrowth and fuel development for years. Mulch additions increase both the load and continuity of surface fuels, and create a new forest floor layer that may act as a physical barrier to plant germination or as a nutrient sink that retards plant growth. Plant inhibition by mulch layers could be short-lived, and, with time plant growth might be stimulated by changes in soil resources and site conditions as mulch layers age. The long-term effectiveness of mulch treatments will depend on physical and chemical conditions of the mulch layer, how these influence forest floor and soil resources and the recovery of herbaceous and ladder fuels. Our multi-year study includes 18 sites in 4 forest types distributed across the southern Rocky Mountains and Colorado plateau. We apply a common study design to assess factors that control mulch treatment longevity and quantify how the ecological responses to mastication vary with mulch quantity and arrangement and through time.

Asymmetric communication between media and stakeholders and its influences to the ineffectiveness of forest fire risk management in Indonesia. Ekayani, M. (*Bogor Agricultural University, Indonesia; metieka@yahoo.com*).

There were several asymmetrical perspectives between media discourses and stakeholder's perceptions about causes of fires and solutions to combat forest fires in Indonesia. Stakeholders perceived that forest fires were mostly caused intentionally. In contrast to stakeholders' perceptions, many causes of forest fire according to global media discourses were identified as accidental, due to natural factors. Although both media and stakeholders pointed to praxis as the most important solution in addressing forest fire, they emphasized different matters. Stakeholders usually emphasized on application of zero burning in land clearing activities and promoting community participation in forest management as the most effective solutions in fire risk management. Global news media, however, pointed out the direct efforts to address forest fires, such as extinguishing fires with water shooters or spraying water by using airplanes as the most frequent solutions. There were also some asymmetrical perspectives between stakeholders' perceptions and media discourses in defining the problem of forest fires. Stakeholders perceived that forest fires were closely related to economic problems, but media usually discussed forest fires on the perspective of ecological concerns. This study concluded that the asymmetric communication between media and stakeholders created ineffectiveness of forest fire risk management.

Targeting forest management through fire and erosion modeling. Elliot, W. (*U.S. Forest Service, USA; welliotfs@gmail.com*), Miller, M. (*Michigan Technical Research Institute, USA; mmaryellen@gmail.com*).

Forests deliver a number of ecosystem services including clean water. When forests are disturbed by wildfire, the timing, quantity, and quality of runoff are altered. A modeling study was carried out in the forested watershed in California to determine the risk of wildfire, and the potential sediment delivery from wildfire for approximately 6-ha polygons within the basin following wildfire. Wildfire severity was estimated with the FLAMMAP prediction tool based on current vegetation condition. The fire severity was estimated by the predicted flame length for each pixel and averaged for each polygon. Sediment delivery was estimated from each polygon using the WEPP Model in a GIS framework. Fire intensity and prefire fuel condition were used to estimate fire severity to build soil files. Polygons generating the greatest amount of sediment or were critical for reducing fire spread were "treated" by reducing the amount of fuel available for a wildfire. The fire and erosion models were run a second time to see if the treatment resulted in a reduced fire intensity, and hence a reduced erosion rate. Polygons showing the greatest net decrease in sediment delivery from treatment or important to protect other values at risk were prioritized for fuel reduction activities.

Planned burning vs. wildfire impact on soil methane flux: implications for forest fire management. Fest, B., Arndt, S., Livesley, S. (*The University of Melbourne, Australia; bfest@unimelb.edu.au; sarndt@unimelb.edu.au; sjlive@unimelb.edu.au*), Wardlaw, T. (*Forestry Tasmania, Australia; Tim.Wardlaw@forestrytas.com.au*).

Soils in forests ecosystem represent the largest land based methane (CH_4) sink and therefore provide an important ecosystem service. Fire can alter soil properties linked to soil CH_4 uptake potential but this has rarely been studied to date. We measured soil CH_4 flux at temperate eucalypt forest sites (Victoria, Australia) that had different planned fire frequency treatments applied (burns every 3 years and 10 years) in the last 27 years. We also studied soil CH_4 flux along a wildfire chronosequence spanning over 200 years (Tasmania, Australia). Our data show that planned fire and wildfires had contrasting effects on forest soil CH_4 uptake. The repeated planned burning treatments did not alter CH_4 flux patterns of forest soil. In the wildfire chronosequence, the CH_4 uptake capacity of the forest soil was closely related to stand development and stand water use, with stands that used more water having greater CH_4 uptake. Our data demonstrate that unmanaged wildfire can have substantial impact on the CH_4 sink capacity of forest ecosystems in Australia while the less intense planned burning fires have little effect. The effects of fire were more related to changes in stand structure rather than impacts of fire on soils per se.

Potential impacts of climate change on fire socioeconomic vulnerability in the Mediterranean area. González-Cabán, A. (*U.S. Forest Service, USA; agonzalezcaban@fs.fed.us*), Molina Martinez, J., Rodriguez y Silva, F. (*University of Cordoba, Spain; o92momaj@uco.es; ir1rosif@uco.es*).

Climate change is one of the most significant problems of the 21st century because of its potential social, economic and ecological consequences. Recent years have seen an increase in research and technologies trying to help refine efficiencies in mitigation and adaptation to climate change. Weather forecasting models alert us to increases in temperature and a decrease in rainfall. A corollary effect of these changes is an increase in climatic related events such as wildfires. Increases in temperature and decreases in rainfall contribute to a reduction in hazardous fuels humidity causing an increase in the intensity of wildfires and resulting damage. This translates into greater consumption of vegetation, loss of natural resources and ecosystem services, and reduced ecosystem resilience. Using GIS allows comparing current conditions to predicted future scenario conditions as well as socioeconomic vulnerability among current, mid-, and long-term conditions (2041–2070). For example, we estimate an increase of between 2.50 and 23.37% in socioeconomic vulnerability for the Córdoba Province, Spain. Digital models to estimate socioeconomic vulnerability increase natural managers' capabilities to respond and adapt to future climate change scenario predictions.

Quantifying management priorities in urban interfaces threatened by wildfires. Lafortezza, R., Elia, M., Sanesi, G., Colangelo, G. (*University of Bari, Italy; raffaele.lafortezza@uniba.it; mario.elia@uniba.it; giovanni.sanesi@uniba.it; giuseppe.colangelo@uniba.it*).

Wildfires are increasingly impinging upon human populations because of anthropogenic changes to the global fire cycle. Large investments are therefore required to prevent fire from spreading into urban areas to protect human life and reduce property damage. However, prioritizing fuel management by identifying sites where the greatest number of people are affected by wildfires is often a challenge for governments because of limited resources. Here, we show how to quantify management priorities and allocate interventions (i.e., fuel removals from forests) in interfaces between urban and wildland areas threatened by wildfires. We developed a landscape-level management priority index which integrates social, economic, and ecological factors. We apply this method to southern Italy as a case example, where fires have been increasing in both magnitude and frequency. Our results highlight the need to prioritize fuel removals in densely populated landscapes in terms of maximizing the number of people

affected by wildfire suppression per dollar spent on fuel removal. More broadly, we suggest that this approach could form the basis of wildfire suppression in urban regions across the globe and can be applied easily towards allocating any type of management intervention in any ecosystem.

Spatial data mining application in forest fire assessment in tropical peat areas. Nuruddin, A. (*Universiti Putra Malaysia, Malaysia; ainuddin@upm.edu.my*), Sitanggang, I. (*Bogor Agricultural University, Indonesia; imas.sitanggang@gmail.com*), Yaakob, R., Mustapha, N. (*Universiti Putra Malaysia, Malaysia; razaliy@upm.edu.my; norwati@upm.edu.my*).

Forest fires are considered a potential hazard that causes physical, biological, and environmental losses. Recent forest fires in tropical peat areas have created atmospheric haze and transboundary pollution. Identifying high fire hazard areas in tropical peat areas can help in forest fire management and reduce atmospheric haze pollution. With the advancement of computer technology, data mining techniques and tools can be used to assess areas with the potential for high hazard to forest fires. This work explores spatial data mining techniques for predicting occurrence of hotspots. The study area was conducted in Rokan Hilir district in Riau Province in Indonesia where peat fires occur during the dry season. The spatial dataset containing spread of hotspots, land cover, rivers, roads, city centers, and peatland was used with socio-economic factors and weather factors. The results showed that spatial decision trees for predicting hotspots had higher accuracy compared to those not using spatial data mining techniques. This study shows the potential of spatial data mining techniques in forest fire hazard assessment in tropical peat areas.

Spatial analysis of forest fire and burnt area in the Northwest of Madagascar: role in forest management and biodiversity conservation. Rakoto Ratsimba, H., Ratovoson, A., Rabenilalana, F. (*University of Antananarivo, Madagascar; rrharifidy@moov.mg; rainanavale@yahoo.fr; rmihajamanana@yahoo.fr*), Bogaert, J. (*Université de Liège / Gembloux Agro-Bio Tech, Belgium; j.bogaert@ulg.ac.be*).

Mapping forests and extent of fires has a crucial role in forest management and biodiversity conservation in Madagascar. Fire remains one of the main causes of deforestation. Even though the forests of Madagascar are among the most biologically rich and unique in the world, few researches have studied at the regional level the spatial relationship between fires (forest and other types) and deforestation. The northwestern forests of the country are one of the most regularly affected by fire and whose frequencies and extents are not known at the spatial level. Fire is a disturbance factor that affects directly (deforestation) and indirectly (greenhouse gas emission, soil degradation in the watershed) the habitat and is generally considered as a key factor of species extinction. Fires have different origins in the region and affect all or some of the different land uses in the landscape linked with their size. MODIS burnt area images have been used from 2000 to 2013. The images have been selected each month to provide a consistent database. This collection of images shows the frequencies of fire (regularly or punctual burnt areas) and the frequency of forest and nonforest fires.

Influencing factors on early vegetation restoration in burned area of *Pinus pumila*–larch forest. Zhao, F. (*Chinese Academy of Forestry, China; zhaofengjun1219@163.com*).

Pinus pumila, a rare conifer and key species in high latitude and high altitude mountains, has an important role in soil and water conservation. This evergreen shrub grows in the Greater Kingan Mountain Range in *P. pumila* – larch (*Larix gmelini*) open forest. Fires are major natural hazards to the forest. We studied the factors which influence early vegetation restoration, especially those related to *P. pumila* seedling establishment. The results show fires in *P. pumila* – larch forest usually resulted in severe burns. Typically almost no *P. pumila* survived after fires. Second growth after fires exhibited low species richness. The dominant tree seedlings found after fires were birch (*Betula platyphylla)* and larch, with a small number of *P. pumila*. Important factors influencing early vegetation restoration after fires include seed dispersal, burned area extent, and site condition. The main factor influencing seedling establishment in *P. pumila* is its weak seed dispersal ability. Although the *P. pumila* seeds can germinate in all burned areas, natural regeneration rarely restores burned areas to the original *P. pumila* – larch forest. Planting seeds and/or seedlings may facilitate burned area restoration to *P. pumila* – larch forest.

Investigation of emissions from heated essential-oil-rich fuels. Zhao, F., Shu, L., Wang, M., Tian, X. (*Chinese Academy of Forestry, China; zhaofengjun1219@163.com; slfhxk@126.com; oldchoff@163.com; tianxr@caf.ac.cn*).

Essential oil of fuels is closely linked with the behavior of forest fires, especially high intensity fires and eruptive fires. It is assumed that the potential reason is the large quantities of flammable gases released from essential-oil-rich fuels before pyrolysis in fire environment. However, few studies have been done on the hypothesis. The purpose of the present study is to investigate the emissions from essential-oil rich fuels. The fuels were collected from three coniferous species. In the experiment, needles and twigs were heated in a vacuum oven at 200 °C, and the emissions within 15 min had been sampled using Tenax-tubes. Gas chromatography–mass spectrometry (GC-MS) served as an analytical instrument. The results showed that the emissions contained high proportions of monoterpenes, such as α-pinene, camphene, β-pinene, 3-carene, and d-limonene. The monoterpene emissions from heated needles and twigs of *Pinus pumila*, *Larix gmelinii*, and *Pinus sylvestris* were 61.221 μg/g DW (dry weight), 49.606 μg/g DW, 37.853 μg/g DW, and 211.727 μg/g DW, 139.957 μg/g DW, 121.505 μg/g DW, respectively. Statistical analyses showed the significant differences not only among species but also between needles and twigs.

C-09 Dendrochronology: detecting and modelling climate change and fire impacts

Organizer: Pekka Saranpää (Finnish Forest Research Institute, Finland)

Seasonal distribution of processes responsible for radial diameters and wall thickness of scots pine tracheids. Antonova, G., Stasova, V. (*Sukachev Institute of Forest, Russia; antonova_cell@mail.ru; gfantonova@ksc.krasn.ru*).

The objective of the study was to evaluate timeframes of processes responsible for the number of cells, their radial diameters, and wall thickness in annual wood increment of Scots pine in the course of season vegetation. The processes are production of cells

by cambium, radial cell expansion, and secondary wall thickening. Throughout the season, these processes occurred at different times but overlapped each other. In the conditions of Middle Siberia (Russia), the production of cells by cambium was observed in June and July. Radial diameter growth of earlywood tracheids occurred mainly in June, latewood tracheids in July. The development of secondary wall thickening of earlywood cells occurred in June-July, latewood ones in August and the first half of September. Hydrothermal conditions of these months considerably affected morphological parameters of these tracheids. Each of these processes reacted on environmental factors independently and had their own optimum temperatures, which is the cause of differences in cell wall biomass deposited in separate periods of the season. The data should be taken into consideration in the solution of the problem of productivity and quality of wood produced in different climate conditions.

Fire impact on the structure and dynamic of *Prosopis caldenia* woodlands in the Argentinean pampas. Bogino, S. (*State University of San Luis, Argentina; stellabogino@gmail.com*), Vivalda, F., Dussart de la Iglesia, E (*State University of La Pampa, Argentina; florvivalda@hotmail.com; estebangdussart@yahoo.fr*).

Prosopis caldenia (Burkart) woodlands dominate the driest part of the Argentinean Pampas covering more than 30 000 km^2. Fire is considered as the main natural disturbance factor affecting this area. The objective of this work was to detect the fire impact on the age structure and the radial growth of *P. caldenia* woodlands. Standard dendrochronological analysis of 70 cross sections was applied on samples from mature and renewal stands. Mature forest establishment occurred in the 1890s as a result of regrowth of post-fire stumps, but presently they are dominated by post-fire trees regenerated in the 1920s. Since the 1990s, regeneration has been dominated by *Schinus fasciculatus*. Renewals forests originated in the mid 1960s, with a massive recruitment of caldén trees in the 1980s as a result of fire. Since 1990, fire events have doubled. The analysis of variance determined significant differences between radial growth of the eldest and the youngest individuals of both stands. The eldest individuals of both stands showed similar growth rates. This work suggests that these woodlands dynamic is historically linked with fire events and their growth rates depend on woodland initial density.

Site selection for dendroclimatological studies with *Bertholletia excelsa*. Mattos, P., Santos, A., Garrastazu, M., Muñoz-Braz, E., Tonini, H. (*EMBRAPA, Brazil; patricia.mattos@embrapa.br; andreiataborda@yahoo.com.br; marilice.garrastazu@embrapa.br; evaldo.braz@embrapa.br; helio.tonini@embrapa.br*).

In this study, the dendroclimatological potential of four sites selected for characterizing the genetic variability of *Bertholletia excelsa* in the state of Mato Grosso, with available samples (SISBIO-32932), was evaluated. *Bertholletia excelsa* is a long-lived species with wide distribution in the Amazon region and present visible annual growth rings. The geographic coordinates of the trees in the state of Mato Grosso, Brazil were obtained, and they were complemented with the coordinates available at CRIA site (Reference Center on Environmental Information), from different herbariums. The layers were obtained from the weather database Worldclim. The algorithm Environmental Distance was applied in the openModeller software. It was observed that in all four sites with samples available, the species occurrence potential was above 90%, suggesting that those sites will present growth rings with low sensitivity to climatic variables. However, at the sites at Alta Floresta and Itaúba counties, it was observed in adjacent areas where the *Bertholletia excelsa* occurrence potential was between 50 and 70%. As the pixel size to generate the information was about one kilometer, it is suggested that the samples from Alta Floresta and Itaúba may present potential for application in dendroclimatological studies in the Amazon region from Mato Grosso State.

Responses of the radial growth of trees to climate change at the timberline in southeast Tibetan Plateau. Shang, H. (*Chinese Academy of Forestry, China; shanghechina@126.com*).

Southeast Tibet is characterized by a cold and humid climate and a high diversity of forest types with the highest timberlines in the world. In order to examine the difference in climate response between the shade-tolerant and intolerant tree species, tree-ring width chronologies of Georgei fir (*Abies georgei var. smithii*) growing on the shady slope and *Sabina saltuaria* (Rehd. et Wils.) Cheng et W. T. Wang on the sunny slope at the timberline in the Sygera Mountains in southeast Tibet of China were developed. Both standard chronologies show significantly positive correlations with mean summer (June-August) temperature. The tree-ring width growth of *Sabina saltuaria* responded sensitively to recent warming observed in the instrumental record since 1961, with the last decade being the warmest period in the past 242 years, while tree-ring width of Georgei fir did not track the warming trend in southeast Tibet. In brief, at the timberline of Sygera Mountains, the growth of *Sabina saltuaria* responds more sensitively to climate change than that of Georgei fir. Respective biological characteristics and habitat adaptation of both the tree species might result in the differences, implying the significance of tree species selection in paleoclimatic reconstruction.

C-10 Vegetation zone shifts in response to climate change

Organizers: Constance Millar (U.S. Forest Service) & Pavel Cudlin (Global Change Research Centre, Academy of Sciences of the Czech Republic)

Can the shift of vegetation zones be thought of an efficient adaptation mechanism or just a wishful thinking? Cudlin, P. (*Academy of Sciences of the Czech Republic, Czech Republic; pavelcu@usbe.cas.cz*), Hlásny, T. (*National Forest Centre, Slovakia; hlasny@nlcsk.org*), Matějka, K. (*IDS, Czech Republic; matejka@infodatasys.cz*), Treml, V. (*Charles University in Prague, Czech Republic; treml@natur.cuni.cz*), Macků, J. (*Forest Management Institute, Czech Republic; macku.jaromir@uhul.cz*), Marek, M. (*Global Change Research Centre, Czech Republic; marek.mv@czechglobe.cz*).

A growing body of evidence suggests that processes such as treeline upward expansion, drought induced retraction of species lower-range limit, and shift of vegetation zones may occur in response to global climate change. Vegetation shift needs to be considered as an inherent adaptation mechanism allowing species to track climatically suitable sites. Such shift can, however, be limited by a variety of nonclimatic factors such as nutrient availability, soil conditions, landscape fragmentation, or species-specific traits such as dispersal capacity, competition with ground vegetation, or presence of mycorrhizal fungal symbionts. Many

changes have been observed in species distributions, but no evidence of complete community exchange has been registered yet. Climatic signal can also be confounded by human influence; for example increased forest dynamics at tree line ecotone owing to coupled effect of climate change and agricultural land abandonment frequently occurs in Central European mountain ranges. The aim of this study was to review critically the recent observations and projections of climate change induced shifts of forest tree species with focus on Central Europe, the region with limited knowledge of climate change effect on ecosystems. Moreover, implications of our findings for forest development and provision of key ecosystem services are discussed.

Integrated approach for Aleppo pine assisted migration toward expected climate change in the Mediterranean basin (Spain). Del Campo, A. (*Universidad Politécnica de Valencia, Spain; ancamga@upv.es*), Taibi, K. (*University of Tiaret- UPV, Algeria; khaledtaibi@hotmail.com*), Mulet, J. (*UPV, Spain; jmmulet@ibmcp.upv.es*), Aguado, A. (T*he Spanish Ministry of Agriculture, Food and the Environment (MAGRAMA), Spain; aaguado@magrama.es*).

Large-scale biogeographical shifts in forest tree distributions are predicted in response to the altered precipitation and temperature regimes associated with climate change. Adaptive forest management to climate change either in stable or rapidly changing environments must consider this fact when carrying out reforestation programs or specifically assisted population migration for conservation purposes. Our hypothesis was that current marginal habitat due to low temperature is shifting to central habitat and that current central habitat will shift to warmer and dryer marginal habitat. Thus, our experimental design reproduced real conditions of reforestation in potential future climatic conditions. Intraspecific variability of planted *Pinus halepensis* genotypes (covering a wide natural range in Spain) was evaluated in cold and dry marginal habitat sites and in a control (central habitat) site for the species as well as under greenhouse controlled conditions, to screen according to specific conditions. An integrated approach was compiled based on the study of survival, growth, and ecophysiological behavior coupled with the evaluation of stability through genotype by environment interactions and the optimization of the proteomical tools for the identification of molecular markers of tolerance to specific conditions. Relationships between genotypes characteristics and inhabited environments are also discussed.

Towards climate-smart forest landscape management in the neo-tropics: climate, soil and spatial effects on vegetation in three altitudinal gradients. Finegan, B. (*CATIE, Costa Rica; bfinegan@catie.ac.cr*), Ruiz, C. (*CATIE, Colombia; eruizo@catie.ac.cr*), Veintimilla, D. (*CATIE, Ecuador; darioalfredov@yahoo.com*), Vilchez, S. (*CATIE, Costa Rica; svilchez@catie.ac.cr*), Chavarría, A. (*Independent consultant, Honduras; achavarria1981@hotmail.es*), Delgado, D., Bejarano, L., Jiménez, M, Nieto, V., Gaitán, E., Imbach, P.

Tropical mountain forests are vital ecosystems gravely threatened by climate change. Greater understanding of factors underlying forest change on altitudinal gradients is necessary as a basis for adaptation measures. We report results from research in rain forest landscapes in Honduras, Costa Rica, and Colombia. We implemented baseline studies of forest taxonomic (trees, palms, and tree-ferns >10 cm DBH, lianas >2 cm DBH) and functional (eight leaf and stem traits) composition and diversity. Downscaling of present and future climates in each landscape was done using the FIC two-step statistical approach (four ESMs, RCP 2.6, 4.5, and 8.5). Climate, soil, and spatial predictors were used in variation partitioning analysis to determine drivers of spatial change in forest characteristics. By 2085, precipitation may increase by up to 15–30% in each landscape, though temperature increases of up to 2–3.5 °C will have greater ecological impacts. Downscaling resolution was limited by very scarce local meteorological data, so vegetation analysis used Worldclim data. Temperature and rainfall seasonality are the main drivers of spatial change in forest taxonomic and functional composition (weighted mean trait values), but the latter suggests resilience is greatest at intermediate altitudes. Follow-up will apply these results in socio-ecological vulnerability analysis to direct adaptation measures.

Global tree range shifts under forecasts from two alternative gcms using two future scenarios. Hargrove, W. (*U.S. Forest Service, USA; hnw@geobabble.org*), Potter, K. (*North Carolina State University, USA; kpotter@ncsu.edu*).

Global shifts in the environmentally suitable ranges of 215 tree species were predicted under forecasts from two GCMs (the Parallel Climate Model (PCM), and the Hadley Model), each under two IPCC future climatic scenarios (A1 and B1), each at two future dates (2050 and 2100). The analysis considers all global land surface at a resolution of 4 km^2. A statistical multivariate clustering procedure was used to quantitatively delineate 30 thousand environmentally homogeneous ecoregions across present and eight potential future global locations at once, using global maps of 17 environmental characteristics describing temperature, precipitation, soils, topography, and solar insolation. Presence of each tree species on Forest Inventory Analysis (FIA) plots and in Global Biodiversity Information Facility (GBIF) samples was used to select a subset of suitable ecoregions from the full set of 30 thousand. Predicted present ranges correspond well with current understanding for all but a few tree species, which can then be tracked into the future to determine whether the suitable home range remains the same, moves, grows, shrinks, or disappears. Using associative clustering, we scaled up the FIA point measurements into continuous maps that show the expected growth and suitability for individual tree species across the continental United States.

Climate change shifts environmental space and limits transferability of treeline models. Lehtonen, A. (*Finnish Forest Research Institute (Metla), Finland; aleksi.lehtonen@metla.fi*), Schibalski, A. (*University of Potsdam, Germany; anett.schibalski@uni-potsdam.de*), Schröder, B. (*Technical University of Braunschweig, Germany; boris.schroeder@tu-braunschweig.de*).

Our study aims at gaining insights into the processes determining the current treeline dynamics in Finnish Lapland. Using forest surveys conducted in 1978 and 2003, we modelled the occurrence and abundance of three dominant tree species in Finnish Lapland (*Pinus sylvestris*, *Picea abies,* and *Betula pubescens*) with boosted regression trees. We assessed the importance of climatic, biotic, and topographic variables in predicting tree occurrence and abundance based on their relative importance and response curves. We compared temporal and spatial transferability by using an extended transferability index. Site fertility, the abundance of co-occurring species, and growing degree days were generally the most important predictors for both occurrence and abundance across all species and datasets. Climatic predictors were more important for modelling occurrences than for modelling abundances. Occurrence models were able to reproduce the observed treeline pattern within one time period or region.

Abundance models underestimated basal area but captured the general pattern of low and high values. Comparing the environmental space between datasets revealed that transferring models means extrapolating to novel environments, providing a plausible explanation for limited transferability. Our study illustrates how climate change can shift the environmental space and lead to limited model transferability.

Assessment of vulnerability and impacts of climate change on tropical forests in Papua New Guinea (PNG). Maiguo, E., Keenan, R., Nitschke, C. (*University of Melbourne, Australia, Australia; emaiguo@student.unimelb.edu.au; rkeenan@unimelb.edu.au; cnitschke@unimelb.edu.au*).

The vulnerability and impacts of 20 tree species in PNG to climate change were assessed using a mechanistic modeling approach that assesses suitability for regeneration and growth under varying climate scenarios. By the year 2080, the lowland tree species were modelled to shift to higher elevation, while their probability of regenerating below 400 m was modelled to fall below 10%. Nothofagus and coniferous species that currently dominate the upper montane forest zone were modelled to lose climatic suitability below 2 500 m but are unlikely to migrate above the current treeline at 3 500 m elevation due to continual frosts and drought effects exacerbated by the shallow alpine soils. Forests that occur between 800 m to 2 000 m in elevation may see increases in plant richness, as both lowland and mid-elevation species will find this region suitable for regeneration and growth by the 2080s. Climate change may cause impacts on species composition within the forests of PNG, which in turn would have effects on the national economy, biodiversity, and community dependency from forests. Further research is needed to explore the roles of seed ecology, disturbance, and interspecific competition in these forests, as these processes may facilitate changes in species composition and distribution.

Contrasting modes of response to historic and contemporary. Millar, C. (*U.S. Forest Service, USA; cmillar@fs.fed.us*).

Conifer species respond to changes in historic and ongoing mountain climates in diverse and individualistic manners that vary within and across mountain ranges. Projections from bioclimatic modeling, e.g., that species will shift upslope, serve as organizing hypotheses against which to assess observational data. From the standpoint of pattern (e.g., treeline shift), many responses to climate change in addition to upslope movement become apparent, including changes in community composition, shifts in aspect, movement downslope, changes in mortality, and genetic adaptation. Considering process, meso- to micro-scale climate forces drive ecological change in complex mountain environments as well as the more widely assumed responses to macro- or synoptic climates. Storm track movements, wind funneling, and cold-air pooling, for example, create mosaics of habitat that many species track more closely than upper atmospheric influences. Some of these processes, such as cold-air pooling, are highly localized, at least partially decoupled from ambient regional climates, and subject to abrupt change. I use examples from the Sierra Nevada and Great Basin to illustrate the importance of these patterns and processes for understanding future responses to global warming, for model projections, and for planning effective climate adaptation strategies.

Conservation and management of western North American trees in complex landscapes: considering glacial refugia, post-glacial migration, and the velocity of climate change. Roberts, D., Hamann, A. (*University of Alberta, Canada; drr3@ualberta.ca; andreas.hamann@ualberta.ca*).

Historical biogeography can provide valuable information about the conservation of genetic diversity, migration capacities, and adaptation potential of species. To assess potential for species to cope with future climate change, we examine patterns of post-glacial migration and phylogeography of North American trees. First, using reconstructions of Late Pleistocene glacial ranges from species distribution models, we attempt to quantify the effect of glacial bottlenecks on genetic diversity, finding that species with strong genetic differentiation had widespread and large glacial refugia while those with restricted refugia show little differentiation despite being common over a diversity of environments today (66% and 27% of the variance in allelic richness and heterozygosity, respectively, was explained by reconstructed glacial ranges). Second, while today's species have proven their ability to cope with the glacial-interglacial climate cycles of the Quaternary, future migration requirements will be different with respect to speed, direction, geographic barriers, and availability of nearby climate refugia. Utilizing a metric of climate change velocity, we conduct a geospatial analysis of post-glacial vs. future migration requirements for North American trees. Implications for human-assisted migration and conservation action to address climate change at the genetic population level will be discussed.

Siberian potential forest types and fire load projected from IPCC climates in the 21st century. Tchebakova, N., Parfenova, E. (*Sukachev Institute of Forest, Russia; ncheby@ksc.krasn.ru; lyeti@ksc.krasn.ru*), Soja, A. (*Natioanl Institute of Aerospace, USA; Amber.J.Soja@nasa.gov*), Conard, S. (*U.S. Forest Service, USA; sgconard@aol.com*).

We modeled progressions of potential vegetation cover, forest-forming tree species and forest types in Russia in the warming climate during the 21st century. Large-scale bioclimatic models were developed to predict Russian zonal vegetation (RuBCliM) and forest types (ForCliM) from three bioclimatic indices (1) growing degree-days above 5 °C; (2) negative degree-days below 0 °C; and (3) an annual moisture index (ratio of growing degree days to annual precipitation). Additionally, the presence or absence of continuous permafrost was explicitly included in the models as limiting the forests and tree species distribution in Siberia. All simulations to predict vegetation change across Russia were run by coupling our bioclimatic models with bioclimatic indices and the permafrost distribution for the baseline period and for the future 2020, 2050, and 2100 simulated by three global climate models (CGCM3.1, HadCM3 and IPSLCM4) and three climate change scenarios (A1B, A2, and B1). With these projected climates, the zonobiomes would need to shift far to the north in order to reach equilibrium with the change in climate. Under the warmer and drier projected future climate, about half of Russia would be suitable for the forest-steppe ecotone and grasslands rather than for forests. Water stress tolerant light-needled taiga (*Pinus sylvestris* and *Larix* spp.) would have an increased advantage over water-loving dark-needled taiga (*Pinus sibirica, Abies sibirica, Picea obovata)* in a new climate. The permafrost-tolerant *L. dahurica* taiga would remain the dominant forest type across the permafrost areas.

C-11 Forest resistance and resilience in the face of natural hazards

Organizers: Alexia Stokes (National Institute for Environmental and Agricultural Science and Research, France), Frank Telewski (Michigan State University, USA) & Thierry Fourcaud (CIRAD, France)

Understory dynamics after disturbance accelerate succession from spruce to beech dominated forest. Bolte, H., Hilbrig, L. (*Thünen Institute of Forest Ecosystems, Germany; andreas.bolte@ti.bund.de; lutz.hilbrig@ti.bund.de*), Grundmann, B., Roloff, A. (*Dresden University of Technology, Germany; grund@forst.tu-dresden.de; roloff@forst.tu-dresden.de*), Brunet, J. (*Southern Swedish Forest Research Centre, Sweden; jorg.brunet@slu.se*).

It is assumed that climate change will favor European beech (*Fagus sylvatica* L.) to Norway spruce (*Picea abies* [L.] Karst.) at its northern range margins due to climate change and induced disturbance events. An old-growth mixed forest of spruce and beech, situated near the northern beech margin in Sweden, was studied to reveal effects of disturbances and response processes on natural forest dynamics. We carried out analyses on understory dynamics of beech and spruce in relation to overstory release. This was done based on a sequence of stand and tree vitality inventories after a series of abiotic and biotic disturbances from 2004 to 2011 (storm, drought, and bark beetle attacks). It became apparent that beech (understory) has a larger adaptive capacity to disturbance impacts and overstory release (68% standing volume loss) than spruce. Understory dynamics can play a key role for forest succession from spruce to beech dominated forests. Disturbances display an acceleration effect on forest succession in the face of climate change. Beech is poised strategically to replace spruce as the dominant tree species at the study area. Due to an increasing productivity and a lower risk of stand failure, beech may raise into the focus of forestry in southern Sweden.

Spatial analyze of trends in extreme precipitation and prediction the landslide susceptibility of national forestland in Kaoping Basin, Taiwan. Huang, Y., Chen, M. (*National Pingtung University of Science and Technology, China-Taipei; goodrinoa93@gmail.com; billchen3994@yahoo.com.tw*), Wu, S. (*Shih Chien University, China-Taipei; stwu@mail.kh.usc.edu.tw*), Chen, C., Chen, J. (*National Pingtung University of Science and Technology, China-Taipei; cct@gisfore.npust.edu.tw; zzz.john@msa.hinet.net*).

The purposes of this study were to create an understanding of long-term rainfall information and predict the potential landslide area in Kaoping basin, Taiwan. We collected precipitation data during 1993–2009 on the study site via spatial analysis of Kriging method. The rainfall from Typhoon Morakot concentrated on the upstream basin of Kaoping in 2009, and it caused severe landslides. Moreover, we calculated the precipitation data of 17 years in place with frequency methods**.** We found the frequency trends variation of climate was higher after 2005 from trends of long-term precipitation data. Furthermore, the precipitation intensity became stronger. Besides those subjects, we were also predicting the potential landslide area using the dangerous value method in Kaoping basin. The FORMOSAT-2 image collected in 2009 was used to make the potential map of landslides. It classified five levels as Low, Mid-low, Middle, Mid-high, and High via the Jenk Natural Break method. The result were compared with the landslide area in 2012 and showed that 91.39% of the landslide area mostly occurred above the Mid-high potential area. We suggested implementing the restoration strategy on the mid-low potential landslide area in cooperation with some slope stabilizing projects on the weak mid-high potential area to deal with challenge of extreme climate by strengthen the forest health and reducing weaknesses to ensure the sustainable forest management.

Multi-year response to historic drought-induced canopy dieback in a Mediterranean-type forest in southwestern Australia. Matusick III, G., Ruthrof, K., Fontaine, J., Hardy, G. (*Murdoch University, Australia; G.Matusick@murdoch.edu.au; K.Ruthrof@murdoch.edu.au; J.Fontaine@murdoch.edu.au; g.hardy@murdoch.edu.au*).

Although records of forest dieback from drought are becoming increasingly common, little is known about the response of forests to this disturbance. We examined the changes in tree health, forest structure, and composition following an historic drought-induced forest dieback event on severely- and minimally-affected forest plots in the Northern Jarrah Forest of southwestern Australia. Forest structure and composition were measured at 0, 16, and 26 months post-disturbance. Tree health dynamics suggest the dieback resulted from severe, acute stress. Overstory trees in severely-affected forest patches responded strongly, with 66% of trees resprouting by 16 months post-dieback. Recruitment of new individuals was higher in severely-affected plots, and living tree densities reached pre-dieback levels by 26 months following the event. On severely-affected plots, large diameter trees that died were replaced by greater numbers of small stems, decreasing the height of forest canopy and creating a dense thicket of regrowth. No direct evidence of forest composition change was detected in overstory trees. We propose that adequate rainfall following the event combined with species adaptation to drought contributed to the rapid response of affected trees. This research highlights the stabilizing properties of Mediterranean-type forests and their resilience in preventing ecosystem-type changes seen elsewhere following drought.

Strategies for improving hybrid-mechanistic windthrow models. Mitchell, S. (*University of British Columbia, Canada; stephen.mitchell@ubc.ca*).

Windthrow results when the wind loads acting on individual trees exceed their stem or anchorage resistance, leading to stem breakage or uprooting. Recurrent windthrow is an important natural disturbance process, impacting stand and forest level plans, and can pose a threat to human safety and infrastructure. Hybrid empirical-mechanistic approaches provide scientists with useful frameworks for integrating knowledge of component processes, but they are simplified representations of the biology and mechanics of windthrow and of the range of site and stand conditions within which windthrow occurs. Hybrid-mechanistic models have been integrated with regional climate models, forest inventories, and growth and yield models within GIS-based decision support systems that enable practitioners to evaluate contrasting management and climate scenarios. They could be further improved by better representing the interaction of wind and canopies, tree-to-tree interactions, acclimative growth responses, and the process of damage propagation during storms. New information sources and strategies for incorporating these processes into hybrid-mechanistic windthrow models will be discussed.

Natural hazards in forests – does time heal all wounds? Stokes, A. (*National Institute for Agricultural Research* (*INRA), France; alexia.stokes@cirad.fr*), Fourcaud, T. (*CIRAD, France; thierry.fourcaud@cirad.fr*), Telewski, F. (*Michigan State University, USA; telewski@cpa.msu.edu*).

Forests subjected to severe anthropogenic pressure or naturally occurring pressures in marginal environments are extremely susceptible to climate change. Extreme weather events, such as excessive temperatures, storms, and droughts, will have short- and long-term effects on tree health and mortality. Tree uprooting or breakage of stems or branches in response to soil-saturating rains, strong winds, or heavy ice or snow loading during a storm, or damage induced by avalanches or landslides after heavy precipitation, will require a rapid response from forest managers. Any immediate danger to people and infrastructure can be dealt with and insurance claims pursued. However, the long-term consequences can be more difficult to discern. For example, storm damage which has injured trees without causing immediate mortality can weaken trees, rendering them susceptible to insect and pathogen attack, and ultimately resulting in death. We will overview both the short- and long-term consequences of natural hazards on natural, plantation, and urban forests. We will explore how forests can withstand geomorphological and weather hazards through either natural processes or adapted management methods. We will also investigate the mechanisms of ecosystem failure and resilience if a disturbance does occur, and will aim at obtaining a holistic vision of the problems encountered and potential solutions.

Thigmomorphogenesis: increasing tree resistance to wind storms. Telewski, F. (*Michigan State University, USA; telewski@cpa.msu.edu*).

The influence of wind on tree growth and form was first reported by Theophrastus in 300 B.C., with the first experiments conducted on trees by Knight in 1803. Thigmomorphogenesis, first coined by Jaffe (1973), describes the influence of wind and other mechanical perturbations on tree growth and form. Trees growing in windy, exposed regions are shorter with thicker stems and shorter branches which sometimes obtain a wind-swept growth form. These alterations in allometry provide a reduced profile of the crown, reducing wind-induced drag while increasing overall stiffness of the main trunk. Internally, mechanical loading alters the development of wood structure and mechanical properties. Wood production is increased in the direction of the prevailing wind direction, but the mechanical property, the elastic modulus, is reduced. This provides for a stiffer trunk of greater diameter which is capable of absorbing increased mechanical energy. The physiological response to wind-induced flexure is rapid, with the first phase of perception occurring within seconds after exposure. This talk will review the thigmomorphogenetic response in trees to wind.

Impact of changing climate and disturbances on forests providing protection from gravitational hazards. Vacchiano, G., Berretti, R., Bottero, A., Meloni, F., Sibona, E., Motta, R. (*University of Torino, Italy; giorgio.vacchiano@unito.it; roberta.berretti@unito.it; alessandra.bottero@unito.it; fabio.meloni@unito.it; mannyx@teletu.it; renzo.motta@unito.it*).

Protection of people and infrastructures from gravitational hazards (rockfall, avalanches, debris flows) is an important service provided by mountain forests in the world's populated areas. In Europe, silvicultural options to maintain, improve, and restore the protective function of such forests have been suggested. However, to maximize future protection from gravitational hazards, management of these forests must take into account the effects of climate change on their composition, structure, landscape pattern, and stability in the face of disturbances. Using a mountain region of Italy as a working example, we summarized our decade-long research efforts in maximizing rockfall and avalanche protection by mountain forests. We illustrated how we mapped protective forests, assessed their current and future functionality, and pinpointed management needs. Moreover, we evaluate the impact of natural disturbances on protective forests at the stand and landscape scale, discuss interactions between disturbance severity and resistance/resilience to gravitational hazards, and illustrate different uses of simulation models to forecast the combined effects of climate, disturbances, and silviculture on the effectiveness of hazard protection by the forest.

Posters

Spatio-temporal heterogeneity of water and root distribution and their impact on the slope stability in a mixed mountain forest. Kim, J. (*National Institute for Agricultural Research, France; john.kim@cirad.fr*), Mao, Z., Bourrier, F. (*National Research Institute of Science and Technology for Environment and Agriculture, France; maozhun04@126.com; franck.bourrier@irstea.fr*), Fourcaud, T. (*CIRAD, France; thierry.fourcaud@cirad.fr*), Stokes, A. (*National Institute for Agricultural Research*, *France; alexia.stokes@cirad.fr*).

Current mountain forest management has seldom taken into account the dynamics of both hydrological and root mechanical reinforcement when evaluating slope stability. We aimed at (1) characterizing the spatio-temporal variation of water and root dynamics; (2) estimating their contribution to the reinforcement to soil, and (3) evaluating the impact of water and roots on the likelihood of slope failure, i.e., the factor of safety (*FoS*). This study was conducted in a mixed forest ecosystem at an altitude of 1 400 m a.s.l. in the French Alps. Ground truth data of the vertical distribution of water matric suction and root density were measured in two types of ecological patches (tree island and gap). Impacts of water and roots on *FoS* were evaluated by *Ecosfix 1.0*, a 3D model based on a finite element method. We found that the reinforcement due to water generally played a more dominant role in slope stabilization than that due to roots, especially in the growing season and in tree island. However, roots seemed to be a more permanent source of reinforcement to soil and slope stability, as it happened that reinforcement due to water dropped to a very weak value due to abundant rain or snow melting.

How does the asymmetry of root system architecture modify soil strength and slope stability? Mao, Z. (*National Research Institute of Science and Technology for Environment and Agriculture, France; maozhun04@126.com*), Jourdan, C., Rey, H., Griffon, S., Barczi, J. (*CIRAD France; christophe.jourdan@cirad.fr; herve.rey@cirad.fr; sebastien.griffon@cirad.fr; barczi@cirad.fr*), Bernard, A., Fourcaud, T., Stokes, A., Bourrier, F.

Evaluating the effect of plant root architecture on soil reinforcement and slope stability is an important issue for the improved mitigation of shallow landslides. Nevertheless, few studies have examined tree root architecture on steep slopes where root systems tend to be asymmetric. Using a modelling approach based on the finite element method, we aimed at examining how tree root system asymmetry affects soil strength and slope stability. We designed a three-dimensional slope using ABAQUS© software. Based on ground truth data, root system architecture for silver fir (*Abies alba* Mill.) and Norway spruce (*Picea abies* (L.) Karst), two of the most common species in European mountain forests, was generated using DigR and Xplo software (http://amapstudio.cirad.fr/) and was then embedded in the soil of mid-slope. Three root system asymmetry types were examined: a constant total biomass: skewness to upslope, axisymmetric, and skewness to downslope. The likelihood of failure of the slope, as well as stresses and strains within the soil medium and roots, were then computed and visualized. Root system asymmetry had a significant effect on the efficiency of the slope stabilization. Within a root system, roots skewed upslope and downslope differed in their mechanical response and strategy of reinforcement.

Drought effects on forest health and growth in the western part of the Eurasian steppe region. Popa, I., Neagu, S., Leca, S., Nechita, C., Badea, O. (*Forest Research and management Institute, Romania; popaicas@gmail.com; stefanneagu@yahoo.com; leca_d_stefan@yahoo.com; nechitadendro@gmail.com; badea63@yahoo.com*).

Regional warming and consequent higher water deficits along with air pollution are most likely the main driving forces behind forest health and growth dynamics. They are more important in the case of forest ecosystems existing under marginal or restricted ecological conditions such in the western part of the Eurasian steppe (east and south of Romania). Information on recent climate change dynamics in this region confirm higher temperatures by 0.7–0.8 °C and less precipitation by 20–80 mm during the period from1981–2010 when compared with 1961–1990 reference period. During the last decade (2001–2010), the precipitation amount was even higher compared with the same reference period by 37–60 mm. The direct consequences upon forest health are represented by the high number of damaged trees (crown defoliation above 25%) during 1992–2001 period, consistently above 50%, and in several extreme years above 75% (1992, 1994, 1995, 1998, and 2000). Since the year 2006, forest health recovered gradually, fluctuating within a more or less stable interval of 31–35%. The relation between the forest growth and crown defoliation parameter along with climate allow formulating predictions on potential changes of forest ecosystems. In this region, it has been found that forest ecosystems reduced their growth by 13–22% as a consequence of the recent climate fluctuations.

Simulating forest dynamics and vulnerability of cork oak woodland production systems: a new index for vulnerability assessment and control. Ribeiro, N.C.A. (*University of Evora, Portugal; nribeiro@uevora.pt*).

The cork oak (*Quercus suber* L.) woodland production system value is closely related with sustained production from its components. Considering this fact, cork oak woodlands are vulnerable with respect to soil loss, crown cover reduction, and lack of regeneration. Ruptures in the balance between the agro-silvo-pasture components can result in high tree mortality risk by lack of fire protection or increased grazing intensity. The vulnerability control of these forest structures is closely related with the continuous crown cover management and soil protection, therefore the success of natural or artificial regeneration is the driver for system resilience and elasticity. In our present work, a new computer-assisted vulnerability assessment system is used to evaluate risk, define critical thresholds with respect to stand stability, and establish consistency in providing goods and services, and hence, the economic viability of these managed systems. For that purpose, a new index for vulnerability as a function of erosion risk index, soil limitations class, stand structure index, and crown cover stability index is presented. These new developments in the cork oak tree spatial growth simulator CORKFITS are used to simulate system response to a set of natural regeneration timing and intensity combinations in order to find the solution for vulnerability control for cork oak stand areas in the case study region.

Impacts of natural forest landslides in a rural community of Morretes, pr-Brazil. Rosot, N., Correa, C.C. (*Federal University Of Paraná, Brazil; ncrosot@ufpr.br; cmcamargocorrea@gmail.com*), Rosot, M. (*EMBRAPA, Brazil; augusta_rosot@hotmail.com*).

Landslides in steep forest hills are relatively common in the mountainous regions of Brazil, especially in the months of greatest rainfall. However, in 2011 a landslide caused major flooding and silting in a rural community located in Morretes, State of Paraná, southern Brazil. Rainfall of 400 mm in only 3 days was responsible for the displacement of blocks of large rocks and soil over a rural area of 125 ha, destroying more than 50 homes, rural roads, and a concrete bridge on a nearby highway. Large trees typical of humid tropical forests were dragged to the lower parts of the valley, causing the damming of rivers and flooding. Families were removed to nearby locations, but now, 2 years after the tragedy, they are returning to areas considered at risk. To enable the resumption of productive activities, and at the same time reduce risk and minimize the effects of landslides, government agencies and educational and research institutions developed a program to rehabilitate the affected areas. Actions being carried out include mapping, monitoring, and containment of the slopes, as well as providing support to the local community.

Rehabilitation process of natural mixed forest after wind disturbance by typhoon in Hokkaido, Japan in northern, Hokkaido. Takahashi, M., Kuramoto, S., Ishibashi, S., Iida, S., Furuya, N. (*Forestry and Forest Products Research Institute, Japan; martaka@ffpri.affrc.go.jp; shkura@ffpri.affrc.go.jp; sa9267@ffpri.affrc.go.jp; iida34@ffpri.affrc.go.jp; nfuruya@ffpri.affrc.go.jp*).

The objective of this study was to investigate structural history and the rehabilitation process of the natural mixed forest in Hokkaido, Japan that successfully recovered after wind disturbance by typhoon in 1954 and salvage logging. Multitemporal aerial photo interpretation was used for three dimensional analyses of structural transformation of the target area. Ground plot surveys and tree ring analyses were also conducted. As a result, we investigated that rapid recovery was caused by (1) favorable growth of small to middle sized trees that was consistent even after wind disturbance and salvage logging, (2) rapid growth of juvenile and small size trees that survived from wind disturbance, and (3) regeneration of light-tolerant species. The recovery patterns were affected by the degree of damage by wind disturbance. Significantly damaged areas were mainly recovered by light-tolerant species. On the other hand, lightly damaged areas were mainly recovered by small to middle sized survived trees. Different recovery patterns caused the different species mixture based on the patches and the degree of damage. Multitemporal aerial photo interpretation can provide structural transformation of natural mixed forest, and it is useful for natural forest management.

C-12 Quantifying uncertainty in forest measurements and models: Approaches and applications

Organizers: George Gertner (University of Illinois, USA), Bogdan Strimbu (Louisiana Tech University, USA), David Paré (NRCan-Canadian Forest Service) & Peter Clinton (Scion, New Zealand)

Quantifying uncertainties in national estimates of living biomass – a comparison of methods. Breidenbach, J. (*Norwegian Forest and Landscape Institute, Norway; job@skogoglandskap.no*), Staahl, G. (*Swedish University of Agricultural Sciences, Sweden; goran.stahl@slu.se*), Heikkinen, J. (*Finnish Forest Research Institute (Metla), Finland; juha.heikkinen@metla.fi*), Petersson, H., Ringvall, A. (*Swedish University of Agricultural Sciences, Sweden; hans.petersson@slu.se; Anna.Ringvall@slu.se*), Astrup, R. (*Norwegain Forest and Landscape Institute, Norway; rasmus.astrup@skogoglandskap.no*).

The uncertainty associated with forest inventory estimates is of high relevance in the further use of inventory results in policy making and international reporting. Recently, the topic got renewed attention because countries reporting to the Climate Convention under the United Nations Framework Convention on Climate Change (UNFCCC) are required to provide the uncertainty of their estimates. Uncertainties of national biomass estimates result from three main sources: (i) measurement error, (ii) sampling-related variability, and (iii) model-related variability. In this study, we review two general approaches to quantify model- and sampling-related variability in national estimates of living biomass, the analytical approach based on Taylor series linearization and the Monte Carlo approach. We use Swedish, Finnish, and Norwegian National Forest Inventory (NFI) data to compare the analytical approach with the Monte Carlo approach. Advantages and disadvantages of both approaches will be discussed.

Modeling the intra-stand variability of carbon and water fluxes in clonal *Eucalyptus* plantations. Christina, M., Le Maire, G., Laclau, J. (*CIRAD, France; mathias.christina@cirad.fr; guerric.le_maire@cirad.fr; laclau@cirad.fr*), Stape, J. (*North Carolina State University, USA; stape@ncsfnc.cfr.ncsu.edu*), Nouvellon, Y. (*CIRAD, UMR Eco&Sols, Brazil; yann.nouvellon@cirad.fr*).

Modeling the variability of tree characteristics and their consequences on carbon and water fluxes is fundamental in forestry. Carbon and water fluxes have been predicted over the first half of a *Eucalyptus* plantation rotation in Brazil (3 years) using the ecophysiological process-based model MAESPA. Measurements of morphological and physiological model inputs have been carried out at different tree ages, social status, and within-crown position to assess their spatio-temporal variability. The consequences of their variability on simulated light and water use efficiencies have been examined at the tree and the stand scales, using an uncertainty analysis. The simulations matched the carbon and latent heat fluxes measured by eddy covariance in the same stand, as well as the gap fraction measurements. The largest trees exhibited the highest light and water use efficiencies only the first year after planting. Uncertainty analyses showed the need to take into account the variability of leaf area distributions and photosynthetic capacities within the tree crown to predict accurately stand light interception and C flux. By contrast, the impact of the variability of leaf inclination distribution was low. Our results showed that the accuracy required for the parameters of the MAESPA model is highly dependent on the time period, the scale, and the tree features studied.

Characterizing uncertainty in forest disturbance maps derived from Landsat time series. Cohen, W. (*U.S. Forest Service, USA; wcohen@fs.fed.us*), Yang, Z. (*Oregon State University, USA; zhiqiang.yang@oregonstate.edu*), Stehman, S. (*State University of New York, USA; svstehma@syr.edu*), Huang, C. (*University of Maryland, USA; cqhuang@umd.edu*).

A new Landsat revolution is changing the way forest disturbance is mapped. With high quality, standardized datasets now freely available, a fundamental shift has occurred in how forest disturbance mapping algorithms are conceived and structured. Dense time series of data collected over several decades enable extraction of subtle forest disturbance signals heretofore indistinguishable from the noise inherent in bi-temporal slices of imagery. This presents a significant challenge to long-standing, routine approaches to map quality assessment and requires extending the design and analysis considerations beyond the basic agreement measures to provide a fuller exploration of uncertainty. I will present several features of a modern perspective on forest disturbance map uncertainty analysis. These include the sources of reference data now employed, the sample design freedom made possible by these data sources, a change data visualization tool (TimeSync) for reference data collection, adjustments to mapped class areas and disturbance rates to remove mapping bias and derive annual disturbance estimates with confidence intervals, and partitioning annual estimated disturbance rates into classes associated with causal agent and disturbance magnitude. This approach to forest disturbance map uncertainty will be demonstrated in the context of a national level forest disturbance mapping effort for the United States.

Assessment of scenario generation approaches for forest management planning through stochastic programming. Eyvindson, K., Kangas, A. (*University of Helsinki, Finland; kyle.eyvindson@helsinki.fi; annika.kangas@helsinki.fi*).

The development of any planned course of action relies upon a prediction of available resources in the future. In forest planning this prediction contains a number of different sources of uncertainty, all of which contribute to selecting forest management alternatives which may be suboptimal. One way to manage this uncertainty is through the use of stochastic programming. Through the use of a set of predefined scenarios stochastic programming can use a set of scenarios to integrate the uncertainty into the decisionmaking process. In this context, a scenario set of information which would be used to generate a forest plan in a deterministic format. How the set of scenarios is generated has a direct impact on the generation of the stochastic solution. In a forest planning, the uncertainties involved can be fully-independent (inventory errors), correlated (climate change errors) and partially correlated (prediction errors) which adds complexity when generation a scenario set. A series of scenario generation approaches are compared varying the sources of uncertainty. The generation approaches are compared through the use of an even-flow stochastic programming formulation.

Total error propagated and partitioned in a LiDAR driven single tree growth model. Gertner, G. (*University of Illinois, USA; gertner@illinois.edu*).

The U.S. Forest Service FVS (Forest Vegetation Simulator) is a very widely used growth model developed for projecting individual trees and forest development through time. FVS is now being used to evaluate a variety of global change scenarios as it relates to forest health, carbon life cycle analysis, sustainability, wildlife habitat, and wildland fires. In this paper, the total error in form of an uncertainty budget is developed for FVS projections, where initial model inputs are spatially explicit single-tree stem maps developed with small-footprint airborne LiDAR (Laser Imaging Detection and Ranging). An uncertainty budget shows the overall precision of estimates/predictions made with a system, partitioned according to different types of uncertainty sources within and outside of the system. In a comprehensive fashion, sources of uncertainties due to measurements, classification, sampling error, and model parameter estimates are accounted for in the LiDAR derived stem maps and within the FVS system. Spatially identifying the sources of uncertainties in time, modeling their propagation and accumulation, and finally, quantifying them locally on a tree basis and globally on a forest level are presented. Uncertainties in future forest responses due to uncertainties in projected global climatic change predictions that will also drive this type of forest model will also be discussed.

Parameterization of 3-PG model for slash pine trees: assessing climate change effects on stand dynamics and productivity. Gonzalez-Benecke, C., Gezan, S., Bracho-Garrillo, R., Jokela, E., Martin, T. (*University of Florida, USA; cgonzabe@ufl.edu; sgezan@ufl.edu; rbracho@ufl.edu; ejokela@ufl.edu; tamartin@ufl.edu*).

The physiological-process based model 3-PG was parameterized for slash pine stands. New functions were included to better estimate changes in NPP allocation, biomass allometry, mortality, and canopy structure dynamics. Species-specific physiological parameters were determined using long term experimental data, as canopy quantum yield and the sensitivity of canopy conductance to vapor pressure deficit, which were determined using more than 10 years of eddy-covariance measurements on two sites. The fertility rating, the arbitrary growth modifier that has been largely argued as the weakest aspect of the model, was determined as a function of stand's site index using data from a long-term experiment that manipulated resources availability. New general functions to estimate tree height and merchantable volume partitioning were also included, allowing economic analysis. The model was validated against a large number of studies and operational plots across the natural range of distribution of the species. The model was also validated against data of stands growing in South America. Using the new set of functions and parameters, the model was used to estimate the impact of future climate change scenarios on stand dynamics and productivity in the SE United States**.**

On identifying and establishing confidence limits of trends. Guan, B. (*National Taiwan University, China-Taipei; btguan@ntu.edu.tw*).

By definition the effect of recent warming on an ecosystem attribute should be a trend. The question is how to detect the trend and to establish confidence bounds on the trend. One possibility is to combine a time series bootstrap method to generate bootstrap samples with characteristics resemble that of the original series, and a trend extraction method for extracting trends embedded in the time series. In this study, the approach was applied to two long-term European first flowering dates (FFD) series and the corresponding average February to April (FMA) monthly mean of daily maximum temperature (Tmax) series. For each anomaly series (base period 1961–1990), bootstrap samples were generated using Maximum Entropy bootstrapping, and each sample was then decomposed into an oscillatory component and a trend using ensemble empirical mode decomposition. Based on point-wise 95% confidence limits, the FFD of both species began to advance around 1977~1978, whereas the two regional FMA Tmax started to warm up around 1982~1983. Thus, recent warming has already impacted the phenophase development before we can declare the warming to be significant statistically.

A systematic framework for Monte Carlo simulation of remote sensing errors map in carbon assessments. Healey, S., Patterson, P., Urbanski, S. (*U.S. Forest Service, USA; seanhealey@fs.fed.us; plpatterson@fs.fed.us; surbanski@fs.fed.us*).

Remotely sensed observations can provide unique perspective on how management and natural disturbance affect carbon stocks in forests. However, integration of these observations into formal decision support will rely upon improved uncertainty accounting. Monte Carlo (MC) simulations offer a practical, empirical method of accounting for potential remote sensing errors as maps are used as inputs in ecosystem carbon assessment. We present a generic approach for coordinating the MC alteration of map values so that specific levels of both pixel-level and map-wide systematic error may be simulated. This approach is based on constructing systems of linear equations and inequalities which incorporate results of map validation exercises. Solution of these systems provides probability functions capable of simulating different levels of error. We illustrate this approach, using error assessments calibrated by the United States (U.S.) national forest inventory data, in an assessment of the effects of wildfire and harvest on carbon storage over 20 years on a forested landscape in the western U.S. This assessment utilized the Forest Carbon Management Framework approach, which is being implemented across the U.S. National Forest System. Results showed that systematic map errors can contribute significant uncertainty in MC analysis, but that impacts of fire and harvest on landscape-level carbon storage can nevertheless be clearly identified and differentiated using remotely sensed maps.

Testing of soil carbon models using repeated inventories. Lange, H., Dalsgaard, L., Borgen, S., Skår, S. (*Norwegian Forest and Landscape Institute, Norway; holger.lange@skogoglandskap.no; lid@skogoglandskap.no; sbo@skogoglandskap.no; ssk@skogoglandskap.no*).

Reliable methods are required to predict changes in soil carbon stocks. Process-based models often require many parameters which are largely unconstrained by observations. This induces uncertainties which are best met by using repeated measurements from the same sites. Here, we compare two carbon models, Yasso07 and Romul, in their ability to reproduce a set of field observations in Norway. The models are different in the level of process representation, structure, initialization requirements and calibration- and parameterization strategy. Field sites represent contrasting tree species, mixture, and soil types. The number of repetitions of C measurements varies from two to six over a period of up to 35 years, and for some of the sites which are part of

long-term monitoring programs, plenty of auxiliary information is available. These reduce the danger of overparametrization and provide a stringent testbed for the two models. Focus is on the model intercomparison, using identical site descriptions to the extent possible, but another important aspect is the upscaling of model results to the regional or national scale, utilizing the Norwegian forest inventory system. We suggest that a proper uncertainty assessment of soil C stocks and changes has to include at least two (and preferably more) parameterized models.

Scaling of uncertainty in carbon emission estimates and implications for locally appropriate designs to reduce emissions from degradation, deforestation and agroforestation in landscape mosaics. Lusiana, B., van Noordwijk, M. (*Woirld Agroforestry Centre (ICRAF), Indonesia; b.lusiana@cgiar.org; m.vannoordwijk@cgiar.org*), Cadisch, G. (*University of Hohenheim, Germany; georg.cadisch@uni-hohenheim.de*).

Uncertainty of carbon emission estimates depends on scale while local stakeholders' views on plausible REDD+ and similar schemes influence and limit transaction costs. We quantified the scale relations of uncertainty for a case study district in Sumatra (Indonesia) using known inaccuracy of land cover classification and variation in carbon stocks assessment per land cover type. With decreasing spatial resolution of carbon emission maps, uncertainty in carbon estimates decreased. At 1 km^2 resolution, uncertainty dropped below 5%, retaining most of the coarser spatial variation in the district. Fairness, efficiency and transaction cost issues in the design of REDD+ mechanisms were readily recognized by local stakeholders. A striking difference occurred in desirable transaction costs (which include monitoring, reporting and verification), with non-governmental organizations (NGOs) aiming for 8%, while government and researchers accepted transaction costs of 40%. Feasible measures for emission reduction in the district, derived from a participatory planning process, are compatible with the 1 km^2 spatial resolution of performance measures.

The effects on large area forest volume estimates of uncertainty in individual tree volume model predictions. McRoberts, R. (*U.S. Forest Service, USA; rmcroberts@fs.fed.us*), Moser, P., Oliveira, L., Vibrans, A. (*Regional University of Blumenau, Brazil; paolo.moser@gmail.com; laiozoliveira@gmail.com; acvibrans@gmail.com*), Westfall, J. (*U.S. Forest Service, USA; jameswestfall@fs.fed.us*).

Parameters related to large area volume, biomass, and carbon are among those most frequently estimated by forest inventory and monitoring programs. The common approach is to estimate the volumes of individual trees using statistical models based on observations of species and measurements of diameter and perhaps height, and then to aggregate the individual tree estimates at plot-level. When assessing the uncertainty of the large area estimates, the uncertainty associated with the tree volume model predictions is often ignored under the assumption that it is negligible relative to sampling variability. This assumption is seldom evaluated analytically. Further, when inventory programs enhance estimates using auxiliary information, the role of sampling variability is replaced by within strata variability when post-stratified estimation is used or mean square error when model-assisted regression estimation is used. When stratified and model-assisted estimators are used, model prediction uncertainty may no longer be negligible. For study areas in the United States and in Brazil, the uncertainty of individual tree model predictions is estimated in absolute terms using Monte Carlo techniques, and its effects on the uncertainty of large area estimates obtained using simple random sampling, stratified, and model-assisted methods are evaluated. Two components of model prediction uncertainty are emphasized, residual uncertainty and nonlinear model parameter uncertainty.

Uncertainty in estimating the timing of greenhouse gas emission balance of forest bioenergy. Pare, D., Bernier, P., Thiffault, E. (*Canadian Forest Service, Canada; dpare@rncan.gc.ca; pbernier@rncan.gc.ca; ethiffault@rncan.gc.ca*).

One major incentive for promoting the use of biomass as an energy source is its potential to mitigate greenhouse gas (GHG) emissions. Because forest management cycles generally span over several decades, much discussion about the appropriate way of estimating the potential for forest bioenergy to mitigate GHG emissions concerns the representation of the temporal aspects of GHG dynamics. We estimated the temporal CO_2 dynamics between the forest and the atmosphere for a reference scenario (no bioenergy) and for two bioenergy scenarios, one using harvest residues and one using whole trees for heat production. The uncertainty attached to the different parameters of the basic equations for CO_2 emission or removal was assessed and propagated using Monte Carlo simulation. The results revealed that much of the uncertainty in CO_2 dynamics was based on land based emissions (forest dynamics, natural disturbance, management and land use) and that the level of uncertainty increased rapidly with time in all scenarios. Incidentally predicting when bioenergy options will meet GHG emission reduction targets is much easier for options that show a short term carbon payback time.

Allometric equations for biomass estimation in Central African rain forests: state of the art and challenges. Picard, N. (*Commission des Forêts d'Afrique Centrale, Cameroon; nicolas.picard@cirad.fr*), Henry, M. (*FAO, Italy; Matieu.Henry@fao.org*), Fonton, N. (*ONF International, Cameroon; hnfonton@gmail.com*), Kondaoule, J. (*TEREA, Cameroon; jokondah@yahoo.fr*), Fayolle, A. (*Gembloux Agro-Bio Tech, Belgium; adeline.fayolle@ulg.ac.be*), Birigazzi, L., Sola, G., Poultouchidou, A., Trotta, C., Maïdou, H.

Estimating forest carbon stocks in an accurate and precise way is a requirement of REDD+. Allometric equations are the cornerstone to convert forest inventory data into estimates of forest biomass and carbon stocks. The most used allometric equations in tropical forests of Central Africa are pantropical equations that do not rely on any data from Central Africa. However, destructive measurements of tree biomass have recently been undertaken in Central Africa, providing the first local allometric equations that can be compared to the pantropical equations. We analyzed and compared the different sources of errors that propagate when estimating biomass and carbon stocks. Although important at the tree level, the residual error of the models is leveled off at the plot level. The error due to the measurement and to the uncertainty on the model's parameters contribute much less to the overall error than the choice of the allometric equation, that we quantified using Bayesian Model Averaging. In conclusion, more destructive measurements of tree biomass are needed in Central Africa to improve biomass and carbon stock estimates, to identify and understand the variations in tree allometry, and thus clarify the choice of the appropriate allometric equations.

Quantifying sources of uncertainty through traceable and empirical approaches at the National Ecological Observatory Network. Roberti, J., Csavina, J., Streett, S., Metzger, S., Taylor, J. (*National Ecological Observatory Network (NEON), USA; jroberti@neoninc.org; jcsavina@neoninc.org; sstreett@neoninc.org; smetzger@neoninc.org; jtaylor@neoninc.org*).

The National Ecological Observatory Network (NEON) is a continental-scale research platform with a projected lifetime of 30 years. NEON's purpose is to provide high quality data products that will facilitate discovering and understanding the impacts of climate change, land-use change, and invasive species on ecology. To accomplish this, NEON will perform in-situ, sensor-based measurements of approximately 55 000 high quality data streams and generate uncertainty estimates. Only when uncertainty is sufficiently quantified can meaningful interpretations be made about mean quantities and their interrelations. These in turn are the main ingredients for constructing or constraining process-based models and the like. Because NEON data will be publically available, our goal is to ensure that all sources of uncertainty are identified, and if possible, quantified in a traceable and transparent manner. To meet this goal, laboratory calibrations and measurement uncertainty estimates follow ISO protocols, and quantifiable as well as unquantifiable (i.e., those that can only be identified) uncertainties are provided in publically available documents. Additionally, empirical uncertainty estimates are formulated and realized as data are being collected. Using these methods we aim to gain a better understanding of sensor-specific uncertainties to quantify known, previously unquantifiable uncertainties.

Distribution of errors along stem in carbon estimation using hemispherical photography. Strimbu, B. (*Louisiana Tech University, USA; strimbu@gmail.com*).

Quantification of the carbon amount within stem is commonly executed using ground based methods which tend to be expensive and time consuming. An alternative to ground measurements is to estimate carbon using tree taper deducted from hemispherical photos. This photographic technique provides accurate taper estimates with reduced costs and data acquisition time. However, precision depends on equipment specifications whose impact on carbon amount can be assessed by determining spatial distribution of errors throughout the stem. An assumed uniform distribution of errors in measurements at same heights leads to non-analytical expression of errors in amount of carbon. More complex distribution of measurement errors lead to complex formulas, which do not reduce significantly the errors in carbon estimation. For individual loblolly pine, the error in estimating the amount of carbon stored in the stem is less than 5% for heights less than 6 m, 10% for heights less than 10 m, and 15% for heights less than 12 m. For more than 10 loblolly pines, the error decreases to values close to the ground measurements, which indicate that hemispherical photography can be used successfully as an alternative to traditionally techniques of carbon estimates.

Uncertainty and sensitivity analysis of a tree mortality monitoring system. Xu, C., Muss, J., McDowell, N. (*Los Alamos National Laboratory, USA; xuchongang@gmail.com; muss@lanl.gov; mcdowell@lanl.gov*), Fisher, R. (*National Center of Atmospheric Research, USA; rosieafisher@googlemail.com*).

The critical urgency of forecasting climate impacts and feedbacks makes understanding, quantifying, and predicting terrestrial carbon balance and subsequent climate impacts one of the greatest science challenges currently facing the world. In this study, we developed a tree monitoring system for drought and insect-caused tree mortality which fuses real-time mortality signals from Moderate Resolution Imaging Spectroradiometer (MODIS) imagery, predicted vegetation dynamics information from an ecosystem demography (ED) model, radiative transfer and reflectance information from a forest canopy reflectance and transmittance (FRT) model, and different sources of background information from forest inventory and remote sensing products. In order to assess the reliability of this monitoring system, we first conducted a comprehensive global sensitivity analysis that identifies key parameters responsible for tree mortality detection from MODIS. Then we used an ensemble Kalman filter to estimate the amount of tree mortality by fitting the simulated reflectance to that observed from MODIS. The corresponding uncertainty range for tree mortality was estimated correspondingly from the Kalman filter. The development of the tree mortality monitoring system and the uncertainty quantification is a key step forward in our understanding and prediction of terrestrial carbon feedback to atmosphere.

C-13 Modeling and simulation systems

Organizer: Grant Domke (U.S. Forest Service)

Considering climate change: growth and yield forecasting using Climate-FVS. Crookston, N. (*U.S. Forest Service, USA; ncrookston.fs@gmail.com*).

Climate change will change forest species and size composition and growth rates as well as disturbance regimes. This paper presents the use of a modified version of the Forest Vegetation Simulator (FVS) that takes climate change into account. FVS is widely used by forest planners and silviculturists to support forest planning and in preparing stand management prescription. A goal in building the modification is to enable existing FVS users to account for climate change in their analyses using a tool that already use. Simulations of three example landscapes from Oregon, Utah, and Colorado, USA, are presented. Management options designed to maintain forests in these landscapes in the face of climate change are considered. Results indicate that the introduction of novel species and genotypes will be required if ecosystem services derived from forests are to be maintained in the future. Shorter rotations are needed to insure that trees will be growing in suitable climates during their expected life span. Ignoring climate change impacts until they occur is one management option that is illustrated. The paper includes an argument that even though climate-change impacts predicted by this model are severe, they may indeed be conservative.

New tools for the use of spatially-explicit forest disturbance data in the estimation of forest carbon budgets within North America. Greenberg, D. (*Commission for Environmental Cooperation, Canada; David.Greenberg@NRCan-RNCan.gc.ca*), Kurz, W. (*Canadian Forest Service, Canada; werner.kurz@nrcan.gc.ca*), Olguín Alvarez, M. (*Proyecto Mexico-Noruega, Comision Nacional Forestal, Mexico; olguin.conafor@gmail.com*), Birdsey, R. (*U.S. Forest Service, USA; rbirdsey@fs.fed.us*), Wayson, C. (*SilvaCarbon, USA; cwayson.silvacarbon@gmail.com*), Morken, S., Fellows, M., Zhang, G., Magnan, M., Dai, Z., Silva Mascorro, V., Gregorio, A.

The governments of Canada, the USA, and Mexico are collaborating under the North American Agreement on Environmental Cooperation to analyze their forest carbon budgets and to develop decision support tools that may facilitate mitigation of greenhouse gas emissions from land use, land-use change, and forestry. This effort requires the efficient use of vast quantities of data becoming available, from both remote sensing and field investigations, by which spatial patterns of forest disturbance over time may be estimated. We will report on methods by which we use spatially-explicit datasets on such processes as forest clearing and regeneration, wildfire, defoliation by insects, and wind-throw to estimate and forecast forest carbon dynamics with a well-developed forest carbon accounting model, the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3). We will in particular describe processing frameworks and related software tools that we are developing for the conversion of such spatially-explicit datasets into forms suitable for use in carbon accounting models. We will furthermore illustrate our use of these methods and tools in Tier 3 modeling of greenhouse gas emissions following IPCC guidance, both for reporting to the UNFCCC and for the evaluation of potential greenhouse gas emissions mitigation policy and related actions.

REDD options as a risk management instrument under policy uncertainty and market volatility. Khabarov, N. (*International Institute for Applied Systems Analysis (IIASA), Austria; khabarov@iiasa.ac.at*), Fuss, S. (*Mercator Research Institute on Global Commons and Climate Change, Germany; fuss@mcc-berlin.net*), Szolgayova, J., Obersteiner, M. (*International Institute for Applied Systems Analysis (IIASA), Austria; szolgay@iiasa.ac.at; oberstei@iiasa.ac.at*).

In this paper we explore the potential of REDD (reducing of emissions from deforestation and forest degradation) based offset options as a risk management instrument for an electricity producer. Power generation accounts for about one third of the total anthropogenic CO_2 emissions, and hence is of high importance in the climate mitigation context. We investigate how under different emission market conditions carbon capture and storage (CCS) technology and REDD offset options may improve producer's cost profiles. Within a stochastic real-options framework, we simulate market development scenarios with high price volatility and high policy uncertainty that are relevant at the current stage of development. From an electricity producer's perspective, high policy uncertainty is modeled by a random jump process. We include bioenergy into the considered set of power generation technologies and allow for a net negative emissions effect by adding CCS to a biomass power plant. According to our results, the risk management potential of CCS is diminishing with high policy uncertainty, whereas the risk management potential of fairly priced (nondiscriminating for both supplier and consumer) REDD offset options remain high and allows electricity producers to shape their risk profiles in a desired manner.

Modelling the economics of the reference levels for forest management emissions in the EU. Laturi, J., Lintunen, J., Uusivuori, J. (*Finnish Forest Research Institute, Finland; jani.laturi@metla.fi; jussi.lintunen@metla.fi; jussi.uusivuori@metla.fi*).

In the recent climate change conferences of UNFCCC, new accounting rules have been suggested for forestry sector to provide incentives for forest management and emission mitigation actions. There has also been pressure to modify accounting rules to avoid giving credits for sequestration which would occur naturally. Country-specific reference levels for Annex I countries have been suggested to be used as baseline for carbon sequestration target of forest sector. Each country has proposed a reference level based on baseline harvest and growth of forest, accounting for the effect of policies implemented before 2009. A country will gain carbon credits if emissions from forest management are below the baseline reference level, while a country whose emissions exceed the baseline reference level will lose carbon credits. Gains and debits are limited with caps which are proportional of the national carbon emissions in the year 1990. With an economic model, we study how the setting of reference levels will affect the forest sector, harvesting volumes, carbon reservoirs in harvested wood products, and price of wood. Also the effects of setting caps for gains and debits as a function of the carbon dioxide emission allowance (EUA) are studied.

Exploring economic optimization for managed tropical forests using individual-based modeling: an exercise with data from Quintana Roo, Mexico. Palmas Perez, S., Sierra Huelsz, J. (*University of Florida, USA; spalmas@ufl.edu; jasierra@ufl.edu*).

Efforts in forest production and economic modeling has been focused in single even-aged species forests, with only a few examples on tropical forests. Forest growth simulation of mixed uneven-aged stands faces many difficulties (e.g., high data requirements, lack of inventory data). These difficulties result in high uncertainty on forest simulations. In addition, most simulations are based on optimization on harvested timber volume and may not be equal to an optimization strategy considering economic variables, such as cost of production and sale price. This simulation code uses growth, yield, stand conditions, and economic data to develop a simulation model of management of tropical forests based on data from inventories and economical studies on the managed forest of Quintana Roo, Mexico. The processes were simulated in an individual-based model for 100 years, and optimized to determine optimal cutting regimes and to estimate their potential benefits. Optimized management strategies greatly differed from the actual forest management, with an average of a 10 year difference for cutting regimes. Several forest species were found to be economically unproductive with the current conditions. This simulation approach can help explore alternative management strategies for the forest in Quintana Roo and across mixed and uneven-aged forests.

Estimating the fertility rating parameter of the 3PG model from soil properties: application to *Eucalyptus globulus* in Portugal. Tomé, M., Oliveira, T. (*Technical University of Lisbon, Portugal; magatome@isa.utl.pt; tsoliveira@isa.utl.pt*), Pacheco, C. (*University of Lisbon, Portugal; arruda-pacheco@clix.pt*), Araújo, C. (*ALTRI Florestal, Portugal; caraujo@altri.pt*), Vega-Nieva, D. (*University of Santiago de Compostela, Spain; danieljvn@gmail.com*), Tomé, J.

The use of process-based models to make projections of production forest development is gaining relevance over the traditional empirical models. Such models, integrating the main physical, biogeochemical and physiological processes involved on forest growth and development, give a mechanistic description of the interactions between the living plants and their environment and are able to assess the energy balance and the cycling of water, carbon and nutrients within a given ecosystem. The 3PG model, a simple process-based stand model requiring few parameter values and only readily available data as input, has been parameterized for growth simulation of eucalyptus plantations in Portugal. The 3PG model includes the effect of soil fertility through a subjectively estimated parameter in the 0–1 range, the fertility rating (FR). There have been some previous works trying to model

the FR as a function of soil characteristics and the results are promising. This presentation explores data from fertilization trials established in six regions of Portugal to contribute to the FR estimation and also to the modification of FR due to application of fertilizers. Data available include tree growth data and a very detailed description of the soils, including a description of a complete soil profile and nutrient content.

C-14 Forest biomass and carbon inventory on successive occasions

Organizers: Bianca Eskelson (Oregon State University, USA), Cris Brack (Australian National University) & Teresa Fonseca (University of Trás-os-Montes e Alto Douro, Portugal)

Challenges with quantifying causes of forest carbon flux from remeasured inventories. Gray, A. (*U.S. Forest Service, USA; agray01@fs.fed.us*), Whittier, T. (*Oregon State University, USA; Thom.Whittier@oregonstate.edu*).

Carbon flux from forests are determined by the balance of establishment, growth, mortality, and logging across millions of hectares of land. Remeasurement of permanent field plots allows calculation of change in live and dead wood carbon pools, and in characterizing the causes of those changes, including land use change, natural disturbance, and management. This study determined the importance and magnitude of these drivers on forest carbon flux in Oregon and Washington, USA, using repeated measurements on 12 000 Forest Inventory and Analysis (FIA) plots. Although land use change affects a small proportion of the land base it can have a disproportionate impact on carbon flux. Land-use change resulted in a net loss of only $1.0x10^4$ ha of forest land, but there was a net loss of 12.3 Tg of live tree C because losses were on more productive forests than gains. Live woody C decreased in drier forests affected by insect outbreaks and wildfires, while C stores increased on productive public lands managed to promote late-successional habitat. Patterns of C accumulation varied with stand age and site productivity. While carbon sequestration in undisturbed stands can be prodigious in the Pacific Northwest, land use change and disturbance have been equally important.

National biomass and carbon inventory based on sample plots. Heikkinen, J., Haakana, M., Lehtonen, A., Tuomainen, T., Puolakka, P. (*Finnish Forest Research Institute, Finland; juha.heikkinen@metla.fi;; aleksi.lehtonen@metla.fi; tarja.tuomainen@metla.fi; paula.puolakka@metla.fi*).

Finland reports annually carbon stock changes in tree biomass, dead wood, litter and soil to UNFCCC (http://www.metla.fi/ghg). The estimates of tree biomass increment are based on 5 year increment cores and height increments from the sample trees in temporary field plots of National Forest Inventory (NFI). Losses in tree biomass contain natural mortality, which is estimated from permanent NFI plots, and loggings obtained from wood-use statistics. On upland soils, carbon stock changes of dead wood, litter, and soil organic matter (SOM) are estimated with Yasso07 model, which uses litter input derived from NFI estimates of tree biomass stock combined with weather data. Changes in land use are monitored on a set of 80 000 NFI plots utilizing both field observations and remote sensing materials. The aim of this presentation is to highlight the advantages of plot-based inventory: (1) tree-level biomass models can be utilized efficiently, (2) some land classifications needed in the inventory can be recorded reliably only through field observations, (3) coherency of results is improved, when litter input for soil carbon change estimation is based on the same observations as tree biomass estimates, and (4) sample-based approach provides a good basis for statistical assessment of uncertainty.

Difference of carbon balance through forest management and timber utilization at different cutting periods. Iwaoka, M. (*Tokyo University of Agriculture and Technology, Japan; iwaoka@cc.tuat.ac.jp*), Yamazaki, H. (*Nice Corporation, Japan; hiroha7161@gmail.com*), Matsumoto, T. Fujiwara, M. (*Tokyo university of Agriculture and Technology, Japan; tmatsu@cc.tuat.ac.jp; fujiwara@fe.rn.tuat.ac.jp*), Inomata, Y. (*Forest Survey, Japan; myumyu_vc3000@yahoo.co.jp*).

The purpose of this study is to clarify the influence of different cutting periods on the carbon balance of wood during its life cycle. For this purpose, carbon stock and emissions through silviculture, logging, timber utilization, and abandonment stages were estimated for a Japanese standard cutting period of about 40 years and a long cutting period of about 80 years as the current planning period of Japan. As a result, in the standard rotation management, the harvested volume of planted trees was small because they were in the growing stage at standard cutting age. This means that carbon stock during timber utilization was also small. In the long rotation management, carbon stock in the forests was large because planted trees were continuously growing during the cutting period. This means that harvested volume and carbon stock during timber utilization were also large. These results showed that the long rotation management has better carbon balance than the standard rotation management when the standard rotation management is repeated during the long rotation period. This result indicates that the cutting period of the largest mean annual increment may provide the best carbon balance.

Evolution and maintenance of a permanent plot system in an evolving political and technical landscape. Mannes, D. (*Forestry Tasmania, Australia; david.mannes@forestrytas.com.au*).

Australian state forest management agencies have a long history of establishing extensive systems of long-term permanent monitoring plots on public forests, with plot establishments dating back into the 1920s. Tasmania is no exception and Forestry Tasmania is one of the few agencies that has managed to keep its program supported, maintained, and continuously measured with only minimal changes to measurement standards over that time. This has left Forestry Tasmania in an enviable position of having a large network of continuously measured plots across the production forest estate. In the age of carbon modelling and research, the plot network has provided opportunities for detailed characterization of aboveground carbon dynamics across all of the bioregions represented in Tasmania's State Forest. However, permanent plot networks are expensive to maintain, margins continue to decline, and our estate shrinks a little further at every election cycle. Maintaining commitment for a permanent plot program has been challenging in an increasingly commercial environment. This presentation will outline the program itself, its history, and the strategies employed to keep it viable, supported, and relevant to modern forest management. Specific examples will highlight changes that were necessary to allow biomass and carbon monitoring as well as optimal use of remote sensing information.

Sources of sampling errors due to the changes of sampling design in forest monitoring. Merganic, J., Merganicova, K., Mistrik, M. (*Technical University Zvolen, Slovakia; j.merganic@forim.sk; merganicova@tuzvo.sk; mistrik@tuzvo.sk*).

Forest inventory and monitoring represent methods of efficient gathering of data that are important for decisionmaking and planning of sustainable forest management. Historical development of these methods from relatively simple sampling designs up to more complicated versions and their designs, as well as their practical application and implementation in the field measurements brings a number of challenges. Multiresource principles stimulate design modification and widening of the information spectrum, while data collection should be optimized from the point of costs and accuracy. In the presented study, we analyze the sources of errors that occur when sampling units are changed during successive forest inventories. This is the case of the regional inventory at the University Forest Enterprise of Technical University of Zvolen, Slovakia, which was already repeated four times (in 1986, 1992, 1998, and 2011/2012), however each time using a different sampling unit. The analysis aims at examining the error sources from the production and biodiversity points of view. The results indicate that the changes of sampling units primarily affect ecological characteristics of forests.

A synthesis of recent model evaluation activities conducted in support of Canada's national forest carbon monitoring, accounting, and reporting system. Metsaranta, J., Kurz, W., Shaw, C., Stinson, G., Boisvenue, C. (*Canadian Forest Service, Canada; jmetsara@nrcan.gc.ca; wkurz@nrcan.gc.ca; cshaw@nrcan.gc.ca;; Celine.Boisvenue@NRCan-RNCan.gc.ca*), Smyth, C., Hember, R., Greenberg, D.

Canada's National Forest Carbon Monitoring, Accounting, and Reporting System (NFCMARS) reports annually on greenhouse gas emissions and removals for 230 million ha of Canada's managed forest using a one inventory plus change approach. Good practice guidance suggests that a system like NFCMARS should be subject to on-going evaluation and improvement. We have recently undertaken a number of evaluation exercises for NFCMARS and its core ecosystem model, the Carbon Budget Model of the Canadian Forest Sector. These include (1) model inter-comparison studies at various spatial scales, (2) comparisons against field measured above- and below-ground carbon stocks at ground plots of Canada's National Forest Inventory, and (3) comprehensive uncertainty and sensitivity analyses. In coming years, new modeling tools and systems for a next generation NFCMARS will be developed. Our recent evaluations show that the results can increase understanding about both modeling systems and ecosystems that they represent, but also that interpreting results and translating them to the best course of action remains challenging. Among others, these include methods for weighting model results in inter-comparison studies, standards for judging success when models are compared against ground measurements, and effective communication of model uncertainties.

The role of remote sensing in U.S. forest inventories: past, present and future. Moisen, G. (*U.S. Forest Service, USA; gmoisen@fs.fed.us*), Brewer, K., Czaplewski, R. (*U.S. Forest Service (retired), USA; ckbrewer01@gmail.com; ray.czaplewski@gmail.com*), Healey, S., Megown, K., Finco, M. (*U.S. Forest Service, USA; seanhealey@fs.fed.us;; mfinco@fs.fed.us*).

In the current budget climate, the U.S. Forest Inventory and Analysis program is under increased pressure to do more with less. While reliance solely on field data under the current annual inventory system is a suitable solution when funding is adequate and stable, decreasing budgets and increasing need for timely information may necessitate solutions that can augment field data collection with remote sensing and forest projection models in a cost-effective way. There is a long, rich history of using remote sensing in forest inventory applications. As the role of remote sensing has expanded, so has the need for more flexible statistical procedures to take advantage of increasingly better ancillary data. In this paper, we document pivotal remote sensing projects in our history, and simultaneously track the evolution of statistical methods accompanying them. We highlight current studies improving statistical efficiency and information quality, and recommend viable alternatives for reducing costs in forest inventories across the continental United States.

Efficient sampling techniques for the estimation of deadwood volume and carbon storage in managed forests. Ritter, T., Saborowski, J. (*University of Göttingen, Germany; tritter@gwdg.de; jsaboro@gwdg.de*).

Deadwood is an important component of many ecosystems and plays a major role for biodiversity, soil protection and carbon sequestration. However, it is not in the main focus of traditional forest inventories. Statistically, deadwood is a rare event with strong clumping and high spatial variability. Due to limited search areas, traditional sampling techniques, as commonly used in forest inventories around the globe, may therefore be inefficient for surveys of deadwood. A sampling technique that seems to be more sufficient here is point transect sampling, where as a matter of principle, all objects that are sighted from a fixed location (e.g., a sample point) are counted and used to estimate a so-called detection function. We compare the efficiency of point transect sampling to well-established sampling approaches (fixed area sampling, line intersect sampling, angle count sampling) for the estimation of volume, necromass, and carbon storage in terms of precision and sampling effort. Drawing on the example of the state forest district inventory in the German state Lower-Saxony, it is shown that efficiency is tremendously increased using point transect sampling for standing deadwood and line intersect sampling for coarse woody debris.

Recent technical changes to the United States forest carbon inventory. Woodall, C. (*U.S. Forest Service, USA; cwoodall@fs.fed.us*).

A national system of field inventory plots is the primary data source for the annual assessment of US forest carbon (C) stocks and stock-change to meet reporting requirements UNFCCC. The Forest Inventory and Analysis (FIA) program of the U.S. Forest Service is charged with conducting the field inventory of US forest C. The FIA program does not directly measure forest C stocks. Instead, a combination of empirically derived C estimates (e.g., standing dead trees) and models (e.g., forest floor C stocks related to stand age and forest type) are used to estimate forest C stocks. A series of recent refinements in FIA estimation procedures have replaced some of the purely modeled forest C stock estimates (e.g., downed dead wood) with estimates based on direct measurements from the national field inventory. Results indicated that models of non-live tree C pools differ significantly from field-based estimates at the plot-level but demonstrate only slight divergences of total C estimates at the national scale. The results of these studies in the context of forest carbon accounting and future refinements are discussed.

C-15 Monitoring soil carbon stocks and dynamics at variable spatial scales

Organizer: Robert Jandl (Research and Training Centre for Forests, Natural Hazards and Landscape, Austria)

Biomass and soil carbon stocks of Sudanese Acacia savanna woodland. Alam, S., Starr, M. (*University of Helsinki, Finland; ashraful.alam@helsinki.fi; mrstarr@mappi.helsinki.fi*).

We estimated tree biomass carbon (C) and soil organic carbon (SOC) stocks for 39 map sheet grids (1° lat. × 1.5° long.) covering the *Acacia* savanna woodland of Sudan (10–16º N; 21–36° E) and evaluated how biomass and soil C stocks relate to each other and vary across the region with mean annual precipitation (MAP) and mean annual temperature (MAT). Data from the Sudanese national forest inventory, Harmonized World Soil Database, and FAO Local Climate Estimator were used to calculate C stocks, MAP, and MAT. Aboveground biomass C and SOC (up to 1 m) socks averaged 112 and 5 453 g C/m^2, respectively. Belowground biomass C stocks, estimated using root shoot ratios, averaged 33 g C/m^2. Biomass C stocks and MAP increased southwards across the region while SOC stocks were lowest in the center of the region and increased westwards and eastwards. In spite of woodland and soil degradation, biomass C and SOC stocks remained positively and significantly correlated with each other, and both were significantly correlated to MAP but not to MAT. The low biomass C and SOC stocks clearly indicate substantial under stocking of trees, depletion of SOC and potential for regional C sequestration.

Estimating soil carbon dynamics in northern forests for reporting to the United Nations Framework Convention on Climate Change (UNFCCC). Dalsgaard, L., Borgen, S., Antón-Fernández, C., Astrup, R., Lange, H. (*Norwegian Forest and Landscape Institute, Norway; lid@skogoglandskap.no; sbo@skogoglandskap.no; caf@skogoglandskap.no; rasmus.astrup@skogoglandskap.no; holger.lange@skogoglandskap.no*), Smith, A., Stokland, J., Søgaard, G., Breidenbach, J.

In Norway, large variation in climatic conditions and an extensive and heterogeneous forest area pose a challenge when forest soil organic carbon (SOC) changes are estimated for the national greenhouse gas inventory. While SOC changes are slow, they are significant on the country scale. Land cover data from the National Forest Inventory (NFI) are detailed for living trees; however, information on soil is limited. Due to a lack of data on measured SOC change on a large scale, estimates for areas on mineral and organic soil rely on model predictions. For mineral soil, SOC change is predicted using the Yasso07 model with NFI-derived litter input. Yasso07 is applied on the NFI-plot level reflecting the spatial and climatic variability in forest development and in decomposition. For organic soil, Scandinavian emission factors are applied. We present the experiences from the first two UNFCCC submissions with the method used on mineral soil and focus on (i) how does the spatially disaggregated method deviate from a national aggregated model application, and (ii) how sensitive is the estimate to key input variables and parameters. Further, we present the challenges related to organic soils including the possibilities to use NFI-derived data to improve the current method.

Carbon loss and degradation indicators in *Nothofagus* forests of the Andes and Coastal range in the Mediterranean region of Chile. Dube, F., Müller-Using, B., Stolpe, N., Zagal, E. (*University of Concepcion, Chile; fdube@udec.cl; bmullerusing@udec.cl; nstolpe@udec.cl; ezagal@udec.cl*).

Changes in land-use such as deforestation are important anthropogenic factors that have contributed to the increase of atmospheric CO_2 concentrations. Forest degradation imply that the vegetation removed no longer fixes C, and damaged trees and soils sequester less C, resulting in an increase in total C emissions to the atmosphere. The specific objectives of this study are to measure the size of C stocks in plant biomass and soil as well as annual C fluxes in *Nothofagus* forests, considering variations in soil temperature and moisture, and determine the influence of forest degradation on the quality and distribution of soil organic matter. Preliminary results show that initial decomposition rates of litterfall (64% mass loss in six months) and soil respiration (0.44 g CO_2 /h/m^2) were highest in non-degraded Andes forests. Additionally, soil moisture at 0–20 cm depth was significantly higher in the degraded forests in southern slopes in both areas, whereas soil (0–20 cm depth) and air temperatures above the soil (+5 cm) were highest in the degraded Andes forest in northern slope. The use of forest degradation and soil quality indicators will permit adequate quantification of the degree of deterioration of *Nothofagus* forests in the Mediterranean region of Chile.

Humus dynamics in timberline ecotones : case studies from the Austrian Alps. Katzensteiner, K. (*University of Natural Resources and Life Sciences, Austria; klaus.katzensteiner@boku.ac.at*), Jandl, R. (*Forest Research Center, Austria; robert.jandl@bfw.gv.at*).

Soils of timberline ecotones are frequently characterized by thick organic surface layers. Mor or Tangel humus forms may be found on different substrates but are usually associated with heath communities or coniferous species. These humus forms react sensitive to any disturbance. Land use and climate change may alter vegetation community structures and thereby influence soil organic matter dynamics. Increased NPP may lead to increased litter input rates, changes in litter quality, snow distribution, soil climate and soil microbial community structures will affect mineralization. There is even empirical evidence of an initial decline in organic layer thickness when alpine shrubland is replaced by coniferous forests, eventually leading to a decline in total soil organic carbon pools. Based on case studies from timberline ecotones on calcareous and silicious substrate a conceptual model framework for humus dynamics in timberline ecotones will be presented.

Soil organic carbon and nitrogen sequestration over an age sequence of *Pinus patula* plantations in Eastern Highlands of Zimbabwe. Mujuru, L. (*Bindura University, Zimbabwe; lzzmjr2009@gmail.com*), Gotora, T. (*SADC Secretariat, Botswana; timothyagotora@gmail.com*), Velthorst, E. (*Wageningen University, Netherlands; Eef.velthorst@wur.nl*), Nyamangara, J. (*International Crops Research Institute for the Semi-Arid Tropics, Zimbabwe; j.nyamangara@cgiar.org*), Hoosebeek, M. (*Wageningen University, Netherlands; marcel.hoosbeek@wur.nl*).

Forests play a major role in regulating global atmospheric carbon dioxide (CO_2) concentrations creating a need to investigate ability of exotic plantations to sequester atmospheric CO_2. This study examined pine plantations located in eastern highlands of

Zimbabwe relative to carbon and nitrogen storage along an age series. Samples of stand characteristics, forest floor and soil were randomly taken from replicated stands in *Pinus patula* of 1, 10, 20, 25, and 30 years plus two natural forests. Sodium polytungstate was used to isolate free light fraction (fLF), occluded light fraction(oLF) and mineral associated heavy fraction(MaHF). Aboveground tree biomass was the major ecosystem C pool followed by forest floor's humus layer in addition to the 45%, 31%, and 24% of SOC contributed by 0–10, 10–30, and 30–60 cm soil depths respectively. Stand age caused significant differences in total organic C and N stocks. Carbon and N declined initially soon after establishment but recovered rapidly at 10 years, after which it declined following silvicultural operations and recovered again by 25 years. Contribution of fLF C, oLF C, and MaHF C to SOC was 8–13%, 1–7%, and 90–91%, respectively. Results highlight importance of considering forestry age based C pools in estimating C sink potential and possibilities of considering conservation of existing natural forests as part of future REDD+ projects.

Estimating forest floor carbon content in the United States. Perry, C., Domke, G., Wilson, T. Walters, B., Woodall, C. (*U.S. Forest Service, USA; charleshperry@fs.fed.us; gmdomke@fs.fed.us; ty_wilson@yahoo.com; bfwalters@fs.fed.us; cwoodall@fs.fed.us*).

The U.S. Forest Service conducts a national forest inventory (NFI) including measurements of forest floor. Samples are collected on a nation-wide array of approximately 7 800 plots, and 10–20 percent of these plots are measured on a recurring basis. In the USA, the current method of reporting C stocks to international parties uses mathematical models. Forest type maps are combined with national soil survey data (STATSGO) to generate soil C storage by forest types, but STATSGO is based agricultural soils and consistently underestimates C storage in forest floors. The NFI data represent an opportunity to improve our modeling and reporting capabilities because data are directly linked to forest cover and other geospatial information, and it is an equal probability sample of all forested soils. NFI field observations could be used to evaluate current estimates if not replace them. Here we combined forest floor measurements with predictors of forest floor formation (e.g., climate, tree species and density, topography, and landscape position) to impute forest floor C storage across the USA. We produced an estimate of landscape-level forest floor C stocks from plot-level observations. Future work will include comparisons of these imputed results with simpler models currently used by the U.S. greenhouse gas inventory.

Warming effects on soil C-cycling: recap after nine years of artificial soil warming in a temperate spruce forest. Schindlbacher, A., Jandl, R. (*Forest Research Center, Austria; andreas.schindlbacher@bfw.gv.at; robert.jandl@bfw.gv.at*), Wanek, W., Schnecker, J. (*University of Vienna, Austria; wolfgang.wanek@univie.ac.at; joerg.schnecker@univie.ac.at*), Hubach, A., Borken, W. (*University of Bayreuth, Germany; mibelle@gmx.de; werner.borken@uni-bayreuth.de*).

Global warming will affect the carbon cycling of many forest ecosystems. Major biological processes such as the decomposition of soil organic matter are primarily driven by temperature. Increasing surface temperatures can accelerate process rates and the corresponding C fluxes. Decomposition of organic matter produces CO_2 which is set-free from the soil surface. As the soil CO_2 efflux is one of the largest fluxes in the global C-cycle, a temperature driven increase could affect atmospheric CO_2 concentrations. We artificially warmed the soil of a mature spruce stand by 4 °C throughout the snow-free seasons since 2004. Soil warming increased the CO_2 efflux by 40–50%, but in contrast to many other warming studies, the warming effect did not decline over time. Our results suggest that soil warming fuelled the labile C pool by greater transfer of assimilates to the rhizosphere.

Estimation of forest floor carbon stocks in a tropical montane forest. Vijayanathan, J. (*Forest Research Institute Malaysia, Malaysia; jeyanny@frim.gov.my*), Mohd Hanif, A. (*Putra University, Malaysia; husni@agri.upm.edu.my*), Kadir, W. (*Forest Research Institute Malaysia, Malaysia; rashidah@frim.gov.my*), Balasundram, S., Abdu, A. (*Putra University, Malaysia; siva@agri.upm.edu.my; arifinabdu@upm.edu.my*).

Forest floor (FF) carbon stocks which include different components of litter, hemic, sapric, duff (sapric +hemic) and its total has not been empirically quantified in tropical montane forest although they influence the soil C pools. This study quantifies the bulk density of FF components separately, the carbon fraction (CF) and estimates the C stocks using mathematical exponential models to increase accuracy of forest floor carbon (FFC) stock reporting. Forest floor components were measured for depth, area density, and dry mass separately in Sungai Kial Forest Reserve, Pahang, Malaysia. Results of bulk density against FFC stocks (Mg/ha) were fitted into a regression analysis based on significant coefficient of determination (R^2) at $p < 0.01$. Bulk density for litter, hemic, sapric, duff, and total FF were 0.04, 0.16, 0.21, 0.19, and 0.14 g/cm^3, respectively. The duff material had the highest CF (0.55) compared to litter and total FF (0.43), indicating FFC stocks for duff were 6–14 Mg C/ha compared to litter ($\leq$ 3 Mg C/ha) based on the regression models. Efficient monitoring and management of FFC stocks would require refined bulk density and CF protocols to increase precision in FFC stocks reporting for tropical montane forest.

C-16 Remote sensing in carbon balance evaluation and monitoring

Organizers: Tomasz Zawila-Niedzwiecki (General Directorate of the State Forests, Poland), Mathias Schardt (Joanneum Research, Austria) & Radomir Balazy (Forest Research Institute (IBL), Poland)

Satellite-observed changes in terrestrial photosynthetic activity trends across the Asia-Pacific region associated with land cover and climate from 1982 to 2011. Chen, B., Coops, N., Innes, J., Wang, G. (*University of British Columbia, Canada; baozhang.chen@ubc.ca; nicholas.coops@ubc.ca; john.innes@ubc.ca; guangyu.wang@ubc.ca*).

In this study we detected regimes for vegetation photosynthetic activity dynamics in the Asia-Pacific (AP) region, by discerning gradual changes into two key metrics of vegetation photosynthetic activity: (1) the cumulative annual NDVI in each year, and (2) the seasonality or variance in that index. We then assessed abrupt changes and changes with a turning point using three statistical models (least-square linear, expanded paired-consecutive linear, and piecewise regression modes) based on the updated Global Inventory Modeling and Mapping Studies (GIMMS) third generation global satellite NDVI dataset (1982–2011). We found that the AP region (including Australia, South East Asia, China, and the Pacific Coast of North America) experienced increasing

NDVI from 1982 through 2011 with an average rate of 5.30 $\times 10^{-4}$ NDVI/yr (0.13% per year). The annual NDVI gradually increased from 1982 at a faster rate of 26.14 $\times 10^{-4}$ NDVI/y^1 (0.65% per year) until an abrupt break in the trend after 1991 (the breakpoint year after which the trend dropped down to 5.78$\times 10^{-4}$ NDVI/yr). Pearson's correlation and multiple linear stepwise regression analyses were applied to identify the main drivers for these NDVI interannual variability, such as climate anomalies and land cover change.

Carbon mapping of regrowth in tropical rain forest using airborne LiDAR data in Berau, East Kalimantan, Indonesia. Hussin, Y., Asmoro, P. (*University of Twente, Netherlands; hussin@itc.nl; j.p.panjiasmoro@student.utwente.nl*).

Several remote sensing based approaches have been developed for plant response to environmental pressures and assessment of ecosystem services. However, there is no comprehensive assessment of plant growth forms or plant life forms using remote sensing. Most of the existing methods used remote sensing data as a proxy for some kind of variable (e.g., height) which is one of the important plant traits for assessment of vegetation. In this context, LiDAR data may provide more accurate detection and estimation of regrowth and growth in tropical rain forest than other previous approaches. Airborne LiDAR has demonstrated that it can be used to accurately assess object height, and nonetheless it cannot differentiate the species with low point density. Therefore, individual tree and stand-level physical attributes such as tree height, canopy height, canopy closure, and density can be generated from LiDAR data. The main aim of this research was to develop an approach for detection re-growth of sapling and accurate estimation and mapping of existing carbon of pole and tree after selective logging in tropical rain forest using airborne LiDAR data.

Assessing carbon stocks and socioeconomic indicators of complex landscapes. Neufeldt, H. (*World Agroforestry Centre (ICRAF), Kenya; H.Neufeldt@cgiar.org*), Gumbricht, T. (*Karttur, Sweden; thomas.gumbricht@gmail.com*), Norton-Griffiths, M., Herr, H., Kuyah, S. (*World Agroforestry Centre (ICRAF), Kenya; M.Norton-Griffiths@cgiar.org; H.Herr@cgiar.org; s.kuyah@cgiar.org*).

In this session we will present powerful new tools to assess biophysical and socioeconomic characteristics of complex landscapes including forests and trees on farms. ICRAF has developed a tree biomass assessment tool that is suitable for agricultural landscapes with tree mosaics to closed forest canopies and is based on an automated multispectral analysis of tree canopies using high to medium resolution satellite imagery. In combination with allometric equations, this approach allows to effectively estimate the above- and belowground biomass of heterogeneous landscapes and can thereby be used as a cost-effective monitoring tool for CDM, AFOLU and REDD projects. Further, by connecting this approach to assessing tree biomass to ICRAF's Land Health Surveillance Framework, it is possible to estimate soil organic matter stocks (and changes) as well as other indicators of soil health from the same satellite images. Finally, the biophysical information on tree and soil carbon stocks can be effectively connected to socioeconomic indicators, such as to evaluate net returns to land and tenure effects on land cover change over time.

Forest carbon mapping using multiple source remote sensing data in the Greater Mekong Subregion. Pang, Y., Li, Z. (*Chinese Academy of Forestry, China; pangy@ifrit.ac.cn; lizy@caf.ac.cn*), Huang, K. (*Asia-Pacific Network for Sustainable Forest. Management and Rehabilitation (APFNet), Canada; huang_kebiao@apfnet.cn*), Thongmanivong, S. (*National University of Laos, Laos; sithongth@hotmail.com*).

The Greater Mekong Subregion (GMS) is rich in forest resources. It is important to estimate forest carbon with high accuracy methods in this region. Remote sensing is an efficient way to estimate forest parameters in large area, especially at regional scale where field data is scarce. LIDAR provides accurate information on the vertical structure of forests. In this study, three sites of airborne LiDAR system (ALS) and 100 field plots were used to calibrate the spaceborne LiDAR data of ICESat GLAS waveform metrics. Then the forest carbon was estimated at ICESat GLAS footprint level in GMS. According to different types of ecological zones, a set of categorical regression models was built between ICESat GLAS estimates and ENVISAT MERIS spectral variables. A forest carbon map with continuous value was generated. The results showed that the integrated method based on field measurements, and airborne and spaceborne LiDAR data can be used to estimate forest carbon effectively. The overall average error of the estimation models was 34 ton/ha, with a correlation coefficient of 0.7. In addition, the estimation agreed well with the FAO FRA 2010 report and other published results, and the average difference was 13.3%.

Methods for EU-wide mapping of growing stock and aboveground biomass based on satellite remote sensing and field measurements. Schardt, M., Gallaun, H. (*Joanneum Research, Austria; mathias.schardt@joanneum.at; heinz.gallaun@joanneum.at*).

The objective of the presentation is the introduction of a method for combining national forest inventory data and remotely sensed data to produce pan-European maps on growing stock and above-ground woody biomass. An automatic up-scaling approach making use of satellite remote sensing data and field measurement data was applied for EU-wide mapping of growing stock and above-ground biomass in forests. The approach is based on sampling and allows the direct combination of data with different measurement units such as forest inventory plot data and satellite remote sensing data. For the classification, data from the Moderate Resolution Imaging Spectro Radiometer (MODIS) were used. Comprehensive field measurement data from national forest inventories for 98 979 locations from 16 countries were used for which tree species and growing stock estimates were available. The classification results were evaluated by comparison with regional estimates derived independently from the classification from national forest inventories. The validation at the regional level shows a high correlation between the classification results and the field based estimates. Biomass conversion and expansion factors were applied to convert the growing stock classification results to carbon stock in above-ground biomass.

Forest carbon monitoring with satellite 3D SAR. Solberg, S. (*Norwegian Forest and Landscape Institute, Norway; sos@skogoglandskap.no*).

Monitoring forest carbon can be carried out with satellite based X-band 3D SAR, based on the intuitive relationship between above-ground biomass, and carbon, and the height above ground of the RADAR echo. With 3D SAR we here mean InSAR or radargrammetry, by which we extract a digital surface model (DSM). We have obtained linear models where above-ground

biomass is proportional to SAR height with 15 t/ha change in biomass per m height change, and no tendency of saturation up to 350 t/ha. This relationship was fairly stable for a range of acquisition settings, and during spring, summer, and autumn. This means that changes in biomass and carbon can be extracted from repeated acquisitions. We compared InSAR and radargrammetry and obtained almost identical relationships. This means that we can apply both InSAR from bi-static Tandem-X data or radargrammetry from repeat-pass acquisitions with other missions. The accuracy has been fairly good in comparison with other satellite remote sensing methods, with RMSE values of about 55 t/ha (42%) at the plot level for 250 m^2 plots and about 25 t/ha (19%) at the stand level. Testing this in Indonesia and Tanzania has also provided promising results for REDD, including logging detection.

Forest aboveground biomass estimation in China. Wu, B., Zeng, Y., Zhao, D. (*Chinese Academy of Sciences, China; wubf@irsa.ac.cn; yuanz@irsa.ac.cn; zhaodan@irsa.ac.cn*).

In order to study the carbon cycling in China, we estimated China's forest aboveground biomass (AGB) in 2012 with eight separate sub-areas. More than 5 000 sample plots of different forest types, which included coniferous forest, deciduous forest, and mixed forest, were surveyed nationwide, and airborne LiDAR data was acquired in five sub-areas, each covering 60~200 km^2, respectively. The sample plots and LiDAR data provided a typical AGB sample dataset, while the LiDAR and Geoscience Laser Altimeter System (GLAS) data provided a precise canopy height dataset. Combining these two datasets, a continuous canopy height dataset with MODIS Bidirectional Reflectance Distribution Function (BRDF) product was inversed, and then the AGB in each sub-area was extrapolated with the canopy height dataset, MODIS data, and some other auxiliary data. The extrapolation model was a forest type based remote sensing model of which the main inputs were canopy height time series analyzed parameters of MODIS vegetation indices, and LAI data, terrain elevations, and China's land cover product. Finally, the models were applied according to the different forest typed in each sub-area to get China's AGB.

C-17 New developments in the use of remote sensing and national forest inventories for estimation and mapping

Organizers: Gregory Reams (U.S. Forest Service) & Ken MacDicken (UN-FAO, Italy)

Origin and methodological aspects of national forest inventory in Brazil (NFI-BR). David, H., Netto, S.P. (*University of Paraná, Brazil; hassancamil@gmail.com; sylviopelliconetto@gmail.com*).

Brazil is recognized worldwide as a country with exuberant biodiversity, especially when it comes to the Amazon rainforest. However the information about the Brazilian forest resources is still incipient, due to lack of researches at national level. Some researches had been conducted, but with particular objectives and methodologies, especially the case of FAO mission in the Amazon and the RADAMBRASIL, both happened between the 1950s and 1970s. Aiming at the establishment of public policies and the recognition of forest resources, the Brazilian Forest Service started the National Forest Inventory in Brazil (NFI-BR) in 2011, including landscape and socio-environmental surveys, besides data collection of soil and forest species. A systematic grid was used, in which each point was allocated every 400 km^2, having a cluster composed of four subunits of 1 000 m^2 each, except in the Amazon, where this area will be increased to 2 000 m^2. The grid can be intensified in the future to 100 km^2 or 25 km^2. Until mid-year 2013, the inventory of the Santa Catarina State was carried out completely and partially in Parana, Rio de Janeiro, and Rio Grande do Sul States. The forecast for the beginning of the NFI in the Amazon rainforest is in 2014.

Development of carbon monitoring methods in Ecuador. Granja, D., Segura Ramos, D. (*Ecuador Ministry of the Environment, Ecuador; agranja@ambiente.gob.ec; dsegura@ambiente.gob.ec*).

In recent years, Ecuador has made significant progress in the area of assessment of forest resources by providing an information base for their natural resource monitoring system. Currently there are three important components to the system: (1) a historical deforestation map, whose main objective is to build the historical setting of spatially explicit deforestation at the national level; 2) a continental ecosystems map, aimed at identifying priority areas for conservation, restoration, and sustainable use of natural resources; and 3) the national forest assessment, whose main objectives are to improve the management of forests and associated resources and facilitate participation in REDD + mechanisms. These three initiatives of the Ministry of Environment of Ecuador (MAE) are the basis for its Monitoring Natural Heritage of Ecuador program. MAE has developed this program with technical and financial support from the Food and Agriculture Organization (FAO), the Organization of the Amazon Cooperation Treaty (OTCA), among other national and institutional partners.

Preliminary results of the global forest biomass survey. Healey, S. (*U.S. Forest Service, USA; seanhealey@fs.fed.us*), Lindquist, E. (*United Nations Food and Agriculture Organization, Italy; Erik.Lindquist@fao.org*).

Many countries do not yet have well-established national forest inventories, and among those that do, significant methodological differences exist, particularly in the estimation of standing forest biomass. Global space-based LiDAR (Light Detection and Ranging) from NASA's now-completed ICESat mission provided consistent, high-quality measures of canopy height and density. The United Nations Food and Agriculture Organization, together with the United States Forest Service, has coordinated an international effort to calibrate ICESat measurements with field measurements of aboveground biomass, and is using these measurements in a model-based estimation context around the world. This effort is called the Global Forest Biomass Inventory (GFBI), and each contributing country to the 2015 Global Forest Resources Assessment will be provided with LiDAR-based, national-level biomass density estimates. It is anticipated that many countries now reporting aboveground biomass using only international defaults will choose to report GFBI numbers. Project methodology will be described in this presentation, and preliminary estimates for cooperating countries will be discussed.

Mapping forests as renewable chemicals for biorefineries. Lestander, T., Athanassiadis, D., Nilsson, M. (*Swedish University of Agricultural Sciences, Sweden; torbjorn.lestander@slu.se; dimitris.athanassiadis@slu.se; mats.nilsson@slu.se*).

The Swedish National Forest Inventory (NFI) collects data describing the current state and changes in Sweden's forests, e.g., volume of standing trees in cubic meter above bark. Reliable forest statistics are presented on a national and regional level. As the demand for more local forest information has increased over the years, wall-to-wall raster maps with estimates of forest variables such as stand volume and tree species composition has been produced using a combination of Landsat or SPOT imagery and field plot data from the NFI. However, these forest data maps are difficult to interpret for chemists, engineers, material scientists etc. The need to break away from dependency of fossil carbon sources has increased the demand for sustainable biorefining of biomass. In this work we show and discuss new approaches in mapping renewable forests resources that can be used for producing chemicals, biofuels, biomolecules etc. We will especially target the need for biorefineries to map the amount of forest-based chemicals on a landscape level and the ecosystem services required for sustainable production and development.

A new soil erosion survey method in the national forest inventory of Japan. Miura, S. (*Forestry and Forest Products Research Institute, Japan; miura@ffpri.affrc.go.jp*), Kanamori, M., Ogaya, N. (*Japan Forest Technology Association, Japan; m_kanamori@jafta.or.jp; naoka_ogaya@jafta.or.jp*), Nanko, K. (*Forestry and Forest Products Research Institute, Japan; knanko@affrc.go.jp*), Nagame, I. (*Forestry Agency, Japan; ichiro_nagame@nm.maff.go.jp*), Suzuki, M. (*University of Tokyo, Japan; suzuki@fr.a.u-tokyo.ac.jp*).

Criteria and indicators developed by regional initiatives such as the Montreal Process have played an important role as a propulsion engine for achieving sustainable forest management in the last two decades. However, many variables utilized for indicators have been derived from administrative statistical data. There is a need for new variables to be measured in the field to better indicate ecological trends. This paper reports the analysis of a new variable implemented into the national forest inventory system in Japan. We focused on soil erosion and monitored floor cover percentage by understory or litter, which is related to soil and water protective functions. We scaled evidence of erosion from soil pillar, then rill, up to gully along with increases. Four-year observations using the new erosion survey method all over Japan showed that occurrence of soil erosion increased as floor cover percentage decreased. Forest floor cover influenced soil erosion as much as slope inclination. Floor cover percentage of *Chamaecyparis obtusa* forest known as susceptible to soil erosion was low. Protecting forest floor cover as well as forest canopy cover prevents forest degradation. Introducing these kinds of measurable variables into national forest inventory systems must enhance the value of forest monitoring towards sustainable forest management.

Brazilian national forest inventory: remote sensing and landscape analysis approaches for nationwide forest monitoring and assessment. Oliveira, Y.M., Rosot, M., Garrastazu, M. (*EMBRAPA, Brazil; yeda.oliveira@embrapa.br; augusta.rosot@embrapa.com; marilice.garrastazu@embrapa.br*), Luz, N. (*Fundação de Amparo à Pesquisa do Estado de Goiás (FAPEG), Brazil; naissa@gmail.com*), Mattos, P. (*EMBRAPA, Brazil; patricia.mattos@embrapa.br*), Franciscon, L., Freitas, J., Piotto, D., Gomide, G.

National Forest Inventory (NFI-BR) is under development in Brazil, aiming at generating information on forest resources, both natural and plantations, based on a 5-year measurement cycle, to support the formulation of public policies. One component of this initiative comprises remote sensing and landscape scale spatial analysis, which includes aspects such as land use/land cover (LULC), trees outside forests (TOF), permanent preservation areas (PPA), and forest fragmentation. A 20 km × 20 km grid defines the center of a field registry sample unit (RSU) from which landscape sample units (LSU) are established at each 40 km × 40 km. The LSUs are 100 km^2 wide areas with RapidEye satellite imagery coverage. Methodology development for image classification and landscape analysis are currently underway, based on 20 LSU pilot sample units. While object-based image analysis is the main approach regarding LULC and TOF mapping, GIS-based spatial analysis and landscape ecology metrics are the means to assess forest fragmentation and identify actual PPA readiness to current environmental laws. The developed methodology will be applied to the remaining NFI–BR LSUs distributed countrywide. This information will be used to quantify and qualify forest resources under mentioned perspectives and extrapolate field data using phytoecological regions as well as political divisions.

Going beyond national-level statistics: a new data infrastructure for ecoregion-level forest resource assessment. Smith, B. (*U.S. Forest Service, USA; bsmith12@fs.fed.us*), Stinson, G., Song, A. (*Canadian Forest Service, Canada; gstinson@nrcan.gc.ca; Alex.Song@NRCan-RNCan.gc.ca*), Miles, P., Oswalt, S. (*U.S. Forest Service, USA; pmiles@fs.fed.us*); *soswalt@fs.fed.us*), Rodriguez Franco, R., Leyva, J., Richardson, K., Jafry, Z, Kapron, J.

The United States, Mexico and Canada maintain National Forest Inventories for strategic monitoring of forests at national and sub-national levels. All three countries use their NFI programs to provide statistics aggregated at national levels into the FAO`s Forest Resources Information Management System (FRIMS). While the FRIMS data are of great value for global forest resource assessment purposes, aggregation at scale of ecological strata provides the possibility for more in-depth assessment of regional sustainable forest management successes and challenges. Such aggregation requires a deeper level of data harmonization. The North American Forest Commission's Inventory and Monitoring Working Group (IMWG) piloted this approach by developed an infrastructure for data harmonization and analysis with three basic elements: (i) a harmonized North American ecoregion map, (ii) North American NFI data harmonization rules, and (iii) a relational database for managing integrated North American forest inventory data. These three elements work together, but can also be used individually for other applications. We describe progress to date and discuss lessons learned to stimulate and inform further advances in streamlined forest reporting and improvements to global forest assessment data beyond those already achieved by collaborating international organizations for FRA2015.

Posters

Russian Federation forest resources assessment based on free medium resolution remote sensing data. Lopatin, E. (*University of Eastern Finland, Finland; eugene.lopatin@uef.fi*), Alexeyev, A. (*St. Petersburg State Forest University, Finland; A_S_alekseev@mail.ru*).

To meet the challenges of foresight directional changes in forest ecosystems there is a need to obtain spatial information about forest condition and the variability not only over long periods of time, but also operational. Adoption of ecologically, economically and socially right decisions is only possible with accurate and objective information on the trends in the forest growth, one of the ways to get that is to develop a system for monitoring, mapping and forecasting trends in the growth of boreal forests. The project conducted the development of the Internet service for the assessment of forest Russian Federation based on free data medium resolution. Fully automated system for receiving and processing of time series of satellite images was developed. The basis for monitoring are satellite images freely available from the Internet and materials of own field studies, collected during the research team activities. Based on the time series of satellite images obtained over the Internet (satellites NOAA, Landsat, Terra, and similar sensors) the time series of different vegetation indices and statistics were calculated. The integration of an automated system in to the Russian NFI would create a new information resource for the current assessment of the forests.

Mapping the extent of conifers dominating high conservation value forests in Finland using Landsat data. Lopatin, E., Lopatina, A. (*University of Eastern Finland, Finland; eugene.lopatin@uef.fi; anna.lopatina@uef.fi*).

The largest fragments of high conservation value forests in Finland are protected in the national parks. Besides the large protected fragments there are a high number of small fragments outside the national parks. Those fragments are very valuable due to their role in connecting the large fragments into the functional network of habitats. To map the connectivity of the high conservation value forests outside the national parks is very important to develop the method allowing identification of the potentially valuable stands. The aim of the present study was to test the applicability of Landsat TM data to locate highest conservation value forests in boreal region. The highest overall accuracy of conifers high conservation value forests mapping using classification and regression trees analysis of Landsat data was 98% at pixel level (kappa 0.79).

Measurement and monitoring of carbon in Peru: methods and plans for MRV. Vergara Arellano, R. (*Ministerio de Agricultura y Riego, Peru; rvergara@minagri.gob.pe*), Suarez de Freitas Calmet, J. (*Ministerio del Ambiente, Peru; gsuarezdefreitas@minam.gob.pe*).

The Peruvian government is engaged in several activities related to carbon measurement and monitoring. In addition to participation in international programs like REDD, Peru is interested in enhancing its capacity to monitor the status of and trends in its forest resources. To meet these goals, Peru has developed a remote sensing strategy that involves a combination of Landsat-based change detection, vegetation type map development, and LiDAR analyses. In addition to remote sensing approaches, Peru has also begun its national forest inventory. Multiple Peruvian government agencies are working with FAO and other entities to establish a network of ground plots using a probabilistic sampling approach. The current talk will involve discussions of the inventory, remote sensing methods, MRV strategies, and future plans for Peru's natural resource monitoring system.

C-18 Using multi-source remotely sensed data and nearest neighbor techniques to improve inference for natural resource applications

Organizer: Temesgen Hailemariam (Oregon State University, USA)

A Monte Carlo appraisal of four different interpolation methods to couple remotely sensed and ground data. Corona, P. (*University of Tuscia, Italy; piermaria.corona@unitus.it*), Chirici, G. (*University of Molise, Italy; gchirici@gmail.com*), Fattorini, L. (*University of Siena, Italy; fattorini@unisi.it*), Maselli, F. (*Institute of Biometeorology (IBIMET-CNR), Italy; maselli@ibimet.cnr.it*), Secondi, L. (*University of Tuscia, Italy; secondi@unitus.it*).

The goal of this presentation is to compare cokriging, regression kriging, locally weighted regression and *k*-nearest neighbors techniques when the objective is mapping forest attributes (e.g., timber volume) by exploiting remotely sensed data (e.g., the digital numbers from multispectral remotely sensed images) as auxiliary variables and a tessellation stratified sampling is performed in order to obtain ground data. To this purpose a simulation study is performed in which a set of nine artificial populations of timber volume are generated and uncertainty arises from the random allocation of sampling points. From the resulting Monte Carlo distribution of timber volume predictions, the quartiles of the design-based relative bias and the quartiles of the design-based relative root mean squared error are computed and then used in order to compare the four methods. Cokriging, regression kriging and locally weighted regression perform better than *k*-nearest neighbors for all the nine considered populations. A practical case study with the application of the compared statistical techniques to multispectral remotely sensed data is also provided.

Ensemble approaches to the nearest neighbor problem. Coulston, J., Crookston, N. (*U.S. Forest Service, USA; jcoulston@fs.fed.us; ncrookston.fs@gmail.com*).

The application of nearest neighbor approaches has increased dramatically over the last 10 years. A typical approach is to create a single spatial realization, or imputed map, by leveraging field-based inventory data with remotely sensed information and other geospatial data. An alternative is to create multiple spatial realizations using ensemble approaches. We demonstrate the utility of using multiple spatial realizations for inference and further demonstrate the potential for improved accuracies by employing ensemble approaches to the nearest neighbor problem.

Imputations using the enhanced R package yaImpute: bootstrapping, ensembles, and a new fit statistic. Crookston, N., Coulston, J. (*U.S. Forest Service, USA; ncrookston.fs@gmail.com; jcoulston@fs.fed.us*).

The R package yaImpute supports several approaches to solving the k-NN imputation problem. The package has been credited with making the techniques accessible to practitioners. This paper reports on recent enhancements to the package that support

bootstrapping and ensemble imputations as well as the use of canonical correlation computed using projection pursuit. Functions are included that capitalized on the bootstrapping to provide nonparametric confidence intervals of imputed values and automated identification of the most useful predictor variables. Examples are provided that include the use of the parallel package to speed up bootstrap-based calculations. The new approaches provide better results on example problems as measured by a reduction in error.

Using multi-source remotely sensed data and nearest neighbor techniques to improve inference for natural resource applications. LeMay, V. (*University of British Columbia, Canada; Valerie.LeMay@ubc.ca*), Moss, I. (*Tesera Systems, Inc., Canada; ian.moss@tesera.com*), Hailemariam, T., Eskelson, B. (Oregon State University*, USA; temesgen.hailemariam@oregonstate.edu; bianca.eskelson@oregonstate.edu*).

Accurate and cost-efficient methods for combining ground, remote sensing, and GIS data are essential for providing the geospatial information needed to manage forest resources, including timber, biomass, and sequestered carbon. For each managed resource, information on a suite of related forest variables is needed. For example, increasing carbon sequestration as a means of mitigating climate changes requires information on existing carbon stocks, as well as variables affecting carbon cycling (e.g., species composition, age distribution, etc.). For a single forest variable, univariate variable-space nearest neighbor imputation methods (called k-NN) are effective geospatial analysis methods that combine multisource data to provide localized estimates for a single variable of interest. The k-NN method matches auxiliary variables (e.g., Landsat data) at a non-sampled location with the k nearest neighbors from the reference database of sampled locations, and imputes the average of a variable of interest (e.g., biomass) to this non-sampled location. Alternatively, multivariate variable-space NN methods impute all variables of interest simultaneously. In this paper, we discuss alternatives for ensuring logical consistencies among related imputed forest variables. Comparisons of univariate and multivariate approaches are presented, using an example for a complex, temperate rain forest in Canada.

Approaches for estimating stand and tree-level variables for use in large scale national forest inventories. Lochhead, K., LeMay, V., Bull, G. (*University of British Columbia, Canada; kyle.lochhead@live.forestry.ubc.ca; Valerie.LeMay@ubc.ca; gary.bull@ubc.ca*).

Assessing the impacts of forest management strategies on the landscape, including changes in management to achieve carbon sequestration targets, requires an inventory of forest attributes at a variety of spatial scales. These scales encompass the various levels of ecological organization that define indicators of forest sustainability through time. An informational linkage across these spatial scales is needed to provide detailed information. Multisource National Forest Inventories and imputation methods provide the mechanisms for these multi-scale linkages. However, for very large spatial extents where detailed forest information is often very widely distributed in space, providing reliable information in a timely and consistent manner is more challenging. In this study, we present results of using alternative approaches for utilizing multiple sources of forest land information in conjunction with variable-space nearest neighbor imputation methods, real-space imputation methods, and a combination of variable- and real-space imputation to provide detailed forest information at all locations within the Boreal Forest of Canada (~551 million ha). These methods are then compared with regards to: (i) accuracy; and (ii) computational efficiency.

Variable selection strategies for nearest neighbor imputation in remote sensing based forest inventory. Packalen, P. (*University of Eastern Finland, Finland; petteri.packalen@uef.fi*), Hailemariam, T. (*Oregon State University, USA; hailemariam.temesgen@oregonstate.edu*), Maltamo, M. (*University of Eastern Finland, Finland; matti.maltamo@uef.fi*).

We examined the problem of selecting predictor variables to nearest neighbor imputation in the remote sensing based forest inventory. Predictor variables were calculated from the airborne laser scanning data and aerial images and responses were either dominant height or a set of five common stand attributes. Three different approaches were compared to select predictor variables, in addition to that using all available predictor variables. Analyses were repeated with two different NN imputation methods using varying number of predictor variables. Results indicated that variable selection is justified but it must be done properly. The most accurate method to select predictors was the optimization approach in which an error was minimized by simulated annealing. The most accurate imputation method in the case of single response was random forest proximity matrix based imputation, whereas MSN was the most accurate one in the case of five responses. We also examined the degree to which different imputation methods are prone to overfitting as well as how to properly do cross-validation in nearest neighbor imputation.

Small-area estimation across large areas of forest. Pond, A. (*SilviaTerra / Michigan Tech, USA; nancpond@gmail.com*), Froese, R. (*Michigan Technological University, USA; froese@mtu.edu*), Wilson, B. (U.S. Forest Service*, USA; barrywilson@fs.fed.us*).

There is considerable interest in detection of change, for monitoring forest disturbance, forest utilization, and responses to climate change. In this study, models were developed using multiple remote sensing data products with reference data from the U.S. Forest Inventory and Analysis program. This work summarizes the results of multiple k-nearest neighbor imputation models to estimate forest inventory, growth, and removals. Imputation models for forest attributes of interest are common, but detecting and modelling change using multi-temporal spatial data is more challenging. The study area of interest spanned multiple cover types within the Laurentian mixed forest. We compared the relative predictive abilities of various feature data, and developed a model for estimating volume at a single point in time, as well as a model for estimating components of change from Landsat imagery and data from multiple measurement cycles. This included an application of Fourier series, used to capture the temporal and spatial variation of multi-spectral indices. We explored a novel method of quantifying differences between time series using Fourier power spectrum information, and report the efficacy of spectral coherence as a predictor of forest change.

Restricted imputation for improved forest scenario analysis. Staahl, G. (*Swedish University of Agricultural Sciences, Sweden; goran.stahl@slu.se*), Barth, A. (*The Forestry Research Institute of Sweden, Sweden; andreas.barth@skogforsk.se*).

Increasingly, forest scenario analysis requires spatially comprehensive data, i.e., wall-to-wall coverage, as a basis for analyses where the spatial location of different features in the forest are important. Examples include biodiversity analyses, forest

management planning considering aspects of logistics and road maintenance, and the resulting carbon dioxide emissions/removals due to forestry. With standard imputation techniques, such as most similar neighbor imputation based on remote sensing data, the spatial context of forests may be poorly preserved, i.e., neighboring units may be highly different with regard to species mixture, age, etc. Further, there is no guarantee that the average conditions within a larger area correspond to the average conditions from the sample survey from which field data for the imputation were obtained. In this study we present a technique where, so called, restricted imputation is used in order to ascertain that the overall conditions within an imputation-based large forest area correspond to the conditions from the sample survey. Further, we present algorithms whereby imputed data are reallocated in order to modify the local variability within forest stands to correspond to specified target conditions. Through these procedures, we suggest that the data basis for spatially explicit forest scenario analysis is improved considerably.

C-19 Implementation of silvicultural treatments and their effects into forest growth models

Organizers: Margarida Tomé (Technical University of Lisbon, Portugal) & JP Skovsgaard (Swedish University of Agricultural Sciences)

The forest projection and planning system (FPS). Arney, J. (*Forest Biometrics Research Institute, USA; JDArney@forestbiometrics.com*).

The Forest Projection and Planning System (FPS) is an individual-tree, spatially-explicit growth model which encompasses all aspects of species diversity, genetic variability, site capacities and silvicultural effects in even-aged, mixed-aged, or multi-structure stands for inventory updating or long-term silvicultural planning. This model is the culmination of 40 years of research and development by the author based on growth and yield dynamics of over 20 species in six western States and two Canadian Provinces. Over 80 organizations use this model for all forest management activities on their ownerships across the western United States. All components of FPS are based on nonparametric response surfaces utilizing a database of over 20 000 permanent research plots and 16 000 felled trees for taper and site capacity. FPS components encompass macro-site, micro-site, tree ingrowth, non-tree growth, multi-species, and multi-structure dynamics. Outputs include spatial and dimensional structure; cubic, cord, and board volumes; wood, bark, roots and crown biomass; costs, values and discounted cashflows; and total weight of sequestered carbon by species and component. The FPS Inventory database, growth model, and planning system is the most fully integrated silvicultural planning package offered and fully supported anywhere in the United States.

Using a light-capture based tree growth model to optimize uneven-aged silviculture of Picea mariana in Canada. Groot, A. (*Canadian Forest Service, Canada; agroot@nrcan.gc.ca*).

A long-term experiment has demonstrated that it is technically and biological feasible to manage peatland *Picea mariana* using uneven-aged silviculture. It is not possible, however, to establish experiments to examine all potential combinations of harvest intensity and cutting cycle. This paper examines a number of these combinations using the light-capture based individual tree growth model, IVY. The IVY model was developed to forecast the growth of complex-structured (mixed species, spatially heterogeneous, and uneven-sized) stands. For successive time steps, the model determines the amount of light captured by each tree crown in a stand, and translates this into a volume growth estimate using volume increment efficiency (VIE), the amount of stem volume growth per unit of intercepted light. The model is used to develop response surfaces of forecasted volume growth and stem diameter distribution resulting from various combinations of harvest intensity and cutting cycle. Optimum treatment combinations can be identified from this response surface.

Modeling uneven-aged management of heterogeneous forests within individual based and spatially explicit simulation models. Lafond, V., Lagarrigues, G., Cordonnier, T., Courbaud, B. (*National Research Institute of Science and Technology for Environment and Agriculture, France; valentine.lafond@irstea.fr; guillaume.lagarrigues@irstea.fr; thomas.cordonnier@irstea.fr; Benoit.Courbaud@irstea.fr*).

Central European mountain forests have a long tradition of selection system, but conservative management has led to aging stands with high stocking levels, highly sensitive to disturbances. Forest managers are, therefore, investigating strategies to increase forest resistance and resilience, reducing stocking by increasing harvesting intensities and promoting heterogeneous stands by group selection. Forest simulation models are very helpful to assess the long term effects of such practices but require elaborated silviculture algorithms to adequately simulate them. This contribution aims at presenting a new algorithm for uneven-aged management and illustrating it with a simulation study comparing different group selection practices and harvesting intensity levels. This algorithm have been implemented on the Capsis4 simulation platform and coupled with Samsara2, an individual based and spatially explicit forest simulation model designed for spruce-fir uneven-aged mountain forests. The simulation results helped discussing management options, like the positive effect of group selection practices on stand heterogeneity or the long term implication of intensified harvesting. However, integrating biodiversity and ecosystem services requires increasing sophistication of simulation models and silviculture algorithm, to better consider species mix management or dead wood and large trees retention.

Improve the 3-PG model in *Eucalyptus* fertility modifier using twin-plots. Lemos, C. (*International Paper, Brazil; Cristiane.Lemos@ipaper.com*), Stape, J. (*North Carolina State University, USA; jlstape@ncsu.edu*), Hakamada, R. (*University of São Paulo, Brazil; rodrigo_hakamada@yahoo.com.br*), Carrero, O. (*Proteak, Mexico; ocarrero@proteak.com*).

The twin-plot design is an alternative to determine forest fertilization response on a landscape scale, allowing establishment of the actual and the attainable forest productivity, as well as the nutrients that limit forest growth. Based on this, we used 113 pairs

of twin-plots installed in *Eucalyptus* plantations along the southeast of Brazil to improve the 3-PG soil fertility modifier (FR) estimation. Those twin-plots were stratified into three soils types: Typic, Oxisol, and Ultisol. Twenty percent of those twin-plots were used to calibrate the 3-PG model and 80% to validate it. We evaluated the leaf area index and stem biomass as output. Five meteorological stations were used to cover the study area. The FR was adjusted for each plot and soil type using the control treatment. Entisols were those which had the highest nutritional deficiency, limited by the sums of bases (Ca, Mg and K). Thus, it was possible to correlate the FR to the soil chemistry variable sum of bases. The twin-plots were useful for estimating the FR, being used commercially along the study area. However, this 3-PG modifier is dependent on the traditional management of the company, thus requiring a network of twin-plots for appropriate determination.

Increases in soil carbon and C/N ratio in pine forests 34 years after phosphorus fertilizer addition: measurement and modeling. Polglase, P. (*Commonwealth Scientific and Industrial Research Organisation, Australia; philip.polglase@csiro.au*).

The extent to which forest soils can be managed to store additional carbon varies widely as does understanding of the mechanisms underlying any change. Four pine plantation sites (six treatment responses compared to a Control) established in the 1960s were resampled after 34 years for growth, foliar nitrogen, and soil C and N to 30 cm depth. All sites had P fertilizer added which was the most limiting nutrient. Growth responses were large, increasing mean annual volume increment by 20–80% over Control treatments. Soil C increased in all treatments by an average 17% over the Control (nonfertilized) treatments and ranged from –0.1 to +0.7 t C/ha/yr over the 34-year period. The upper increases are large compared with most values reported in the literature for similar long-term nutritional studies. A simple model of forest growth linked to the RothC model of soil C turnover accurately predicted accumulation of soil C in five of the six treatment responses based wholly on differences in productivity. Foliar and soil C/N ratios increased by up to 50%, showing that soil C can accumulate in the absence of added N. Implications for carbon storage in abatement schemes will be discussed.

Growth and survival of seedlings near clusters of retained overstory trees on forest plantations in Pacific temperate rainforests. Smith, N., LeMay, V. (*The University of British Columbia, Canada; nick.smith@shaw.ca; Valerie.LeMay@ubc.ca*), Beese, B. (*Vancouver Island University, Canada; Bill.Beese@viu.ca*).

In retention silvicultural systems, some overstory trees are purposefully retained at the time of harvesting to provide ecosystem goods and services (EGS), including wildlife habitat, carbon sequestration to mitigate climate change, and genetic diversity from seed rain onto planted areas. These retained overstory trees often have spatially irregular patterns that vary with the target EGS. As a result, predicting regenerating tree growth and survival is challenging. In this paper, we present models of growth and survival of 5 to12 year-old planted Douglas fir (*Pseudotsuga menziesii* var. *menziesii*) proximal to retained overstory trees in an aggregated retention system (i.e., clusters of overstory trees) for temperate rainforests in British Columbia, Canada. Regenerating trees were measured along transects beginning within the clusters through the edge and into the harvested area. Distance from the edge, transect orientation, and photosynthetically active radiation along the transect were used in a nonlinear mixed-effects models for growth and generalized linear mixed-effects models for survival. The effects of overstory trees on seedlings were greater for north-oriented transects, intermediate for east and west, and absent for south transects. These models are being incorporated into an existing growth and yield model for retention systems.

Implementation of thinnings in individual tree and diameter distribution growth models; an application to maritime pine stands in Portugal. Soares, P. (Technical University of Lisbon, *Portugal; paulasoares@isa.utl.pt*), Alegria, C. (*Instituto Politécnico de Castelo Branco, Portugal; crisalegria@ipcb.pt*), Fidalgo Fonseca, T. (*University of Trás-os-Montes and Alto Douro, Portugal; tfonseca@utad.pt*), Nunes, L. (*Instituto Politécnico de Bragança, Portugal; lfnunes@ipb.pt*), Tomé, M. (*Technical University of Lisbon, Portugal; magatome@isa.utl.pt*).

The purpose of this research was to analyze the methods used for implementation of thinnings in three models developed to manage maritime pine stands in Portugal: (1) Pbirrol, an individual tree model that can be applied to uneven-aged stands, (2) Pinaster, an individual tree model to be used in even-aged stands, and (3) ModisPinaster, a diameter distribution model to be used in even-aged or uneven-aged stands. In these models, the decision of which trees are thinned is based on a probability function that can be associated to a cut-off or a density variable (e. g., Wilson's factor, residual basal area, SDI). To assess the suitability of how thinnings are implemented in these models, two analyses were made: (1) even-aged models, Pinaster and ModisPinaster, were used to simulate the thinning practice of several plots of a thinning trial and stand variables estimates after thinning were compared with the measured values, and (2) forest inventory plots were used as a starting point to analyze the effect of considering an uneven-aged or an even-aged stand management using Pbirrol and Pinaster, respectively.

A selective cutting decision model for optimizing spatial structure of spruce-fir forest. Yang, H. (Beijing Forestry University, *China; huayang@bjfu.edu.cn*).

Natural spruce-fir forests are widely distributed in the forest region of ChangBai Mountain in China. By analyzing data from 40 m × 40 m permanent plots with three different selective cutting intensities (non-cutting, low intensity of 20%, medium intensity of 30%, high intensity of 40%) that had been inventoried every 2 years since 1986 with the most recent inventory in 2008, a selective cutting model for spruce-fir forest based on spatial structure was established which took into consideration tree species mingling, spatial distribution pattern, and forest stand competition. The cutting trees probability was calculated by the model using selective cutting indexes that consisted of six parameters about spatial structure, including complete mingling, neighborhood pattern, neighborhood comparison, spatial density index, competition index, and purpose tree species characteristic index. According to the basic principles of sustainable management, 13 restraint conditions were set up; moreover, we put forward an optimization decision of selective cutting to adjust spatial structure in order to attain a healthy and steady goal in uneven-aged mixed forest of spruce-fir forest.

Theme C: Forests and Climate Change

C-20 National forest sector greenhouse gas inventories following IPCC guidance and guidelines: Requirements, methods, and national examples

Organizers: Werner A. Kurz (NRCan-Canadian Forest Service), Gregory Reams (U.S. Forest Service) & Thelma Krug (National Institute for Space Research-INPE, Brazil)

Relative contributions of land use and land cover change to forest carbon stock change. Coulston, J., Reams, G., Woodall, C. (*U.S. Forest Service, USA; jwcouls1@ncsu.edu; greams@fs.fed.us; cwoodall@fs.fed.us*).

Land change is a key driver of carbon (C) stock change. IPCC guidelines provide alternatives for estimating land change and corresponding C stock change. These alternatives include both land use and land cover data to quantify change. However, in many areas of the world land change occurs on a relatively small portion of the landscape, and the distinction between forest cover change and forest use change is important to correctly attribute changes in forest C stocks to actual changes in land use. Here we contrast forest C stock changes associated with both changes in forest land use and forest land cover. We demonstrate that estimates of forest cover change and forest use change can differ substantially which leads to different inferences with respect to forest C change.

The EU greenhouse gas inventory: experience and challenges when dealing with 28 different national forest inventories. Grassi, G., Blujdea, V., Abad Viñas, R., Pilli, R. (*European Commission Joint Research Center, Italy; giacomo.grassi@jrc.ec.europa.eu; viorel.blujdea@jrc.ec.europa.eu; raul.abad-vinas@ext.jrc.ec.europa.eu; roberto.pilli@ext.jrc.ec.europa.eu*).

As a Party to the UNFCCC and its Kyoto Protocol, the European Union (EU) must report annual greenhouse gases (GHG) inventories, including the land use, land use change and forestry (LULUCF) sector. The EU inventory is the sum of 28 member states' (MS) inventories. An EU GHG monitoring mechanism aims, inter alia, to help EU MS in following IPCC guidance. The paper synthetizes the large experience collected in supporting EU MS for developing transparent, accurate, consistent, comparable, and complete GHG inventories in the forest sector. While the need of GHG reporting has undoubtedly triggered a significant improvement in the quality of GHG inventories in Europe, the main open challenge is related to the collection of national land use data consistently with IPCC. The paper will describe examples of common problems (i.e., on assessing forest land use changes, in estimating forest carbon stock changes) and the efforts done on harmonization and verification of GHG estimates. It is concluded that in a complex sector as LULUCF, the accuracy of GHG estimates should not be seen as a static objective, but rather as a long-term process of continuous improvement in which verification activities (i.e., comparison with independent estimates) may play a very important role.

IPCC guidance for the preparation of national forest sector GHG inventories. Krug, T. (Foundation for Science, Technology and Space Applications (*FUNCATE), Brazil; thelma@dir.iai.int*), Kurz, W. (*Canadian Forest Service, Canada; wkurz@nrcan.gc.ca*).

The Intergovernmental Panel on Climate Change (IPCC) has developed guidance for the preparation of national greenhouse gas inventories for the land use, land-use change and forestry sector. The recent report "2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol" builds on two earlier reports, the 2003 Good Practice Guidance and the 2006 Guidelines. Several expert workshops have been conducted to further strengthen and document expertise in related areas. Over the past years, scientific methodology, available tools, and data to develop and implement national forest GHG inventories have advanced considerably, but large differences remain among national implementations. Remote sensing tools to estimate land-cover changes have also advanced, but attribution of the cause of land cover changes, including identification of disturbance type, intensity and the resulting emissions is more difficult. The IPCC provides multi-tiered descriptions of methods that can be used to develop GHG inventories and to identify, quantify and reduce uncertainties as far as is practicable. This presentation will provide a short synthesis of the IPCC guidance and report on experiences in implementing the guidance at the national scale.

Canada's national forest carbon monitoring, accounting and reporting system: experiences and next steps. Kurz, W. (*Canadian Forest Service, Canada; wkurz@nrcan.gc.ca*).

Canada's National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) is an integrated framework that combines forest inventory data, empirical yield curves, and activity data on rates of natural disturbances, human activities, and land-use change with process modeling approaches that link biomass and dead organic matter dynamics. Forest inventory data constrain estimates of forest area, carbon stocks, and stock changes. Emissions of carbon dioxide (CO_2) and non-CO_2 greenhouse gases are estimated and reported in annual time steps for the period 1990 to present. The approach provides the ability to identify the main processes responsible for interannual variability in emissions and to estimate uncertainties in the estimates. The core model, CBM-CFS3, which is freely available and supported by model documentation and scientific publications has been implemented in several countries that benefit from the comprehensive framework that integrates existing and newly collected data. Uncertainties resulting from incomplete representation of global change factors other than natural and human disturbances have been identified and are the primary focus of ongoing research. Other research activities focus on enhancing the ability to process spatially-explicit data on land cover, land cover changes, and their drivers for the estimation of GHG inventories and the development of mitigation strategies.

Plans for integrating carbon accounting models and intensive carbon monitoring sites into a tier 3 approach in Mexico. Olguín Alvarez, M. (*Comision Nacional Forestal, Mexico; olguin.conafor@gmail.com*), Kurz, W. (*Canadian Forest Service, Canada; wkurz@nrcan.gc.ca*), Wayson, C. (*SilvaCarbon, USA; cwayson.silvacarbon@gmail.com*), Santos, L., Maldonado, V., López, D. (*Comision Nacional Forestal, Mexico; lsantos@conafor.gob.mx; vmm_14@yahoo.com; davidlopezmerlin@gmail.com*), Birdsey, R., Gregorio, A., Greenberg, D., Morken, S., Fellows, M., Silva Mascorro, V., Caamal, J., Sanchez, G., Méndez, B., Carrillo Negrete, O., Dupuy, J., Hernández, J., Andrade, J., Arreola, J., Esparza, L., González, N., Michel, J., Leyva, J., Dai, Z., Coops, N., Flores, R., Johnson, K.

Mexico, through its National Forestry Commission project reinforcing REDD+ preparation and promotion of South-South cooperation, is designing a system for monitoring, reporting, and verification to be implemented by 2015. It will provide transparent, consistent, comparable, complete, and accurate estimates on the fluxes of greenhouse gases (GHG), using methods that reduce, to the extent practicable, the uncertainties associated with these national scale estimates. Mexico's priority is to report GHG emissions at an intermediate level of uncertainty (using remote sensing and forest inventory data), while advancing towards lower levels of uncertainty based on the use of available carbon dynamics models (Tier 3 approach). These tools have not been widely used in Mexico and the information available for calibration and validation is scarce. Thus, the project benefits from a multi-agency effort focused on the compilation and synthesis of information derived from forest inventories, remote sensing, disturbance data (e.g., deforestation, degradation, fires) and establishment of intensive carbon monitoring sites to generate inputs required by these models. Proof of concept implementation in strategic forest landscapes is underway to provide the basis for incorporating models into the national monitoring of GHG fluxes as well as for assessment of different REDD+ activities in Mexico.

Estimating carbon stored in harvested wood products for greenhouse gas inventories: IPCC requirements and advances in national methods. Skog, K. (U.S. Forest Service*, USA; kskog@fs.fed.us*).

This paper will first briefly review the 2006 IPCC guideline requirements for preparing national estimates of annual additions to carbon stored in harvested wood products (HWP) including guidelines for methods and data for basic (tier 1) and enhanced (tier 2 and 3) estimates and evaluations of uncertainty. The paper will focus on discussing techniques that have been used in a number of countries with examples to enhance overall tier 2 and tier 3 estimates and what the countries report as the uncertainty in estimates when using enhanced methods. Example enhancements include improving estimates of discard rates of wood products in use via alternate decay functions and data sources for decay parameters, using complementary estimates of carbon stock levels and stock change in buildings, and checking modeled discard rates against national estimates of amounts disposed in solid waste disposal sites. The 2006 IPCC guidelines will be compared to recently developed guidelines for countries to estimate HWP carbon contributions to meet emission targets under the Kyoto Protocol for the second commitment period.

Methods of integrating remote sensing and ground data in carbon accounting systems. Waterworth, R. (*Australian National University, Australia; robert.waterworth@anu.edu.au*), deLigt, R. (*Department of the Environment, Australia; robert.deligt@climatechange.gov.au*).

There is no single method or technology that can directly estimate emissions and removals from the land sector. Greenhouse gas inventories therefore rely on a range of different methods and data. In the past 5 years there has been an increased focus on the potential role of remote sensing in land sector inventories. However, remote sensing alone is not able to directly estimate emission and removals but needs to be supplemented with ground data. The methods to integrate these data represent a key decision point in the design of an inventory system. The choice of method has both practical and scientific considerations. Principal among the issues are national and international reporting requirements, data availability, technical means, standards by which the system and its outputs will be assessed and cost. Despite the clear need to utilize data from a range of sources, methods of integrating remotely sensed and ground data within a coherent framework has largely been overlooked. This paper discusses the different approaches for linking or integrating remote sensing and ground data, including a review of currently operational systems and their relative advantages and disadvantages.

National forest sector greenhouse gas inventory: Russian example. Zamolodchikov, D. (*Moscow State University, Russia; dzamolod@mail.ru*).

State Forest Registry (SFR) of Russian Federation is a national level compilation of local forest inventory data. SFR contains information about areas and growing stocks of different forest types separated by dominant tree species, age groups, exploitation, and protective characteristics. SFR is the main source of initial information for national inventory of greenhouse gases (GHG). Specific sets of conversion factors are used to calculate carbon in biomass and dead wood based on growing stock values. Sets of typical values per area unit are used for estimation of soil and litter carbon pools based on the area information. SFR data, separated by age groups, are used for producing of carbon growth curves and the subsequent assessment of carbon increments. Carbon losses with forest felling, forest fires, and other destructive disturbances are estimated using the information on clear cuts, burnt and dead forest areas from SFR. The carbon budget is calculated as a balance between increments and losses. Uncertainties estimates are based on errors of conversion factors and typical values. The described approach has been used in Russian GHG inventory from 2010 and generates data for UNFCC reporting.

Posters

Carbon dioxide sequestration potential of the national greening program of the Philippines. Exconde, A., Castillo, J., Valle, P. (DENR-ERDB*, Philippines; angelitoexconde@yahoo.com.ph; alan536@yahoo.com; purabeatriz@yahoo.com*).

The objective of this paper was to evaluate the carbon dioxide sequestration potential of the National Greening Program (NGP), the widest reforestation program of the Philippines which targets to plant 1.5 billion trees in 1.5 million hectares of public domain land from 2011 to 2016. The CO_2 removed from the atmosphere by 210.2 million planted seedlings under the NGP from 2011 to 2012 is estimated at 542.95 kilotons. Based on the 1994 Philippine National Greenhouse Gas Inventory, the country had emitted some 100 864 kilotons of equivalent CO_2 to the atmosphere, of which 49% was contributed by the energy sector, 10% by the industry sector, 33% by the agriculture sector, and 7% by the waste sector. Given the 1994 figures, the CO_2 so far removed from the atmosphere by the planted seedlings under the NGP could offset 1% of the 1994 emissions from energy production, 5% from industries, 2% from agriculture, and 8% from wastes. Similarly, the carbon so far sequestered by the planted seedlings could offset the CO_2 emissions or 2009 carbon footprints of 723 933 Filipinos.

Estimation of carbon emission and removal from the harvested wood products pool following the 2013 IPCC KP Supplement in Japan. Hishiyama, Y. (*Forestry and Forest Products Research Institute, Japan; yukot@ffpri.affrc.go.jp*), Aihara, Y. (*Value Management Institute, Japan; aihara4127@vmi.co.jp*), Tonosaki, M., Matsumoto, M. (*Forestry and Forest Product Research Institute, Japan; tonosaki@ffpri.affrc.go.jp*; *machan@ffpri.affrc.go.jp*).

We developed a method for estimating annual changes in carbon stocks and associated carbon emissions and removals from the harvested wood products (HWP) pool in Japan, following the methodology described in the IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement), and considering available data sets including forest products statistics in Japan. Annual carbon emissions and removals due to changes in HWP (i.e. sawn wood, wood panels and paper) pool were calculated using Tier 2 and 3 methods and compared to see how tier selection affects the estimation. In the Tier 2 calculation, we used national statistics for sawn wood, wood panels and paper productions, which were then substituted in the first-order decay function suggested by the KP Supplement. In the Tier 3 estimation, we used an inventory method for the construction sector, as the biggest wood products consumer in Japan, with annual building start statistics and HWP input units. The effects of the ratio of HWP originating from domestic forests in future estimations will be also discussed.

Annual changes in forest longitudinal data for use in greenhouse gas reporting under the UNFCCC and its Kyoto Protocol. Hylen, G. (*Norwegian Forest and Landscape Institute, Norway; gro.hylen@skogoglandskap.no*), Bergland, O. (*Norwegian University of Life Sciences, Norway; olvar.bergland@umb.no*).

It is common to use data from periodical national forest inventories (NFI) for reporting emissions and removals of greenhouse gases from the LULUCF sector as required under UNFCCC and its Kyoto protocol. A recent study by Heikkinen et al. (2012) comparing different methods and models in use for estimating annual increment, and hence carbon sequestration, shows that the application of these methods and models are not giving sufficiently reliable estimates for annual variation. When using periodically rotating sample sites in the NFI, the estimates of annual changes are very sensitive to differences between the specific sites sampled in different periods. In this paper we compare conventional annual increment assessment methods with methods based on (i) extrapolation techniques for annual increments, and (ii) statistical forecasting methods. Our assessment of the different methods are based upon both in-sample and out-of-sample cross-validation using the Norwegian NFI data. We find that combining statistical techniques for the analysis of longitudinal data with a seasonal adjustment method provide a more reliable assessment of the annual increment, and thus the carbon sequestration rate.

Development of country specific EF and NFI system for national GHG inventory in forest sector, Korea. Kim, R., Son, Y., Lee, K., Park, H., Bae, J. (*Korea Forest Research Institute, Republic of Korea; rhkim@forest.go.kr; treelove@forest.go.kr; kyeonghlee@forest.go.kr; hyunpark@forest.go.kr; forestory@forest.go.kr*).

Land use, land-use change and forestry sector, especially forest land, is the only category featuring carbon sequestration in the annual Korea's Greenhouse Gas Inventory, required by the UNFCCC. The National GHG Inventory system was developed based on LULUCF Good Practice Guidance published by IPCC in 2003. We assembled the survey data on the five carbon pools (aboveground and belowground biomass, litters, dead wood, and soil) through the new National Forest Inventory (2006–2010). We also developed the country specific emission factors (basic wood density, biomass expansion factor, and root-shoot ratio) for 18 major tree species. The overall GHG emission in Korean forests was estimated around –54 million ton CO_2-equivalent per year in recent years. In 2011, 62 M ton CO_2-e was removed by stock change of forest biomass, while 8 M ton CO_2-e was emitted due to harvest and firewood production. However, we still devote ourselves to improve some areas such as uncertainty assessment and the estimation of soil carbon by land use change.

Predicting forest carbon storage and sequestration based on national forest inventory using forest growth model. Moonil, K., Kwak, H., Lee, W., Choi, S. (*Korea University, Republic of Korea; windy7up@naver.com; nextsunday@gmail.com; leewk@korea.ac.kr; saymi0630@nate.com*).

This study was performed in four steps: (i) Develop forest growth models using NFI data by considering topographic and climatic factors; (ii) Develop regression models to predict mean DBH, tree height, and number of trees per stand based on radial growth model; (iii) Combine current forest cover map; and (iv) Estimate the forest carbon storage and sequestration using the growth model. In this process, the forest cover data, growth data of NFI, climatic data, and topographic data were integrated with GIS, and GIS-based spatial information was prepared. The volume and the current annual growth rate in 2010, predicted by the growth model, were 127.2 m^3/ha and 5.0%, respectively. Both estimates were similar to that listed in the statistical yearbook of forestry (125.6 m^3/ha and 4.7%). The average forest volume and carbon storage would increase by 228.8 m^3/ha (120.4 C ton/ha). However, the forest carbon sequestration would decrease by 0.58 C ton/ha /year. Therefore, we have to prepare the strategies for adapting climate change in terms of the preservation of forest carbon storage and sequestration. This research was supported by Bio-industry Technology Development Program, Ministry of Agriculture, Food and Rural Affairs.

New Zealand's plantation forest inventories for Kyoto and UNFCCC reporting: 5 years of measuring and modelling in a changing landscape. Paul, T. (*Scion, New Zealand; thomas.paul@scionresearch.com*).

New Zealand initiated a national ground based plot inventory for plantation forests in 2006 to support its commitment to the first commitment period. A well designed and long-term plot based national inventory did not exist previously in New Zealand's extensive plantations. The establishment of this nationwide network of plots was not without hurdles and difficulties. We will describe some of the solutions to overcome problems like access rights into private forests or inaccessibility, increasing inventory costs, and measurement quality, as well as meeting overall benchmarks of our estimates of carbon stocks and carbon sequestration in New Zealand's plantations under the tier tree approach. Matching inventory data with wall to wall mapping proved to be the greatest challenge as estimates need to be unbiased and representative for the mapped area. In New Zealand's case, the changes in plantation area can be swift and mapping of these land-uses has been proven to be difficult, so ways needed to be found to match both approaches in an accepted way. We will present our methods on how to use and combine our national inventory data to estimate total carbon stocks and their change during the first commitment period.

A decisionmaking framework for designing a carbon accounting system. Waterworth, R. (*Australian National University, Australia; robert.waterworth@anu.edu.au*).

Robust measurement, reporting, and verification (MRV) of emissions and removals from the land sector is required to underpin international reporting and support national and sub-national policy development and implementation. MRV system design should therefore commence by identifying a country's policy and reporting requirements rather than a technical discussion. Despite this, most guidance and literature on MRV describe the technical processes involved in establishing a system with little reference to the policy options that may need to be supported. In this poster we propose a decision-making framework to support MRV system design. The framework guides policy makers through the international reporting and policy issues that should be considered when designing the system. We provide examples from four countries in differing stages of system design and implementation that have used this type of framework to decide on the system design. We propose that countries consider using a framework such as this to guide system design to help ensure that the final system meets the policy needs of the government.

Snow dynamics suppressed the carbon emission in North America. Yu, Z., Wang, J. (*West Virginia University, USA; zyu@mix.wvu.edu; Jingxin.Wang@mail.wvu.edu*), Liu, S., Sun, P. (*Chinese Academy of Forestry, China; liusr@caf.ac.cn; sunpengsen@gmail.com*), Liu, W. (*West Virginia University, USA; wliu4@mix.wvu.edu*).

Winter snow regulates regional and global climatic systems and terrestrial carbon pools by changing energy budgets of the lower atmosphere and land surface. We investigated the effects of winter snow dynamics on forest carbon variations in mid- and high- latitude forests in North America. At biome scale, winter ecosystem respiration (RE) ranged from 0.03–1.3 μmol/m^2/s (about 3.77–163.09 g C/m^2) with an average of 0.40 μmol/m^2/s (about 50.18 g C/m^2). Across the entire study area, the winter RE and net ecosystem exchange (NEE) were 0.331 and 0.278 Pg/year, respectively. The spatial variation of the snow cover has suppressed the carbon efflux in North America for about 0.164 Pg during the past 12 years. We found that RE, NEE, and the start of carbon uptake date (SCU) were not correlated with air temperature but were correlated with soil temperature which, in turn, was controlled by the snow depth. The quadratic relationships between RE, NEE, SCU, and snow depth suggest that snow acts as an insulator to influence the ecosystem carbon flux through modulating the underground thermal conditions.

National greenhouse gases inventories in a scope of REDD+: study of case in Nicaragua. Zamora Lopez, S. (*University of Hamburg, Germany; szamora.lopez@gmail.com*).

Carbon sequestration in the Agriculture, Forestry and Other Land Use (AFOLU) sector is an effective approach to reduce and remove emissions, however, in practice it is a challenge to developing countries. To have success in this goal, the national GHG inventory systems with high-quality are critical. The aim of this research was to evaluate the national greenhouse gas inventories in Nicaragua in a context of REDD+. The analyses included data from the national greenhouse gases inventory reported in the reference years of 1994 and 2000, and data from 2010 were updated. The three-time series was suitable to test the trends of emissions and removals, to identify the key sinks and sources of carbon stocks, as well as gaps of information. This study shows the requirements on institutional arrangements, technical capacities, data readiness and financial resources needed to be success in update and improve the framework of the national GHG inventory system, both national and subnational scale, and their scopes with REDD+ initiatives in Nicaragua.

C-21 Complying with the IPCC Good Practice Guidance for tropical carbon stock inventories

Organizer: Ronald E. McRoberts (U.S. Forest Service)

Use of multi-temporal, multi-level remote sensing and field data for retrospective estimation of biomass in remote regions. Andersen, H. (*U.S. Forest Service, USA; handersen@fs.fed.us*).

International carbon monitoring guidelines call for the retrospective estimation of forest carbon stocks going back several decades. Meeting this objective can be particularly challenging in remote regions, such as many areas within the tropical and the high-latitude boreal biomes, without spatially-extensive inventory (i.e., NFI) programs based on permanent field plots. Recent advances in the combined use of multiple sources of remotely-sensed data (airborne LiDAR sampling, satellite imagery) to estimate biomass and other inventory parameters can potentially provide a means to address these challenges in remote areas but require the application of complex multi-level statistical sampling theory. In this paper, we describe a model-based approach to estimating and mapping a time series of biomass using a combination of a limited sample of field plot data (FIA plots from 2007–2013), airborne LiDAR strip sampling (2009), and a Landsat time series (1999–2013) over a large area (~800 000 ha) within the boreal forests on the Kenai Peninsula of Alaska. Model-based estimates of total biomass and plot-level biomass (and corresponding estimates of uncertainty) obtained using this multi-level, model-based approach are compared to estimates obtained using FIA field plots measured in 1999–2003 and airborne LiDAR acquired in 2004.

Assessing REDD+ performance and evolving monitoring needs. Herold, M. (*Wageningen University, Netherlands; martin.herold@wur.nl*).

In response to this need, several international activities have been established, like the REDD+ working group within the Global Observation of Forest and Land Cover Dynamics group (GOFC-GOLD), to foster a continuous interaction mechanism with the UNFCCC to provide technical contributions to the negotiations and for national-level capacity development for monitoring, emphasizing the important role of satellite remote sensing in this context. This presentation will first elaborate on the state of play of REDD+ in the political context and discuss the approach and experiences of the Earth Observation and carbon monitoring

community with the REDD political discussions and to support developing country capacity development. The most important part of the presentation will then put particular emphasis on a series of evolving monitoring issues that are becoming more relevant with the REDD+ process now moving into phase 2 with interim performance assessments. Several important issues will be discussed and elaborated on that will be essential to determining how to assess the results of REDD+ activities including: UNFCCC and IPCC guidance; REDD+ performance on landscape scale; national strategies; sub-national implementation and benefit sharing; reference levels; drivers and REDD+ interventions; interim performance; and broader monitoring needs and linkages.

Techniques for using maps to enhance estimates of forest/non-forest change. McRoberts, R. (*U.S. Forest Service, USA; rmcroberts@fs.fed.us*).

Many of the published guidance documents on tropical forest inventories focus on the role of remote sensing and, accordingly, on construction of remote sensing-based maps of land use and land use change. However, the IPCC Good Practice Guidance (GPG) explicitly states that estimates, not just maps, are the ultimate objective, and that the estimates should satisfy two criteria: (1) neither over- nor under-estimation, and (2) uncertainties are reduced as far as is practicable. Of importance, estimates obtained by aggregating map pixel class predictions do not satisfy these criteria because systematic prediction errors induce bias into the estimation process and map accuracy measures are not equivalent to the uncertainty of estimates. Statistically rigorous techniques for producing estimates from maps that satisfy the GPG criteria are presented. Specific emphases include sampling designs for acquiring accuracy assessment data and comparisons of simple random sample, stratified, and model-assisted approaches.

Estimation of biomass and change in biomass and corresponding uncertainties in sample surveys assisted by airborne laser scanning. Næsset, E. (*Norwegian University of Life Sciences, Norway; erik.naesset@umb.no*).

Reducing uncertainties in tropical inventories to a level at which marginal but real changes in biomass appear as statistically significant is challenging because most tropical countries lack established infrastructure of plot networks and inaccessibility may prevent field work in remote areas. When combined with field surveys, airborne laser scanning (ALS) is one of the most promising remote sensing techniques to assist in precise estimation of aboveground biomass. For smaller areas, ALS may be used to collect wall-to-wall data. In regional applications, sampling by collection of ALS data along a few selected flight lines may be an economically attractive option. In this presentation, design-unbiased estimators for biomass and change in biomass and corresponding variance estimators will be presented. Such estimators comply with the IPCC Good Practice Guidance requirements regarding unbiasedness (neither over- nor under-estimates) and precision (reducing uncertainties). Empirical results from two contrasting environments applying these estimators will be given: a boreal forest region in Europe and a district with tropical savanna in Tanzania. Results based on wall-to-wall coverage and on complex designs involving ALS strip sampling in two phases will be presented, and the efficiency of the designs will be compared. Examples of change estimation will also be provided.

Model-dependent inference for biomass estimation in a LiDAR sample survey in Liwale, Tanzania. Saarela, S. (*University of Helsinki, Finland; svetlana.saarela@helsinki.fi*), Næsset, E., Gobaken, T., Ørka, H., Hansen, E., Mauya, E. (*Norwegian University of Life Sciences, Norway; erik.naesset@nmbu.no; terje.gobakken@nmbu.no; hans-ole.orka@nmbu.no; endre.hansen@nmbu.no; ernest.mauya@nmbu.no*), Zahabu, E. (*Sokoine University of Agriculture, Tanzania; zahabue@yahoo.com*), Staahl, G. (*Swedish University of Agricultural Sciences, Sweden; goran.stahl@slu.se*).

The United Nations Collaborative Program on Reducing Emissions from Deforestation and Forest Degradation in developing countries (UN REDD) has led to a stronger focus on forest information and National Forest Inventories (NFIs), and on how to utilize remote sensing within NFIs. Since infrastructure in remote areas typically is limited, inventory solutions that minimize the need for fieldwork are searched for. In forest inventories with remotely sensed data as auxiliary information, regression models are applied to predict quantities, such as growing stock, at the level of sampling units. The purpose of this study was to elaborate on model-dependent inference in the context of survey sampling and the estimation of parameters related to forest growing stock, such as volume or biomass. For the model-dependent inference, a procedure that accounts for both sampling and model errors in the variance estimation was applied. Data from the Liwale area in south eastern Tanzania were used, comprising a combination of auxiliary information from RapidEye and LiDAR, and field sample plot data collected according to the design of the Tanzanian NFI. Performances of linear and nonlinear regression models were compared, considering the clustered structure of the Tanzanian NFI sampling design. The results of this study will be of importance for the development of REDD+ and for forest inventories in other remote areas, such as Siberia and Alaska.

Properties of the stock change method for estimating greenhouse gas emissions from forests. Staahl, G., Petersson, H. (*Swedish University of Agricultural Sciences, Sweden; goran.stahl@slu.se; hans.petersson@slu.se*).

The estimation of carbon stocks and carbon dioxide emissions from forests is a challenging task. As a result, several different methods have been proposed for the purpose. In this presentation, the main features of inventory and reporting systems that are based on field inventories – such as national forest inventories – and the stock change method will be described. With the stock change method, emissions are assumed to correspond to the changes in carbon stocks between subsequent inventories. Field based methods and the stock change approach have several advantages. All carbon pools can be addressed with detailed measurements using the same methods at all relevant time points. Inventory methods can be designed to provide unbiased results, thus complying with one of the basic requirements of IPCC's Good Practice Guidance. However, the measurement and estimation of the different carbon pools through field inventories also pose substantial challenges. Important problems and potential solutions will be presented and discussed. Further we will describe and contrast the problems that emerge in connection with state estimation with those that emerge in connection with change estimation. Finally, we will show how the major sources of error from sample based surveys can be combined in a novel way based on sampling theory.

C-22 Advances in forest carbon measurements and monitoring for building REDD+ MRV systems

Organizers: Yasumasa Hirata (Forestry and Forest Products Research Institute, Japan) & Andrew Lister (U.S. Forest Service)

REDD+ and wildland fires: the contribution of satellite observation systems. Boschetti, L. (*University of Idaho, USA; luigi@uidaho.edu*), Mollicone, D., Jonckheere, I. (*FAO, Italy; danilo.mollicone@fao.org; inge.jonckheere@fao.org*), Humber, M. (*University of Maryland, USA; mhumber@umd.edu*).

Fire is a complex biophysical process with multiple direct and indirect effects on the atmosphere, the biosphere and the hydrosphere. It is widely recognized that, in some fire prone environments, fire is essential to maintain the ecosystem in equilibrium. REDD+ goes beyond the initial focus of REDD on deforestation and forest degradation and includes the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks. REDD+ associated with fire requires an understanding of fire processes in forest systems (either as an ecological change agent, a disturbance, a forest management tool, or as a process associated with land cover conversion) and how fire emissions are calculated. Although fire might be a threat to REDD+ initiatives aimed at reducing deforestation and forest degradation, fire is an integral and essential component of REDD+ if emissions are directly addressed through integrated fire and forest management programs. The presentation will give an overview of the way satellite observations might be integrated in REDD+ measuring reporting and verification (MRV) national systems. In particular, the presentation will focus on how to use the currently available fire thematic products (active fire detections, burned area maps) to produce a fire emission inventory at country level.

Strategies for forest measurement and monitoring in Colombia. Cabrera Montenegro, E., Barbosa Herrera, A. (*Instituto de Hidrologia, Meteorologia y Estudios Ambientales (IDEAM), Colombia; ecabreram@ideam.gov.co; abarbosa@ideam.gov.co*).

Colombia has a wide range of ecosystems, including a portion of the Amazon River basin. In order to help ensure that the value of these ecosystems is maintained or enhanced, government officials have been implementing several environmental monitoring and assessment activities. These activities include remote sensing assessments using various satellite sensors like Landsat, MODIS, radar and LiDAR, ground plots, and several local intensive monitoring studies. Colombia has also developed a carbon measurement protocol that includes detailed measurement methodology for each of the different IPCC carbon pools. It also has developed a plan for a national forest inventory that will allow it to consistently measure these carbon and pools and other forest attributes across the entire country. The current talk will discuss several of Colombia's natural resource monitoring approaches and their relationship to Colombia's broader natural resource assessment strategy and participation in the United Nations REDD program.

The development of allometric models for prediction of above- and belowground biomass for all major forest types in Tanzania. Eid, T. (*Norwegian University of Life Sciences, Norway; tron.eid@nmbu.no*), Malimbwi, R. (*Sokoine University of Agriculture, Tanzania; remalimbwi@yahoo.com*), Bollandsås, O. (*Norwegian University of Life Sciences, Norway; ole.martin.bollandsas@umb.no*), Zahabu, E., Katani, J., Chamshama, S. (*Sokoine University of Agriculture, Tanzania; zahabue@yahoo.com; josiahkatani@yahoo.com; chamstz@yahoo.com*).

Quantifying amount of carbon in forests is an important component in the implementation of the emerging carbon credit market mechanisms. Until recently no appropriate allometric biomass models that could be used to estimate carbon amounts in Tanzania existed. Appropriate models are of particular importance for Tanzania since the country recently has conducted a National Forest Inventory which includes establishment of a monitoring system through a systematic permanent sample plot design, which among others will provide data for the REDD process. This called for the development of new models. We developed models for all major forest types, i.e., miombo woodland, montane forests (rain forest), acacia woodland, tickets, mangroves, and plantations (*Pinus patula, Tectona grandis*). In total 750 trees from 16 different sites were selected for destructive sampling and about 500 of them were excavated belowground. The selection of trees was designed to cover wide ranges of sizes (DBH of 2–120 cm) and tree species (more than 100). From the data we developed allometric biomass (stem, branches, twigs, total aboveground and belowground) and volume (stem, branches, and total) models. In this paper we describe procedures and challenges related to the destructive sampling, in particular the belowground part, we present some of the models, and finally we discuss their application.

Use of remote sensing for forest monitoring at a national level in REDD+ implementation. Hirata, Y., Takao, G., Saito, H., Takahashi, M., Vega, I. (*Forestry and Forest Products Research Institute, Japan; hirat09@affrc.go.jp; takaogen@ffpri.affrc.go.jp; rslsaito@affrc.go.jp; martaka@ffpri.affrc.go.jp; luis.a.vega.i@affrc.go.jp*), Chivin, L., Chealy, P., Hamzah, K., Omar, H., Faidi, M., Rejalaga Noguera, L., Matsuura, T.

The objective of this study was to conduct forest monitoring at a national level using remote sensing in different countries, which are contained in different ecofloristic zones, i.e., tropical seasonal forest, tropical rain forest, and transitional zone from subtropical forest to dry forest for REDD+ implementation. We conducted this study in Cambodia, Peninsular Malaysia, and Paraguay. Landsat-5 and 7, SPOT-4 and 5, and ALOS/AVNIR-2 data were used as time-series data from 1990 to 2010. We developed methods to reduce the effect of seasonality in tropical seasonal forest, the effect of clouds in tropical rain forest, and classification method of dry forest. Object-based approach was used for classification by forest type and disturbance degree after reducing the effects. The classification maps of latest year were used as base maps and retrospective approach was used to analyze past satellite data due to the limitation of ground truth data. Trajectory of classification classes of each object was confirmed and unnatural change of classes was revised. Forest carbon stock change at a national level could be accounted by multiplying forest

carbon stock per unit area by forest type and disturbance degree obtained from ground-based inventory by the corresponding area from the classification results.

Advance and challenge of remote sensing in assessing tropical forest biomass of Malaysia. Omar, H. (*Forest Research Institute Malaysia, Malaysia; hamdanomar@frim.gov.my*), Ismail, M. (*Putra Univeristy, Malaysia; mhasmadi@putra.upm.edu.my*), Harun, I. (*Forest Research Intitute Malaysia, Malaysia; ismail@frim.gov.my*).

Tropical forest biomass is one of the key parameters in addressing issues relating to climate change as it known to store large amount of carbon. Retrieving tropical forest biomass over large areas has been challenging since decades due to the limited data resource, accessibility, and numerous technical issues. Remote sensing has been used actively for forest biomass estimation since the last three decades and it is proven to be effective. Although there are issues and arguments raised in the estimation accuracy, research is continuously being carried out. Optical or synthetic aperture radar (SAR) system has its own potential in retrieving biomass but several issues remain unaddressed. While optical remote sensing is often hindered by cloud, SAR systems are always limited by signal saturation at high biomass levels. This paper is focusing on the roles of space borne remote sensing in assessing biomass of forest in various ecosystems in Malaysia, i.e., inland dipterocarp forests, mangrove forest, and peat swamp forest. Several attempts (by using optical, SAR, and combination of both) have been made to assess biomass and carbon stock in these forests. The results are highlighted and the advantages and challenges regarding the assessments are described.

Measuring tropical forest degradation from high-resolution remote sensing imagery and field data for building a REDD+ MRV system in Mexico. Paneque Gálvez, J., Mas, J., Gao, Y. (*Universidad Nacional Autónoma de México, Mexico; jpanequegalvez@gmail.com; jfmas@ciga.unam.mx; yangao98@gmail.com*), Salinas Melgoza, M. (*CIGA-UNAM & Twente University, Mexico; ma.masm@gmail.com*), Morales, L. (*Bangor University, Costa Rica; moralesluciacr@gmail.com*), Bee, B. (*East Carolina University, USA; bethbee78@gmail.com*), Skutsch, M. (*Universidad Nacional Autónoma de México, Mexico; mskutsch@ciga.unam.mx*).

In Mexico, several institutions are working together toward the construction of a subnational-level monitoring, reporting and verification (MRV) system, as part of global reducing emissions from deforestation and degradation (REDD+) policy. This entails the establishment of historical deforestation and forest degradation baselines, and the development of methods that allow for future monitoring of deforestation and degradation trends. However, measuring degradation is still plagued with difficulties and there is no consensus on how to measure it (i.e., at what temporal and spatial scales, with what imagery and field data sets). Therefore, establishing baselines and designing a suitable MRV system for degradation remains an elusive task. In this paper we report on on-going research in which we aim at developing a sound methodology to measure degradation using high-resolution remote sensing imagery coupled with field data. Specifically, we assess to what extent degradation can be measured from RapidEye, SPOT, and Landsat time-series imagery, using forest inventories and historical land-use data to validate our imagery results. In addition, we assess whether it is possible to detect and measure forest areas that are degrading, degraded but stable, degraded but recuperating, and non-degraded. Our results are key for building a robust subnational-level REDD+ MRV system in Mexico.

Quantifying forest disturbances as input to carbon budget models in southeast Mexico. Silva Mascorro, V., Coops, N. (*University of British Columbia, Canada; vanessa.mascorro@alumni.ubc.ca; nicholas.coops@ubc.ca*), Kurz, W. (*Canadian Forest Service, Canada; wkurz@nrcan.gc.ca*), Olguín Alvarez, M. (*Comision Nacional Forestal, Mexico; olguin.conafor@gmail.com*).

Quantification of extent and severity of disturbances is crucial for forest management, and for carbon budget models used for reporting of greenhouse gas emissions, and climate change mitigation. Detailed observations of natural and anthropogenic disturbance events that alter forest structure and distribution of carbon are essential to estimate changes in terrestrial carbon pools and fluxes. Changes in land cover are often derived from remote-sensing observations using either Moderate Resolution Imaging Spectroradiometer (MODIS) 250 m–1 km imagery or, more recently, from Landsat 30 m observations. These land-use change estimates however are often poorly validated in tropical areas and the implications on carbon balances and transfer between carbon pools not well understood. Here we present methods that integrate national forest inventory data, imagery, MODIS land-cover classifications and ancillary datasets to quantify forest disturbances for carbon modeling over Mexico's Yucatan Peninsula, a REDD+ early action area. Data are compiled from 2005 to 2010 to produce annual wall-to-wall coverages of spatially-explicit disturbances by type, including fires, hurricanes, and anthropogenic disturbances and compared to changes detected by a MODIS land-cover classification scheme. Our results provide a comprehensive approach for assessing and compiling forest disturbances in a consistent and automated way to provide input to carbon budget models.

Aboveground biomass estimation based on LiDAR and HJ data in subtropical forest. Zhao, D., Wu, B., Zeng, Y. (*Chinese Academy of Sciences, China; zhaodan@irsa.ac.cn; wubf@irsa.ac.cn; yuanz@irsa.ac.cn*).

This study aims to estimate the aboveground biomass (AGB) using airborne LiDAR and China's HuanJing (HJ) data with a forest type based regression, in the biodiversity protection ecological zone of Guangdong Province. The LiDAR data covered an area of 60 km^2 in the study area is acquired with high point cloud density, while the HJ data of the whole study area are acquired synchronously in 2012. Firstly, the tree height and density parameters are extracted from LiDAR data, and a regression relationship is established between them and the field surveying AGB samples to get precise AGB in the LiDAR flight area. Secondly, the vegetation indices and some other parameters are calculated or extracted from HJ data, and these parameters are involved in the AGB extrapolation model, which will extrapolate the LiDAR derived AGB to the whole study area, with some auxiliary data, such as terrain elevation and forest type. Finally, the forest AGB distribution map, with spatial resolution of 30 m, of the study area is obtained by applying extrapolation model.

C-23 Forest management for adaptation to climate change

Organizers: Rodney Keenan (The University of Melbourne, Australia), Carina Keskitalo (Umea University, Sweden), Kalame Fobissie (WWF Central Africa, Cameroon) & Guangyu Wang (University of British Columbia, Canada)

Adaptation of planted forests to climate change: from global to local approaches. Carnus, J. (*National Institute for Agricultural Research, France; carnus@pierroton.inra.fr*), Payn, T. (*Scion, New Zealand; tim.payn@scionresearch.com*), Orazio, C. (*European Forest Institute, France; christophe.orazio@efi.int*), Freer-Smith, P. (*Forestry Research UK, United Kingdom; peter.freer-smith@forestry.gsi.gov.uk*), Tomé, M. (*Technical University of Lisbon, Portugal; magatome@isa.utl.pt*).

Globally, production and provision of ecosystem goods and services from planted forests will be altered by climate change phenomena posing new challenges to local communities, forest managers and forest-based industries which depend increasingly on wood and biomass resources from planted forests. Adaptation strategies and general recommendations have been developed at global (for example, 2013 FAO international congress on planted forests) or regional levels for planted forests in various environmental and socio-economic context but need to be complemented and further elaborated for implementation at local scales in close interaction with policy makers and socio-economic actors. Territorial foresight approaches, landscape simulation platform and web-based tools can provide interactive methodologies and effective decision support tools to better define local management options for adaptation to climate change. Regional examples and best practice case studies from planted forests in various temperate zones around the world will be presented and discussed.

Climate adaptation and forest management: the U.S. forest service perspective. Cleaves, D. (*U.S. Forest Service, USA; dcleaves@fs.fed.us*).

Climate change is exposing forest and grassland ecosystems to new and complex risks, and challenges the mission of the U.S. Forest Service to sustain the health, diversity, and productivity of these systems. Resilience has become an overarching goal of adaptation efforts. Adaptive capacity to resist, recover, or transform under connected and amplified risks is being addressed in ecological, social, and economic dimensions. The agency and its partners are assessing emerging risks, knowledge gaps, current policies and practices; engaging employees and stakeholders to build institutional adaptive capacity; and developing place-based strategies for enhancing resilience in ecosystems and human communities. Broad efforts at active adaptation are being oriented to retaining forests and to regenerating forests after disturbance to be better adapted to future climates. In response to an increasingly dynamic future, forest management is seen as an iterative learning process that applies scientific, managerial, and traditional knowledge through research/management collaborations. Managers and scientists have new partnerships in education, case studies in adaptation management, and forest-level planning. Assessments of carbon stocks and tools for local management have been developed for all National Forests. Climate change response is being built into performance management for all branches – federal lands, private forestry, research, and international programs.

Climate change impacts and adaptation in the Canadian forest sector. Johnston, M. (*Saskatchewan Research Council, Canada; johnston@src.sk.ca*), Edwards, J. (*Canadian Forest Service, Canada; jason.edwards@nrcan.gc.ca*), Nelson, H. (*University of British Columbia, Canada; harry.nelson@ubc.ca*), Williamson, T. (*Canadian Forest Service, Canada; Tim.Williamson@nrcan-rncan.gc.ca*).

Research has shown that climate change will affect northern latitude forests to a greater extent than the global average. An understanding of the impacts of climate change on Canadian forests is emerging, and along with it the realization that adaptation needs to become a part of forest management planning and decisionmaking. Several recent Canadian initiatives at the national, provincial and local levels are addressing adaptation, and have shed light on how scientists and practitioners can most effectively work together on identifying adaptation options, choose among them, and implement the options in the context of sustainable forest management. This presentation will provide an overview of recent initiatives involving forestry practitioners, governments and local stakeholders that are providing increased understanding of climate change impacts and adaptation options for the forest sector in Canada.

Overcoming adaptation barriers surrounding climate change in U.S. federal land management agencies: the importance of research-management communication and scale. Kemp, K., Blades, J., Klos, Z., Force, J., Hall, T., Morgan, P. (*University of Idaho, USA; kkemp@uidaho.edu; jblades@uidaho.edu; zion@uidaho.edu; joellen@uidaho.edu; troyh@uidaho.edu; pmorgan@uidaho.edu*).

Western U.S. forests are vulnerable to multiple impacts from climate change. While federal land managers recognize this challenge, there remains a substantial disconnect between the information emerging from scientific research and its application in management decisions at regional-to-local levels. This disconnect presents challenges for adapting to climate change impacts. Our research focuses on the exchange of current climate change science across research-management boundaries. We interacted with 109 U.S. Forest Service personnel, scientists, and stakeholders through semi–structured interviews, surveys, and collaborative workshops. During the workshops, we emphasized the types of changes expected in forests in Idaho and western Montana, different scales of climate change information, and how climate change information can be incorporated into planning efforts. Our mixed-methods approach evaluates perceptions of usefulness and efficacy for adaptation-focused management. Workshop participants reported an increase in perceived effectiveness of management activities for climate change adaptation. Regional-scale climate change information was considered most effective for land management planning. While many managers feel the best available information may help them make adaptive management decisions, barriers such as time to access current information, lack of public interest, and funds to implement adaptation programs were cited as limiting action.

The role of forestry in national climate change adaptation policy: cases from Sweden, Germany, France, and Italy. Keskitalo, E. (*Umeå University, Sweden; carina.keskitalo@geography.umu.se*), Legay, M. (*French Forestry Commission, France; myriam.legay@onf.fr*), Marchetti, M. (*Italian Academy of Forest Sciences, Italy; marchettimarco@unimol.it*), Nocentini, S. (*University of Florence, Italy; susanna.nocentini@unifi.it*), Spathelf, P. (*Eberswalde University for Sustainable Development, Germany; Peter.Spathelf@hnee.de*).

Forestry is one of Europe's largest land uses, for which adaptation to climate change will require coordinated action among multiple actors. However, so far adaptation has been less placed in focus than has mitigation, and adaptation in the forest sector has mainly been reactive. This paper explores and reviews the integration of forestry in the development of planned adaptation policy in different countries. Sweden, Germany, and France are taken as examples of countries with different development of adaptation policies, and that also all have different preconditions for working with adaptation given their forest systems and actors. Italy is utilized as an example of how adaptation actions for forestry have been defined in a country where no national adaptation policy as of yet exists.

Integrating multi-discipline models to estimate impacts of climate change and mitigation policies on the global forestry economics sector. Kim, J. (*U.S. Forest Service, USA; jbkim@fs.fed.us*), Sohngen, B. (*Ohio State University, USA; sohngen.1@osu.edu*), Ohrel, S., McFarland, J. (*U.S. Environmental Protection Agency Climate Change Division, USA; Ohrel.Sara@epa.gov; mcfarland.james@epa.gov*), Monier, E. (*Massachusetts Institute of Technology, USA; emonier@mit.edu*), Drapek, R. (*U.S. Forest Service, USA; rdrapek@fs.fed.us*), Pitts, G. (*Oregon State University, USA; bear.pitts@oregonstate.edu*).

The Climate Change Impacts and Risk Analysis (CIRA) project by the U.S. EPA Climate Change Division integrates global-scale socioeconomic, climate and climate-impacts models to estimate the biophysical and economic effects of greenhouse gas mitigation policy scenarios on a variety of sectors. This study illustrates this dynamic integrated modeling system applied to assessing impacts in forested ecosystems and the forestry sector. The Emissions Predictions and Policy Analysis (EPPA) model and the Integrated Global System Model (IGSM) created three socioeconomic & emissions scenarios: Business as usual and two mitigation policy scenarios that stabilize radiative forcing levels in 2100. NCAR Community Atmospheric Model (CAM, Version 3) linked to the IGSM generated 10 future climate projections. Two dynamic global vegetation models (DGVMs), MC2 and BioMAP, were run using the 10 climate projections, and the biophysical results from these models were used as boundary conditions for a global forestry and land use model (GTM). The resulting integrated ecosystem-economic modeling system was used to assess the implications of these scenarios on various forest stocks, prices, and land use. Using the model, we assessed the implications of climate change on forest mitigation policy on the international timber trade, and the economic efficiency of alternative adaptation policies.

A multiple values trade-offs framework for climate change adaptation. Li, Q. (*BC Ministry of Forests, Lands, and Natural Resources Operations, Canada; Qinglin.Li@gov.bc.ca*), Wang, G., Wang, T., Seely, B., Innes, J. (*University of British Columba, Canada; guangyu.wang@ubc.ca; tongli.wang@ubc.ca; brad.seely@ubc.ca; john.innes@ubc.ca*).

Traditionally, timber has been the major concern in forest management, but the values of ecosystem services provided by forest should also be recognized, especially under current climate change. Forest ecosystem also has the great potential to contribute climate change mitigation portfolio through carbon sequestration. Thus, climate change adaptation and multi-values are becoming new challenges in current forest management and planning. In this research, a conceptual resource-modeling framework was developed to maximize the overall benefit through trade-off analyses between social, economic and environmental values. In this modeling, the following value accounts were built: timber volume, revenue, carbon, wildlife habitat, visual quality objectives, integrated resource management, and road density to represent the various forest resource values. A meta-heuristic modelling approach was employed to demonstrate the proposed multi-value trade-off analyses framework. A study area, Pitt River watershed in BC, Canada, was selected to demonstrate the development of this framework. The local current forest management plan and timber supply review analysis were compared to demonstrate the effectiveness of the new multi-value framework, and the advancement of the new climate change strategy development. In order to analyze and develop climate change adaptation strategy, several scenarios were compared. The case study demonstrated that the proposed approach benefits managers in managing forest resources under changing climate.

How fast can European forests adapt to climate change? Nabuurs, G., Hengeveld, G. Schelhaas, M., (*Alterra, Wageningen University and Research, Netherlands; gert-jan.nabuurs@wur.nl; geerten.hengeveld@wur.nl; MartJan.Schelhaas@wur.nl*), Reyer, C. (*PIK, Germany; reyer@pik-potsdam.de*), Hanewinkel, M. (*Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland; marc.hanewinkel@wsl.ch*).

The large diversity in abiotic and biotic circumstances in European forests makes it extremely difficult to predict what the impacts of climate change will be on the various tree species, and ecosystems at the various localities. This makes it even more difficult to analyze how forest management should adapt. The case studies in EU Motive-project provide, however, a basis for upscaling to the European scale. For the first time we combine species changes as predicted by a climate envelop model with an incorporation of forest management responses in an empirical European forest resource model (EFISCEN). It is assumed that only then a forest owner will decide to change tree species at that site towards one that is more preferred according to the climate envelop model. The results indicate that tree species composition will change only slowly at the European scale. By 2070, 10% of the total forest area will have changed species.

Climate change impacts in the temperate forests of Southeast Australia: can forest management reduce vulnerabilities? Nitschke, C. (*University of Melbourne, Australia; craign@unimelb.edu.au*).

The temperate forests of Southeast Australia are comprised of a high diversity of species and ecosystems that range from fire tolerant to fire sensitive. The steep altitudinal gradient in the region also provides a diversity of drought to frost tolerant species with the former dominating at lower elevations and the latter at higher elevations. The forests of the region are the source for 90% of the region's drinking water, are important for timber production and recreation, contain some of the most carbon dense forests in the world and have a high level of biodiversity. An analysis of climate change impacts on the region's forests found that increases in area burned, shifts in species distributions to higher elevations, and the contraction of higher elevation and fire sensitive species and their associated ecosystems are likely to occur. The application of alternative silvicultural approaches aimed at addressing key vulnerabilities was found to mediate the contraction of species distributions and maintain habitat for threatened species, water supply, timber yield and the carbon carrying capacity of the forests. Using forest management to address vulnerabilities may facilitate adaptation and foster sustainable forest management in the temperate forests of SE Australia under climate change.

Community forestry as an approach to climate change adaptation. Pairojmahakij, R., Silori, C., Gritten, D., Triraganon, R., Paudel, S. (*The Center for People and Forests, Thailand; regan@recoftc.org; chandra.silori@recoftc.org; david.gritten@recoftc.org; ronnakorn@recoftc.org; shyam.paudel@recoftc.org*).

International debate on the role of forests in climate change has thus far mainly focused on their potential to mitigate Greenhouse Gas emissions (GHGs), particularly through the REDD+ mechanism. However, the role of forests in contributing to climate change adaptation has been gaining recognition. In addition to the efficiencies in linking adaptation and mitigation funding and project activities, a key rationale for focusing on forest landscapes for adaptation is the reliance of approximately 450 million people on forests in the Asia Pacific region alone. The contributions of forests to the livelihoods of these local communities is significantly higher than previously thought and thus a major contributor to their adaptive capacity. Conversely, local communities may prove to be critical in on the ground implementation of activities to support ecosystem resilience. Community forestry (CF) in this context is of particular importance as a modality for providing multiple benefits to local communities, the various assets required for adaptive capacity in a context of climate change. The focus of this research article is to present a CF based climate change adaptation framework, which is grounded in 10 case studies in Cambodia, Indonesia, Nepal, Thailand, and Vietnam.

Testing the insurance hypothesis: Can tree species diversity buffer ecosystem services against disturbance impacts? Pedro, M., Rammer, W., Seidl, R., Lexer, M. (*University of Natural Resources and Life Sciences, Austria; marianapedro@boku.ac.at; werner.rammer@boku.ac.at; rupert.seidl@boku.ac.at; mj.lexer@boku.ac.at*).

Natural disturbances have increased across Europe in recent decades, and climate change is expected to further amplify frequency and severity of disturbance events. This intensification may threaten the capacity of forest ecosystems to sustainably provide society with essential ecosystem services. It has been hypothesized that tree species diversity buffers ecosystems against disturbance impacts (insurance hypothesis). Here we tested this hypothesis by investigating the effect of tree species diversity on productivity and carbon storage at a temperate forest landscape in Central Europe (Hainich National Park, Germany). Using the process-based landscape model iLand, we studied the effects and interactions of different levels of diversity and disturbance on ecosystem services provisioning in a factorial simulation study. Our results demonstrated that increasing disturbance frequency and severity can negatively impact ecosystem services provision. We furthermore found support of the insurance hypothesis, with higher levels of species diversity mitigating negative disturbance impacts. However, the effect size differs with disturbance type (top-down vs. bottom-up, species-specific vs. general) and species identity (response diversity vs. species diversity). Our findings highlight the advantages of diverse ecosystems in sustaining ecosystems services under changing disturbance regimes, and provide important information for adapting forest management to an uncertain future.

Applying resilience thinking to production forest ecosystems. Rist, L. (*Swedish University of Agricultural Sciences, Sweden; lucy.rist@slu.se*).

One of the largest challenges facing humanity is to secure the production of food and fiber while avoiding long-term negative impacts on ecosystems and the range of services that they provide. Resilience and resilience thinking have been described as frameworks for addressing sustainability challenges, or as a way to operationalize sustainability. Despite important theoretical contributions to the understanding of ecosystem dynamics, resilience concepts have to date not been systematically applied to systems that are focused on production of food or fiber, including to forests and forestry. Here, we investigate the application of resilience concepts to the challenges associated with sustainability in key production systems (namely forestry, agriculture, fisheries and aquaculture). We present three propositions for expanding the resilience framework to accommodate specific characteristics of these systems. Further we show how sustained anthropogenic inputs of external resources can lead to a coercion of resilience and describe how the global interconnectedness of many production systems can camouflage signals indicating resilience loss. We elaborate on the implications of these findings specifically in relation to forestry and sustainable management of forests.

Effectiveness of climate change communication in promoting engagement with climate science and adaptation among forestry stakeholders. Vulturius, G., Gerger Swartling, Å., André, K. (*Stockholm Environment Institute, Sweden; gregor.vulturius@sei-international.org; asa.swartling@sei-international.org; karin.andre@sei-international.org*), Nordén, A. (*University of Gothenburg, Sweden; anna.norden@economics.gu.se*).

Climate change is expected to profoundly affect forests worldwide and adaptation is needed for reducing the vulnerability of forestry stakeholders to climate change impacts. Governments and researchers are grappling with the question how to effectively disseminate scientific knowledge about climate impacts and appropriate adaptation measures and how to encourage consequent adaptive action. The objective of this study was to assess the effectiveness of climate change communication in promoting engagement with climate science and adaptation among forestry stakeholders. The study asks if climate change communication (CCC) can lead to cognitive, affective, and relational learning, and changes in attitudes and behavior regarding adaptation. Findings are based on a survey comprising responses from approximately 6 000 forestry owners in Sweden, of which one third took part in a CCC project carried out by the Swedish forestry agency. Propensity score matching and related statistical methods were used to estimate the effect of CCC on the perception of climate risks, perceived efficacy of adaptation measures, perceived self-efficacy and actual adaptive action of participants and non-participants of the project. Results of this study offer insights into how CCC can be improved by better addressing forestry stakeholder's varying objectives and decisionmaking processes.

ClimateAP and its use in projecting the climate niche and productivity of forest trees in future climates in Asia Pacific. Wang, T., Wang, G., Innes, J., Lu, Y. (*University of British Columbia, Canada; tongli.wang@ubc.ca; guangyu.wang@ubc.ca; john.innes@ubc.ca; yuhao.lu.ubc@gmail.com*).

Ecosystems of the Asia-Pacific region are particularly vulnerable to climate changes as aridity is expected to increase more rapidly in a large part of this region than the global average. Mitigation and adaptation to climate change are pressing challenges for the scientific community, stakeholders and policy makers. However, related research and applications in this region are behind many parts of the world. Through a projected supported by Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet), we developed ClimateAP, a software package that descales and integrates historical and future (IPCC

AR5) climate data, and estimates a large number of biological relevant climate variables for any location in the region. The climate data generated through ClimateAP can facilitate niche-based and process-based modelling to predict the shifts in bioclimate envelopes and impact on productivity for major forest tree species due to climate change. Such predictions were conducted in several major species in this region. This information can provide a scientific basis for impact assessments, identification of the most vulnerable species and populations, and developing adaptive strategies. As ClimateAP is an easy-to-use and all-in-one tool, it is expected to considerably promote climate change adaptation related studies and applications in this region.

Impact of and responses to climate change from the perspective of traditional forest knowledge in Guizhou province of China. Yuan, J. (*Guizhou University of Finance and Economics, China; yuanjuanwen@yahoo.com*), Liu, J. (*Centre of Forestry, Environmental and Resources Policy Study, China; liujinlong@ruc.edu.cn*).

Traditional forest-related knowledge plays a very important role in land use systems. Guizhou province is a mountainous province where forests are a very important component of the land use system. Extreme weather including severe drought, flood, and freezing occurs more frequently. Our research shows that extreme weather has a very significant influence on forest-related knowledge and practices. Villagers have had to change their traditional land use system and use new technologies to adapt to the new weather conditions. Higher temperatures have favored population growth of some insects and traditional pest control technologies are not as effective as before. Declining rainfall reduces the availability of water for storage in the paddy fields during the post-harvest period, which traditionally enabled villagers to use paddy fields to feed fish and prevent weed growth, so villagers now have to invest more labor in managing the paddy fields. However, villagers are very observant of and sensitive to climate change and are actively responding to these changes by trying their best to make innovations in the process. So, villagers own adaptations and innovation should be appreciated and considered by other stakeholders for their value in adapting to climate change and using rural landscapes in a more sustainable way.

C-24 Adaptive forest management under climate change – networking from local to global scales in the temperate zones

Organizers: Andreas Bolte (Thünen Institute of Forest Ecosystems, Germany), John Stanturf (U.S. Forest Service) & Palle Madsen (University of Copenhagen, Denmark)

Adaptive forest management in global temperate forests: pathways for a co-operative network concept. Bolte, H. (*Thünen Institute of Forest Ecosystems, Germany; andreas.bolte@ti.bund.de*), Stanturf, J. (*U.S. Forest Service, USA; jstanturf@fs.fed.us*), Madsen, P. (*University of Copenhagen, Denmark; pam@ign.ku.dk*).

Vigorous temperate forests are essential to maintain current forest functions and to contribute to climate change mitigation. Against the background of climate change, greater knowledge is needed of the genetic diversity and the genetic regulation of physiological processes that are important for adaptation. Moreover, appropriate adaptive forest management (AFM) strategies and measures must be elaborated that optimize forest adaptation and adaptability. Today, we observe several separated international networks that could serve as a partial basis to meet critical knowledge needs: (1) international provenance trials, (2) yield and management trials, and (3) national and international forest monitoring networks (e.g., the UN-ECE Level I and Level II program). By combining the experiences and capacities of silviculturists, geneticists, and ecologists an international network can be established that is able to explore and answer urgent questions on the adaptive status of important tree species, potentials of alternative tree species and provenances, and the optimal silvicultural systems for AFM in different regions and locations. The knowledge gained at the international expert level must be diffused to the practitioner level such that it can be implemented in forest operations.

Identifying potential tipping points in forest ecosystems using vegetation function traits and microclimatic indicators. Hobson, P. (*Writtle College, United Kingdom; peter.hobson@writtle.ac.uk*), Ibisch, P. (*Eberswalde University for Sustainable Development, Germany; pierre.ibisch@hnee.de*), Norris, C. (*Writtle College, United Kingdom; Catherine.Norris2@writtle.ac.uk*).

A central tenet in ecosystem theory is that functional integrity and resilience in ecosystems are maintained by conserving energy-dissipative structures in the form of biomass, networks, and information. Human activities that degrade these properties can result in ecosystem functional impairment as well as losses in resilience and adaptive capacity. Identifying potential tipping points before degradation occurs presents challenges in forest management. Vegetation functional traits have been used to measure ecosystem integrity and also appear to influence microclimatic conditions. It is unclear if they provide appropriate signatures for assessing regime shifts and ecosystem thresholds. In this paper, the results of a 3 year study on old growth and used forests in selected areas across parts of Europe suggest forests free of human interference exhibit optimum values in biomass and plant functional traits, and this appears to generate a stabilizing effect in both microclimatic temperature and humidity throughout the year. Significant shifts in vegetation function and microclimatic conditions occur in response to different levels of human-induced change indicating a loss in capacity to conserve energy and retain moisture. Three bio-ecological indicators (vegetation function index, temperature, and moisture) to determine ecosystem tipping points and resilience are recommended for forest condition assessment.

Europe-wide analysis of Douglas-fir provenance trials: insights into assisted migration to address climate change. Isaac-Renton, M., Roberts, D., Hamann, A. (*University of Alberta, Canada; isaacren@ualberta.ca; drr3@ualberta.ca; andreas.hamann@ualberta.ca*), Spiecker, H. (*Albert-Ludwigs-University, Germany; instww@uni-freiburg.de*).

To investigate the realism of climate envelope model predictions, we evaluate the introduction of North American Douglas-fir provenances to Europe as a retrospective experiment on how trees respond when subjected to novel environmental conditions. We conducted a meta-analysis of long-term growth data of 2 800 provenance transfers to 120 European test sites and examined whether a bioclimate envelope model developed for North America to guide assisted migration under climate change can retrospectively predict the success of provenance transfers to Europe. The climate envelope model was generally well suited to

predict the best performing provenances along north-south clines but failed to predict the superior provenance performance of coastal North American populations under continental climate conditions of eastern Europe. However, model projections appear appropriate when considering additional information regarding adaptation of Douglas-fir provenances to withstand frost and drought, even though the model partially fails in a validation against growth traits alone. We conclude by applying the partially validated model under climate change scenarios for Europe, and demonstrate that climate trends observed over the last three decades warrant changes to current usage of Douglas-fir provenance in plantation forestry throughout western and central Europe.

Refugial populations: a source of increased genetic diversity for improved forest adaptation capacity. Madsen, P. (*University of Copenhagen, Denmark; pam@ign.ku.dk*), Bolte, H. (*Thünen Institute of Forest Ecosystems, Germany; andreas.bolte@ti.bund.de*), Sagheb-Talebi, K. (*Research Institute of Forests and Rangelands, Iran; saghebtalebi@rifr-ac.ir*), Stanturf, J. (*U.S. Forest Service, USA; drdirt48@gmail.com*).

Refugial populations of several European tree species are expected to have more genetic diversity and greater adaptation capacity than European populations of these species in general. This phenomenon has been described for European silver fir (*Abies alba*). Compared with 17 other European provenances across its natural range, a Calabrian provenance showed superior growth and health in Danish provenance trials established in the 1930s and inventoried at age 44. This was the southernmost provenance tested in these field trials located more than 500 km north of it northern distribution limit. Similarly, the Caspian forest in northern Iran is an important refugial area for European species of rich deciduous forests covering 1.8 million ha. The Caspian forest holds a rich species diversity that includes both many European species as well as several closely related species. We describe pathways for collaborative research that explore the genetic diversity and the adaptation potential of the Caspian as well as Calabrian provenances compared to commonly used European provenances. One of the main research challenges is to uncover whether the Calabrian silver fir is unique or if a similar superior adaptation potential can be found within the refugial populations of other European tree species.

Field experiments and models as decision support for forest management under increasing drought risk. Rigling, A. (*Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland; andreas.rigling@wsl.ch*), Eilmann, B. (*Wageningen University, Netherlands; britta.eilmann@wur.nl*), Elkin, C. (*ETH Zurich, Switzerland; che.elkin@env.ethz.ch*), Giuggiola, A., Hanewinkel, M., (*Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland; arnaud.giuggiola@wsl.ch; marc.hanewinkel@wsl.ch; marcus.schaub@wsl.ch*), Schaub, M., Wohlgemuth, T., Zweifel, R., Bugmann, H.

For the 21st century, climate scenarios predict an increase in frequency and intensity of drought posing major challenges for forest management. Under current conditions, drought-related tree mortality is already an important constraint for xeric forest ecosystems. We assessed the sensitivity of forest ecosystems to climate change in dry inner-Alpine ecosystems and evaluated alternative forest management strategies and tree species. We integrated data from forest monitoring plots, field experiments, test plantations and dynamic forest models to evaluate the impact on different forest ecosystems and their services. The results suggest that at dry low elevation sites drought tolerance of native tree species will be exceeded so that a transition to more drought-adapted species should be promoted. At medium elevations, the impact from drought and insect disturbances will increase, while at high elevations forests are projected to expand and grow faster. All ecosystem services considered are projected to be impacted by changing forest conditions, with the specific impacts often being elevation-dependent. In the medium term, forest management that aims to increase the resistance of forests to drought can help maintaining forest ecosystem services temporarily. However, the results suggest that relatively rigid management interventions are required to increase forest resistance in the longer term.

Utilizing the intraspecific variation in climate response to select appropriate Douglas fir provenances for European plantations in future climates. Schueler, S. (*Austrian Federal Research Center for Forest, Austria; silvio.schueler@bfw.gv.at*), Chakraborty, D. (*University of Natural Resources and Life Sciences, Austria; debojyoti.chakraborty@boku.ac.at*), Konnert, M. (*Bavarian Office for Forest Seeding and Planting, Germany; Monika.Konnert@asp.bayern.de*), Lexer, M. (*University of Natural Resources and Life Sciences, Austria; mj.lexer@boku.ac.at*), Matulla, C. (*Central Institute for Meteorology und Geodynamics, Austria; christoph.matulla@zamg.ac.at*), Türk, K., Wang, T.

Planting of alternative and also non-native tree species or different provenances better adapted to or having a higher potential for adaptation to future climates has been discussed as an important silvicultural adaptation measure. Douglas fir is considered one of the most promising non-native species in Austria and other European countries because it exhibits superior productivity and high wood quality. Particularly, it is also expected to grow well under the warm and dry conditions of a future climate. In its natural range, Douglas fir occurs under a wide range of environmental conditions. Although provenance experiments in many European countries have already provided recommendations for the best seed material, the prospects of climate change provoke a reassessment and reanalysis of existing trial data. Within the joint project DougLAS, we utilized provenance trial data from about 60 trials throughout Austria and more than 20 trials from Bavaria, Germany. The objective of our study was to understand the genetic variation of climate response. We used universal response and transfer functions to identify provenances that will allow stable and productive plantations under future conditions. Moreover, our analysis will give general insights into the climate response of tree populations within a non-analogous climate.

Potential of thinning to mitigate drought stress in trees: a meta-analysis. Sohn, J., Bauhus, J., Saha, S. (*Univeristy of Freiburg, Germany; jsohn81@googlemail.com; juergen.bauhus@waldbau.uni-freiburg.de; somidh.saha@waldbau.uni-freiburg.de*).

Recent and predicted increases in extremely dry and hot summers emphasize the need for silvicultural approaches to increase the drought tolerance of existing forests in the short-term, before adaptation through species changes may be possible. Thinning is considered a promising means to increase tree vigor and access of promoted trees to soil water, as long as this is available in the rooting zone. However, these trees may also be disadvantaged through increased competition by ground vegetation or a higher transpirational crown surface. Over the last decade, an increasing number of case studies covering different climatic regions and tree species have produced evidence that thinning can help to decrease climatic sensitivity and to mitigate drought-related growth reductions in trees. However, a comprehensive quantitative review of these individual studies has not been done. We conducted a mixed effect meta-analysis to identify a general effect of thinning intensity on drought response in trees. Log response ratios were calculated as effect size estimates to calculate the magnitude of thinning influence on reduction in drought stress. Climate, site

productivity, and plant competition were used as stressors in statistical modeling. The results of this review will provide crucial information for the development of short-term silvicultural adaptation strategies to adapt forest ecosystems to climate change.

Performance of the selected Northern American tree species introduced in Central Europe. Zasada, M., Bijak, S., Bronisz, K., Bronisz, A., Sagan, J. (*Warsaw University of Life Sciences, Poland; Michal.Zasada@wl.sggw.pl; szymon.bijak@wl.sggw.pl; karol.bronisz@wl.sggw.pl; Agnieszka.Bronisz@wl.sggw.pl; jacek.sagan@warszawa.lasy.gov.pl*), Potocki, M., Socha, J.

Non-native forest tree species have been successfully introduced in many regions of Europe over last 200 years. In many cases they provide a large amount of valuable wood in shorter time than native species and are a source of various products such as resins, oils, fruits, or cork. They are also used in land reclamation and as a biocenotic admixture. The presented research focuses on the selected tree species from North America: Douglas fir (*Pseudotsuga menziesii*), red oak (*Quercus rubra*), and grand fir (*Abies grandis*), introduced into Polish forests. The comparison of the studied species with their native counterparts have been performed in terms of their productivity, resistance to the harmful biotic, abiotic and anthropogenic factors, impact on the local plant communities as well as ability to adapt to climate change. The research showed that the introduced species can be a valuable alternative to native species. They reveal high productivity and adaptability to the site and climatic conditions. At the same time, in some cases the anxiety is raised due to the changes caused to the local phytocenoses and their potential invasiveness.

C-25 Forest management options to tackle climate change

Organizers: Hubert Hasenauer (University of Natural Resources and Life Sciences, Austria), Frits G. Mohren (University of Wageningen, the Netherlands) & Jean-Luc Peyron (Ecofor, France)

Assessing forest productivity: terrestrial forest inventory versus MODIS satellite driven estimates. Hasenauer, H., Neumann, M., Moreno, A. (*University of Natural Resources and Life Sciences, Austria; hubert.hasenauer@boku.ac.at; mathias.neumann@boku.ac.at; adam.moreno@boku.ac.at*).

Large scale forest productivity estimates are of increasing interest as more demands are made on forest resources. In principle, three different methods are currently available: (i) forest inventory sampling points based on repeated tree observations; (ii) flux tower observations; and (iii) remotely sensed data for a continuous cover of net primary productivity (NPP) estimates. In this paper we focus on the conceptual challenge in comparing Moderate Resolution Imaging Spectroradiometer (MODIS) satellite driven NPP vs. terrestrial ground based productivity estimates using forest increment data across Europe. Biomass functions are applied to derive ground based NPP estimates using repeated tree observations from the plots. The results of the study show that (i) MODIS satellite driven annual NPP estimates provide a continuous productivity estimate across Europe; (ii) MODIS NPP predictions provide forest productivity estimates of fully stocked forests with a complete crown cover; and (iii) terrestrial driven NPP predictions using biomass functions compared well with MODIS driven estimates after addressing stand density effects due to forest management.

Enhancing forest carbon mitigation potentials by forest management and timber utilization. Koehl, M., Mues, V., Olschofsky, K. (*University of Hamburg, Germany; michael.koehl@uni-hamburg.de; volker.mues@uni-hamburg.de; konstantin.olschofsky@ti.bund.de*).

Discussions on the role of forests in the global carbon cycle are often limited to forest ecosystems, and it seems self-evident to increase the forest carbon stock by reducing timber harvest. In our study, we extend the view from forest to timber utilization, which has a two-sided effect in that it reduces forest carbon pools and reduces emissions by timber utilization. Potential mitigation effects of forest management strategies on the forest and timber sector are quantified according to the gain-loss method. A simulation study over 100 years is performed for three forest management objectives and two climate change scenarios. The forest management alternatives have a stronger influence on the simulated forest mitigation potential than the anticipated future climate change scenarios. The consideration of both, the forest and timber sector, focuses on gains and losses and including substitution effects allows for a holistic assessment of the forest mitigation potential. Optimal strategies for timber production in forests and substitution effects by timber utilization need to be developed and implemented in mitigation policies.

Multiple-use forest management strategies for mitigation and adaptation to climate change: the EU-FORMIT project. Mohren, G., Goudiaby, V. (*Wageningen University, Netherlands; frits.mohren@wur.nl; venceslas.goudiaby@wur.nl*), Hasenauer, H. (*University of Natural Resources and Life Sciences, Austria; hubert.hasenauer@boku.ac.at*).

Forest management can lead to continuous carbon sequestration, while forest biomass as a renewable energy source can replace fossil fuel, thus multiplying the mitigation effect. However, forest management strategies for carbon sequestration have to account for multiple forest functions that depend on ecological conditions, and that meet different demands from society. This requires that management scenarios, including mitigation measures and regional management strategies, include trade-offs between different forest functions. The EU-FORMIT project assesses options for carbon storage in forests accounting for historical management practices, regional differences, and different management aims. This includes biofuel use, biodiversity conservation, and economics of timber production. Mitigation encompasses carbon storage in forests and forest products, and substitution of fossil fuel, and needs to account for time lags and emission displacement. Stand level estimates can be linked to forest inventory data, and thus scaled to regional and national levels. Forest management strategies will be evaluated to identify consistent and flexible scenarios for forest management, with the aim to ultimately deliver management options and implementation strategies for forests and forest management in Europe, focusing on mitigation while safeguarding other forest functions, and accounting for regional differences in environmental and socio-economic conditions.

Approaches to evaluate the carbon neutrality of the forest value chain. Muys, B., Cardellini, G., Almeida, J. (University of *Leuven, Belgium; bart.muys@ees.kuleuven.be; giuseppe.cardellini@ees.kuleuven.be; joana.almeida@ees.kuleuven.be*), Aachen, W. (*Université Libre de Bruxelles, Belgium; wouter.achten@ulb.ac.be*).

This contribution will start with a state of affairs in the scientific debate on carbon neutrality of forest biomass, shortly introducing the terminology and the main issues (carbon neutrality, carbon debt, indirect land use change, substitution, cascading). Then time and space explicit Life Cycle Assessment (tispa-LCA) is introduced as the approach to address the issues and to make accurate predictions of the greenhouse gas impact of wood products compared to their alternatives. The tispa-LCA will be illustrated with examples from tree-based biofuels in Africa and wood products in Europe. Recommendations will be formulated to make tispa-LCA operational.

First signs of carbon sink saturation in European forest biomass: options for management. Nabuurs, G. (*Alterra, Wageningen University and Research, Netherlands; gert-jan.nabuurs@wur.nl*), Lindner, M., Verkerk, H. (*European Forest Institute, Finland; marcus.lindner@efi.int; hans.verkerk@efi.int*), Gunia, K. (*Arbonaut, Finland; katja.gunia@arbonaut.com*), Michalak, R. (*United Nations Economic Commission for Europe, Switzerland; roman.michalak@unece.org*), Deda, P., Grassi, G.

European forests are seen as a clear example of vegetation rebound in the Northern Hemisphere, recovering in area and growing stock since the 1950s after centuries of stock decline and deforestation. These regrown forests have shown to be a persistent carbon sink and are projected to continue for decades, however, there are early signs of saturation. Forest policies and management strategies need revision if we want to sustain the sink. This paper explores the different options we have in forest management to sustain the sink and how the optimal management may vary across Europe.

Synergies and trade-offs between forest adaptation and mitigation. Peyron, J. (*Groupement d'Intéret Public Ecosystèmes Forestiers (GIP ECOFOR), France; jean-luc.peyron@gip-ecofor.org*).

Forests are impacted by climate change through trends (beneficial or detrimental) and extreme events. They may adapt and deserve to be adapted to these gradual or brutal phenomena. They are also able to mitigate climate change through carbon sequestration, storage, and substitution. Adaptation and mitigation have to be distinguished because they are very different responses to climate change. In the same time, they are interrelated since mitigation supports carbon regulation as an ecosystem service influenced by forest adaptation. Synergies and trade-offs between forest adaptation and mitigation may be analyzed through an economic model integrating, for a given forest stand, not only adaptation and mitigation but also different aspects of adaptation (namely trends and extreme events) and different aspects of mitigation (namely sequestration, storage and substitution). Such a model will be presented and discussed. It allows comparing forest management under adaptation strategies, mitigation strategies or both. Such a forest analysis is interesting to compare adaptation and mitigation, and could be an example for the same issue at a more aggregated level incorporating the whole economy.

Future of Russian forests: a need of transformative adaptation? Shvidenko, A., Shchepashchenko, D., Kraxner, F., Obersteiner, M. (*International Institute for Applied Systems Analysis (IIASA), Austria; shvidenk@iiasa.ac.at; schepd@iiasa.ac.at; kraxner@iiasa.ac.at; oberstei@iiasa.ac.at*).

Russia expects the most dramatic climate change over the globe (increase of the annual average temperature from +6 to +11 ˚C compared to the average under global warming of +3.5–4.0 ˚C, and substantial increase of climate's aridity and extreme events). It would generate many risks for Russian forests, such as heat and water stress, alteration of fire regimes, and pandemic outbreaks of dangerous insects. Specific problems will be generated by permafrost's thawing and destructive industrial development of northern regions. Very likely, a major part of Russian forests will become a tipping element. In the presentation, we analyze climatic predictions for the territory including impacts on composition, productivity, vitality and surviving of forests; regional feedbacks of forest ecosystems; and relevant strategies of forests' adaptation to climate change. Modeling predictions show that implementation of adaptive forests management (including genetic efforts, activities addressed to increase permafrost protection forest services, special preparation of structure of forest landscapes) could substantially mitigate the expected risks. We discuss specific features of transformative adaptation. As long as practically all forests in Russia are in the state property, there is a legislative and institutional background for introduction of adaptive forest management in Russia. However, a current decline of forest governance in Russia hinders transition to sustainable forest management there.

Combining forest models with LCA for optimization of the forest's GHG mitigation effect. Soldal, E., Bergseng, E (*Norwegian University of Life Sciences, Norway; ellen.soldal@nmbu.no; even.bergseng@umb.no*), Valente, C. (*Ostfold Research, Norway; Clara@ostfoldforskning.no*).

When increasing the harvest of forest biomass in order to mitigate GHG emissions other environmental and social issues like biodiversity and recreational values may be compromised. In order to include these considerations and climate change, we developed a methodology that combines forest management models with LCA. We used linear programing to find the best forest management in four scenarios (baseline, business as usual, biodiversity, and carbon optimization) that restrict the management options and optimize the mix between carbon storage in forest and the substitution effect. The forest model included carbon cycle in the forest and assumes economic profitability. This methodology used local data in combination with country specific data that provide companies and local and regional government with a tool for more efficient and action oriented climate change mitigation measures. We use a municipality in Norway as a case study and investigate how they best can use the biomass resources available. The analysis showed that the combination of forest management models and LCA is a valuable tool for decisionmakers in environmental issues. The inclusion of forest carbon provides a more complete analysis of products carbon footprint, and at the same time the forest managers can take biodiversity into consideration.

C-26 Forest owners and climate change adaptation

Organizers: (Research and Training Centre for Forests, Natural Hazards and Landscape, Austria), Ulrike Pröbstl (University of Natural Resources and Life Sciences, Austria), Anatoly Shvidenko (International Institute of Applied System Analysis, Austria) & Sandra Luque (National Institute for Environmental and Agricultural Science and Research, France)

Acting as a forest owner in a climate of uncertainty. Deuffic, P. (*National Research Institute of Science and Technology for Environment and Agriculture, France; philippe.deuffic@irstea.fr*).

Forest owners have faced very different risks for decades: pests, forest fires, storms, economic crises. Why would climate change put a new light on forest owners' perception of risks and on their management practices? An 8-year qualitative survey in the southwestern part of France shows that forest owners are aware of climate changes. Their beliefs and practices do not rest only on scientific evidence, but also on the memory of the local community who connects and interprets the succession of natural hazards as a proof of climate changes. However they have to face structural barriers (e.g., current wood market, forest wood chain structuring, forest policy framework, scientific controversies) that slow down and hamper the implementation of adaptative strategies. Despite these difficulties, they take into account the main characteristics of the risks (frequency, strength, impact, insurability), and they adopt different strategies to mitigate climate changes (combination of different silvicultural systems, short and long rotation, species diversification,). These progressive changes suggest a paradigmatic shift in the forest owners' values scale (resilience and safety vs. economic optimization). However it may also increase the gap between forest owners who choose hyper-intensive silvicultural models and those who will adopt close-to-nature forestry.

Scenarios for forest management in a rural municipality in Sweden, with respect to different private forest owners categories. Eggers, J., Öhman, K., Lamas, T., Lind, T. (*Swedish University of Agricultural Sciences, Sweden; jeannette.eggers@slu.se; karin.ohman@slu.se; tomas.lamas@slu.se; Torgny.Lind@slu.se*).

Half of the productive forest area in Sweden is owned by small-scale, nonindustrial private forest owners. The forest management choices of private forest owners have a decisive impact on forest composition and structure, and thus on many ecosystem services that forests provide. However, there are no ready tools available for assessing the long-term effects of different management strategies on forest ecosystem services taking into account a diverse forest ownership structure at landscape level. In this study, we examined the effect of using different forest management strategies for different categories of private forest owners for the municipality of Vilhelmina in Northern Sweden. Forest management strategies were based on quantitative data from a survey of private forest owners. Management strategies were linked to property size, as this factor has been shown to have a decisive impact on management choice of private forest owners. We demonstrate how the different management strategies led to a large variation in ecosystem services at landscape level. Our results highlight the importance of taking different management strategies for private owners into account in medium to long-term scenarios of the development of forest ecosystem services.

Forest owner perceptions of climate change effects on forest management. Hemström, K., Mahapatra, K., Gustavsson, L. (*Linnaeus University, Sweden; kerstin.hemstrom@lnu.se; krushna.mahapatra@lnu.se; leif.gustavsson@lnu.se*).

The climate change effect on the boreal forest, and how to best adapt forest management so to meet the challenges climate change involves is uncertain. Meanwhile, more and more attention is paid to the management of forests and use of forest biomass to reduce society's impact and mitigate climate change effects. About 50% of the Swedish forest is privately owned and most Swedes believe climate change is happening. This study uses the results of a questionnaire survey (n=1465) among Swedish private forest owners to investigate their perceptions of how climate change relate to forest growth and the forest management. These perceptions are likely to influence the forest owner motivation to adapt the forest management. Questions involve the priority given to climate change effects in the forest management, the perceived climate impact of current and intensified forest management practices (fertilizing, cultivating exotics), and perceived impact on forest growth within a 100-year period. The relationship between these perceptions, belief in climate change effects and socio-demographic background is explored. These results are contrasted to forest owners' motivations to intensify the forest management, to understand the implications for the climate change adaptation of Swedish forest management.

Characterizing climate change and forest carbon sequestration attitudes of NIPF landowners in the southern United States. Khanal, P. (*Mississippi State University, USA; khanalpn@gmail.com*).

Very few earlier studies have analyzed climate change and carbon sequestration attitudes of the NIPF landowners in the southern United States. None of the studies has characterized landowners based on their climate change attitude and carbon sequestration. The specific objectives are (i) segment attitudinal clusters about climate change and carbon sequestration of the NIPF landowners; (ii) identify their perceived barriers to forest carbon sequestration in the South; and (iii) identify their major forestry sources of information and their preferred communication strategies. The data for this study was collected from a mail survey conducted between August and October, 2013. A K-means cluster analysis using the Euclidian distance was used on a series of 11 climate change and carbon sequestration questions from the survey questionnaire. Such groupings were used to observe the differences in behaviors and characteristics of the landowners with different forest management objectives. Their socio-economic characteristics, forest characteristics, and management practices were summarized by each cluster. In addition, the sources of forestry information and their preferred communication strategy were identified for each cluster. In addition, factor analysis was used to identify the major barriers for landowners to practice forest carbon sequestration.

What is the baseline of forest carbon stocks in South Korea: overestimation or underestimation? Lee, Y., Seok, H. (*Korea Rural Economic Institute, Republic of Korea; yohanlee76@gmail.com; hdseok@krei.re.kr*).

This study investigates the baseline of forest carbon stocks in South Korea facing the risk of forest disturbances by using a dynamic profit maximization model. The risk of forest disturbances such as fires and diseases affects the land owner's decision on optimal harvesting age. Under the risk of forest disturbances, the optimal harvesting age is shortened, and consequently the total expected benefits of carbon sequestration from forests are decreased. However, the carbon incentive system has a positive impact on the fire protection because carbon incentives can induce landowners' participation in protection activities. However, based on scientific principles, forestry-related carbon projects can produce a counter effect in a short run, depending on a type of incentive systems and its timing. Also, one aspect of ecosystem that has been overlooked in carbon economics was that of carbon storage in soil organic matters. To develop a viable carbon sequestration policy, policy makers need to pay attention to desirable rotation period and forest carbon baseline.

Paths for new services: important factors in owning forests for Finnish NIPF owners in the context of ecosystem services. Mattila, O., Häyrinen, L., Berghäll, S., Toppinen, A. (*University of Helsinki, Finland; osmo.mattila@helsinki.fi; liina.hayrinen@helsinki.fi; sami.berghall@helsinki.fi; anne.toppinen@helsinki.fi*).

Demand for traditional forestry services is changing in countries with extensive private forest ownership and high income level. Previous research indicates that especially women, highly educated people, and city dweller NIPF owners in Finland are less driven by economic and income related factors than the traditional farmer forest owners. Simultaneously, service organizations struggle to change their service portfolios. Still, a majority of forestry services are currently marketed on the basis of roundwood trading, which orientation offers a limited approach to the wider set of benefits that forests produce. In this research, we analyze both conceptually and empirically benefits of the forest ecosystem services with a potentially deeper connection to the current forestry services. Our empirical methodology involves the analysis of open questions on NIPF owners' visions of how to use forests in the future based on telephone interviews (400 respondents) in the context of ecosystem services. We classified forest owners based on traditional background variables (age, gender, etc.) and based on their attitudes as consumers from the viewpoint of responsibility. Based on the classification, we were able to recognize groups with potentially high innovation capabilities for the basis of new service development.

Understanding and directing small-scale private forest owner behavior towards climate change adaptation. Pröbstl-Haider, U. (*University of Natural Resources and Life Sciences, Austria; Uproebst@groupwise.boku.ac.at*), Jandl, R. (*Forest Research Center, Austria; robert.jandl@bfw.gv.at*), Formayer, H. (*University of Natural Resources and Life Sciences Austria; herbert.formayer@boku.ac.at*), Suda, M. (*Technical University of Munich, Germany; suda@wzw.tum.de*), Haider, W. (*Simon Fraser University, Canada; whaider@sfu.ca*), Mostegl, N. (*University of Natural Resources and Life Sciences, Austria; nina.mostegl@students.boku.ac.at*).

Climate change will affect many productive forests across Austria, which may lead to significant economic loss, but also depicts various opportunities for future management. While the Federal Forest Service already takes climate change into account, little is known about adaptation of small-scale private forest owners, who manage 56% of Austria's forests. Consequently, this project will investigate human dimensions of climate change and small-scale forest owners' adaptation strategies. The main focus lies on their climate change perception, ways to influence their implementation of adaptation methods, the rising of their awareness of possible risks of inactivity, and the enhancement of their transition to resilient forests. The key challenge is to "re-interest" this group in their property and to increase the awareness of their required contribution. For this purpose, the project develops innovative concepts for attracting as many forest owners as possible to implement adaptive measures. The core of the study builds a questionnaire combined with a discrete choice experiment, which aims at acquiring a thorough understanding of the salient factors influencing decision-making processes. This innovative methodologically approach initially combines forest growth modeling and visualization of potential effects within a stated preference method.

Family forest landowner interest in carbon management and markets: insights from the U.S. and Norway. Snyder, S. (*U.S. Forest Service, USA; Stephaniesnyder@fs.fed.us*), Kilgore, M., Becker, D. (*University of Minnesota, USA; Mkilgore@umn.edi; drbecker@umn.edu*), Solberg, B., Sjølie, H. (*Norwegian University of Life Sciences, Norway; birger.solberg@umb.no; hanne.sjolie@nmbu.no*), Miller, K., Habesland, D., Lindstad, B.

Family forest lands can be an important contributor to carbon sequestration efforts, but little is known about family forest landowner interest, willingness, and ability to manage for carbon, or to participate in programs that enable them to sell carbon credits generated from the growth of their forests. Forest carbon sequestration has been touted as a low-cost, near-term means of addressing rising greenhouse gas levels. However, whether this bears out depends, in part, on the collective actions of forest landowners. To address this question, we conducted studies to identify family forest landowner interest in forest carbon management and participation in voluntary carbon market trading programs in three U.S. states containing a large amount of family forest land (Minnesota, Wisconsin, and Michigan) and in Norway. Mail surveys were administered to randomly selected family forest landowners in both regions. Follow-up focus groups were conducted to delve more deeply into topics that emerged from the survey findings. Logistic regression models were developed to examine factors influencing potential participation in carbon markets. Comparative results are discussed.

Explaining differences in perception of climate risks and adaptation measures among forest owners and forestry advisors. Vulturius, G., Gerger Swartling, Å. (*Stockholm Environment Institute, Sweden; gregor.vulturius@sei-international.org; asa.swartling@sei-international.org; karin.andre@sei-international.org*).

The present study aims to investigate the changing attitudes of forest owners and forestry advisors towards climate change risks and adaptation measures. It draws from the literature on risk perception and the diversification of forestry stakeholders. Previous research has shown that how forest stakeholders choose among different forestry management options depends on how they value timber production, recreational benefits, and preservation of biodiversity and forestry traditions. The study argues that the variance of opinions forest stakeholders hold about risks from climate change and different adaptive forest management strategies cannot be satisfactorily explained by pursuit of exclusively economic objectives and rational choice. The study examines the influence of preference for different forestry objectives, personal experience with extreme events, trust in climate science, gender, age, social capital, education and dependency on income from forestry activities and other cognitive and emotional factors on how forestry stakeholders perceive of climate change risks, the efficacy of adaptive measures and their own ability to adapt forestry to climate change. Findings are based on a survey study comprising responses from approximately 6000 forestry owners and 1000 forestry advisors. Conclusions are derived from a multiple regression analysis and a social network analysis.

C-27 Sustainable management of spruce dominated ecosystems in response to climate change

Organizers: Phil Comeau (University of Alberta, Canada), Bill Mason (Forest Research, UK), Ulf Johannson & Bjorn Hanell (Swedish University of Agricultural Sciences)

Long-term volume increment, ingrowth and changes in the stand structure in partially harvested uneven-aged Norway spruce stands in Northern Sweden. Ahlström, M., Mörling, T., Valinger, E., Lundqvist, L. (*Swedish University of Agricultural Sciences, Sweden; martin.a.ahlstrom@slu.se; tommy.morling@slu.se; erik.valinger@slu.se; lars.lundqvist@slu.se*).

In Scandinavia there has been an increasing interest in uneven-aged forest management of Norway spruce stands as an alternative to the dominating even-aged management practice. The purpose of the present study was to determine the effect of partial harvest on the diameter distribution and the influence of standing volume on volume increment and ingrowth. We therefore reconstructed stand development based on stand inventory data and growth increment measurements from increment cores in seven uneven-aged boreal Norway spruce stands 15–56 years after partial harvests. Stand development from harvest to inventory, was reconstructed in 5-year periods. All stands showed a decreasing diameter distribution at the time of the inventory, and six of the stands had a similar diameter distribution at the time of harvest. Periodical volume increment increased with increasing standing volume in four of the stands. Mean volume increment was 2.38 to 3.86 m^3/ha /yr. Mean ingrowth of Norway spruce, past 5 cm DBH varied from 6.3 to 22.5 stems/ha/yr. No significant correlation between standing volume and ingrowth were found. Diameter distribution was stable following partial harvest, and both volume increment and ingrowth were sufficient for harvest intensity of 50% and harvest cycle of about 25 years.

Geographic patterns of genetic variation in white spruce (Picea glauca): developing breeding and deployment strategies under climate change. Gray, L., Hamann, A., Liepe, K. (*University of Alberta, Canada; lkgray@ualberta.ca; andreas.hamann@ualberta.ca; liepe@ualberta.ca*), Aitken, S., Smets, P. (*University of British Columbia, Canada; Sally.Aitken@ubc.ca; pia.smets@ubc.ca*).

Commercial forestry programs commonly use locally collected seed for reforestation under the assumption that tree populations are optimally adapted to the local environment. This assumption, however, is no longer valid given the warming trends and changes in precipitation patterns observed over the last 25 years in western North America. Here, we synthesize heterogeneous growth data from field trials (height, diameter, and survival at ages ranging from 4 to 35 years), representing over 600 genotypes tested in 40 progeny or provenance trials, as well as data for adaptive traits (spring and fall phenology, frost hardiness) scored in multiple growth chamber experiments. We use a multivariate regression tree approach to construct genetic norms of reactions and bioclimate envelope modeling to determine the most suitable deployment areas of natural seed collections and improved planting stock from breeding programs under observed climate trends (1970s to 2000s) and multi-model projections for the 2020s, 2050s, and 2080s.

Environmental control of growth variation in Norway spruce in Finland. Mäkinen, H., Nöjd, P., Jyske, T., Mielikäinen, K., Kalliokoski, T. (*Finnish Forest Research Institute, Finland; harri.makinen@metla.fi; pekka.nojd@metla.fi; tuula.jyske@metla.fi; kari.mielikainen@metla.fi; tuomo.kalliokoski@metla.fi*), Repo, T., Lumme, I.

Under anticipated climate change, Norway spruce growth is predicted to increase in the Nordic countries. However, spruce may become increasingly vulnerable to drought, soil frost and mild winter temperatures. The presentation summarizes the case studies we have carried out during the past 15 years. (1) The results illustrate that radial growth annually varies up to 20–30%, July temperature being the most important triggering factor. (2) Artificial extreme drought during consecutive growing seasons reduced height and radial increment, but did not result in major changes in wood properties. (3) Deep soil frost and its delayed thawing may slightly affect the timing and duration of the cambial activity. (4) Optimal nutrition resulted in the formation of ~50% more tracheids. The increased growth was mainly a result of higher tracheid formation rate during the latter half of the growing season. (5) No differences between the Central European and Finnish provenances were found in the timing of tracheid formation period. We conclude that the onset and rate of tracheid formation during summer is primarily controlled by photoperiod, temperature, and availability of water and nutrients. Moreover, the growth and annual cycle of Norway spruce are able to adapt to considerable changes in environmental conditions.

Use of continuous cover forestry enhances delivery of ecosystem services and adaptation to climate change in sitka spruce planted forests. Mason, B. (*Forest Research, United Kingdom; bill.mason@forestry.gsi.gov.uk*).

Sitka spruce (*Picea sitchensis*) is the major species in the forests of the British Isles covering over one million hectares, especially in Ireland and Scotland. First introduced in 1852 and only widely planted since 1920, this species has usually been grown in single species even-aged stands managed on short rotations using a patch clearfelling silvicultural system. Over the last two decades, this prevailing silvicultural paradigm has been criticized for negative impacts upon the provision of cultural and regulating ecosystem services. These criticisms have led to greater interest in Continuous Cover Forestry (CCF), an alternative silvicultural approach which seeks to develop irregular stand structures composed of a number of species. This paper summarizes results from several long-term trials and other experimental studies in the British Isles that demonstrate how to implement silvicultural regimes that foster irregular stand structures in planted forests of Sitka spruce. These results also show that such structures can provide improved aesthetic and biodiversity values compared to the traditional patch clearfelling regime. Recent studies also indicate that developing CCF structures in Sitka spruce forests can offer greater resilience to wind damage and other hazards, and hence are better adapted to withstand the impacts of projected climate change.

Mitigation of drought by thinning: short-term and long-term effects on growth and physiological performance of Norway spruce (Picea abies). Sohn, J. (*Univeristy of Freiburg, Germany; jsohn81@googlemail.com*), Gebhardt, T., Ammer, C. (*University of Göttingen & Technical University of Munich, Germany; Timo.Gebhardt@forst.uni-goettingen.de; Christian.Ammer@forst.uni-goettingen.de*), Bauhus, J. (*University of Freiburg, Germany; juergen.bauhus@waldbau.uni-freiburg.de*), Häberle, K., Matyssek, R., Grams, T. (*Technical University of Munich, Germany; haeberle@wzw.tum.de*); *matyssek@wzw.tum.de; grams@tum.de*).

We hypothesize that reductions in stand density through thinning improve the recovery of radial stem growth in Norway spruce trees (*Picea abies*) from severe drought. However, thinning may not lead to higher relative radial growth during drought. Annual stem growth and stable carbon and oxygen isotopes in early- and latewood were assessed in trees from heavily thinned (HT), moderately thinned (MT) and un-thinned control stands at two sites in southern Germany. Physiological performance of trees as inferred from stable isotope analysis was used to interpret annual stem growth in response to the drought events in 1976 and 2003. Only in recently thinned stands, trees maintained growth probably through higher soil water availability during the

drought year when compared to controls. In contrast, thinning improved the growth recovery in the years following the drought irrespective of the time span between thinning and drought. We conclude that thinning improves drought response in the short and long term and should be considered as an effective management strategy to increase drought tolerance of Norway spruce stands.

Ecophysiological aspects of growing Douglas fir in central Europe. Urban, J., Martinik, A., Kantor, P., Cermak, J. (*Mendel University in Brno, Czech Republic; Josef.urban@email.cz; martinik@mendelu.cz; kantor@mendelu.cz; cermak@mendelu.cz*).

The most common commercial tree species in the forests of central Europe is Norway spruce. However, climate change posts a threat to the stability of Norway spruce based forests. Therefore, apart from introducing more broadleaves, foresters look for the possible replacement among coniferous trees. We hope for high productivity while keeping or increasing ecological stability of single species as well as mixed forest stands. Douglas fir may be an option. First stands of Douglas fir in central Europe were planted in the middle of 19th century on various environmental conditions. We chose two mixed stands of Douglas fir and Norway spruce on climatically similar sites but with contrasting soil nutrient availability. Allometrical and stem increment analysis revealed comparable growth rate and nutrient allocation patterns of both species on nutrient rich sites while much better growth and significant difference in allometry was found for Douglas fir in nutrient poor site. Transpiration of Douglas fir was higher than in Norway spruce upon unlimited soil water availability. But whenever soil water potential dropped under about –2 bars, Douglas fir reduced water consumption to the level of Norway spruce. To sum up, Douglas fir grows better than Norway spruce, especially on nutrient poor sites and does not threaten other tree species in the drought periods.

C-28 Tropical forest wetlands, climate, and land-use change: Adaptation and mitigation opportunities

Organizers: Richard Birdsey, Randall Kolka (U.S. Forest Service), Daniel Murdiyarso (CIFOR, Indonesia) & Boone Kauffman (Oregon State University, USA)

Simulating the impacts of climate change and land conversion on the carbon balance of tropical peatlands in Indonesia. Frolking, S. (*University of New Hampshire, USA; steve.frolking@unh.edu*), Kurnianto, S. (*Center for International Forestry Research (CIFOR), Indonesia; s.kurnianto@cgiar.org*), Warren, M. (*U.S. Forest Service, USA; mwwarren@fs.fed.us*), Murdiyarso, D. (*Center for International Forestry Research, Indonesia; d.murdiyarso@cgiar.org*).

Using a new, simple model of long-term tropical peatland carbon balance, HPMTrop, we assess the 21st century carbon balance of representative peatlands in Indonesia under multiple climate and land use scenarios, including several global climate model (GCM) results for multiple IPCC AR5 RCP (climate change) scenarios coupled with alternative land-use change scenarios such as persistent pristine peat swamp forest; permanent conversion to oil palm plantation, short-rotation forest pulp plantation, or smallholder farm; and conversion followed by restoration (e.g., re-flooded only, re-flooded with rapid reforestation, and re-flooded with slow reforestation). Model outputs include net C balance per unit area per year. Initial simulations have long-term carbon accumulation rates for inland (older) and coastal (younger) peatlands of 0.26 and 0.63 Mg C/ha/yr, resulting in contemporary peat stocks of ~3 000 Mg C/ha. Simulated carbon loss for the coastal scenario caused by forest conversion to oil palm plantation with periodic burning was 1 500 Mg C/ha over 100 years, equivalent to ~3 000 years of accumulation. The study will provide a model-based assessment of the impacts of land-use management decisions on peatland carbon storage under alternative climate and land-use change scenarios.

Land-use change threats and knowledge of climate affecting variables in tropical peat swamp forests: A comparison between Indonesia and Peru. Hergoualc'h, K. (*Center For International Forestry Research, Indonesia; k.hergoualch@cgiar.org*), Gutierrez-Velez, V. (*Columbia University, USA; vhg2103@columbia.edu*), Menton, M. (*Global Canopy Programme, United Kingdom; mcsmenton@gmail.com*), Pinedo-Vasquez, M., Verchot, L. (*Center For International Forestry Research, Indonesia; m.pinedo-vasquez@cgiar.org; l.verchot@cgiar.org*).

Tropical peat swamp forests (PSF) store large amounts of carbon (C) due to low oxygen pressure in waterlogged peat. PSF degradation and conversion can severely affect C stocks and emissions of greenhouse gases (GHG) and contribute greatly to climate change. In the Tropics, Indonesia and Peru are two of the main countries where peatlands are found. In Indonesia the majority of PSF are lowland, ombrotrophic systems overlying deep (depth >3 m) peat deposits. Peatlands in Peru are found at both low and high altitudes, can be ombrotrophic or minerotrophic and support the growth of different vegetation types. In Indonesia, PSF have been under intense pressure during the past two decades, and extreme wildfires have contributed substantially to GHG emissions. The major threat on Peruvian PSF is the overharvesting of the palm *Mauritia flexuosa* which dominates lowland PSF. Quantitative estimates of C stocks and atmospheric impacts of LUC are limited but existent in Indonesia whereas little is known about the peatlands of Peru. Degradation in Peru leads to a significant shift in vegetation characteristics whereas for degradation in Indonesian PSF there is no corollary change in the species composition. Exploratory remote sensing analyses show promise for mapping peatland degradation in Peru.

Carbon stocks and dynamics in the high altitude mountain peatlands of South America. Hribljan, J., Chimner, R. (*Michigan Technological University, USA; jahriblj@mtu.edu; rchimner@mtu.edu*), Suárez, E. (*University of San Francisco Quito, Ecuador; esuarez@usfq.edu.ec*), Lilleskov, E. (*U.S. Forest Service, USA; elilleskov@fs.fed.us*).

Carbon (C) storage and current C flux rates remains poorly understood for tropical wetlands. Our goal is to integrate ecosystem C stock and flux data to gain a better understanding of the C balance in tropical mountain peatland ecosystems of South America, determine potential impacts of climate change, and inform more effective ecosystem management. Our methods include coring and ^{14}C dating, analyzing substrate and pore water chemistry, and measuring carbon dioxide (CO_2) and methane (CH_4) fluxes throughout the tropical Andes. These systems were found to contain peat bodies over 6 m in depth. Most mountain peatlands sampled were small; however, peatlands were found to be very numerous, and given their depth likely represent a substantial regional C sink. Peat accumulation rates are among the fastest reported for mountain ecosystems. These data provide key

insights into the controls on South American mountain peatland C dynamics, and inform effective management of these sensitive ecosystems.

The global significance and future of tropical forested wetlands. Kauffman, B. (Oregon State University*, USA; Boone.Kauffman@oregonstate.edu*), Murdiyarso, D., Hergoualc'h, K. (*Center for International Forestry Research, Indonesia; d.murdiyarso@cgiar.org; k.hergoualch@cgiar.org*), Adame, F. (*Griffith University, Australia; f.adame@griffith.edu.au*), Bhomia, R. (*Center for International Forestry Research, USA; r.bhomia@cgiar.org*), Budi Arifanti, V., Basuki, I., Novita, N., Kurnianto, S, Warren, M., Verchot, L.

Tropical forested wetlands, especially mangroves and freshwater peat swamp forests, provide a multitude of ecosystem services including functioning as significant global carbon sinks. The unique environments at land-water interfaces creates conditions of high productivity and carbon storage in organic soils. Ecosystem carbon stocks frequently exceed 1 000 Mg/ha in mangroves and 2 000 Mg/ha in peat swamp forests. Despite recognition of their values, high rates of loss of tropical forested wetlands are occurring due to land conversions such as oil palm, agriculture, or aquaculture development. Greenhouse gas emissions from the conversion of tropical forested wetlands are dramatically higher even than that of tropical forests on mineral soils because of the emissions arising from the oxidation of the large soil carbon pools. Because of the multitude of ecosystem services and their exceptionally high carbon stocks and large emissions from conversion, tropical wetlands are excellent candidates for inclusion in climate change mitigation strategies. Climate change threats to tropical forested wetlands include shifts in temperature, precipitation patterns as well as sea level rise, ocean acidification, and changes in river hydrology. Effective adaptation, as well as mitigation strategies that conserve or restore these valuable ecosystems is warranted.

Approaches to regional and continental estimates of carbon stocks and fluxes in tropical wetland forests and mountain peatlands. Lilleskov, E. (*U.S. Forest Service Northern Research Station, USA; elilleskov@fs.fed.us*), Chimner, R., Hribljan, J. (*Michigan Technological University, USA; rchimner@mtu.edu; jahriblj@mtu.edu*), Birdsey, R. (*U.S. Forest Service, USA; rbirdsey@fs.fed.us*).

Estimation of wetland carbon stocks and fluxes is critical to our ability to understand their climate interactions, rates of loss due to land use change, and other critical functions. In the Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) we are working on multiple continents to contribute to global estimates of wetland carbon stocks and fluxes. Robust estimates require combinations of field sampling, remote sensing, and scaling of fluxes to regional and continental scales. Stocks estimation presently depends on combinations of intensive and extensive field sampling, sometimes combined with LiDAR, to determine forest stocks, peat depth, and peat carbon content. Sampling should be stratified over wetland types and land uses of interest and based on the most statistically robust approach given logistical constraints. Flux estimates for carbon (CO_2 and CH_4) can be accomplished using a combination of approaches such as ground-based chamber methods and eddy flux towers. Each of these provides varying levels of spatial resolution and inherent biases. Remote sensing approaches include analysis of multispectral and side aperture radar (SAR) imagery. These are subject to error, e.g., in assignment to correct land cover categories. Scaling requires appropriate modeling approaches to convert in situ estimates to regional or continental scales.

Sediment and C accumulation rates in mangrove forests. MacKenzie, R., Foulk, P. (*U.S. Forest Service, USA; rmackenzie@fs.fed.us; foulkpb@gmail.com*), Klump, J., Weckerly, K. (*University of Wisconsin at Milwaukee, USA; vklump@uwm.edu; weckerly@uwm.edu*), Purbopuspito, J., Murdiyarso, D. (*Center for International Forestry Research, Indonesia; j.purbopuspito@cgiar.org; d.murdiyarso@cgiar.org*).

Belowground carbon (C) pools in mangrove forests are an important component of global carbon pools, storing 3–5 times more C than any other tropical forested ecosystem. High rates of tree growth coupled with low-oxygenated, water-logged soils result in massive and long term stores of C. Deposition of C-rich, exogenously produced sediments can also contribute to these stores. While mangrove C pools have become high priorities in climate change adaptation and mitigation strategies in developing nations, it remains unclear how rates of carbon accumulation can vary across mangroves as well as how land-use and land cover-change can influences those rates. This is not only important for adaptation and mitigation, but is a critical ecological function that is needed to maintain the forest floor height relative to increased rates of sea level rise. Using naturally occurring 210Pb radionuclide tracers, we determined sediment and C accumulation rates from several mangroves in Vietnam and the Republic of Palau. We will present this data as well as discuss potential factors influencing these processes. Understanding how sediment and C accumulation rates differ across mangroves will help identify mangrove forests more resilient to impacts of climate change and that should be prioritized for conservation and/or restoration actions.

A preliminary account of carbon stocks in mangrove ecosystems in the Mekong deltas. Nam, V. (*Nong Lam University, Viet Nam; drvnnam@gmail.com*), Purbopuspito, J., Sasmito, S. (*Center for International Forestry Research, Indonesia; j.purbopuspito@cgiar.org; s.sasmito@cgiar.org*), MacKenzie, R. (*U.S. Forest Service, USA; rmackenzie@fs.fed.us*), Murdiyarso, D. (*Center for International Forestry Research, Indonesia; d.murdiyarso@cgiar.org*).

Being in the lowest part of the Mekong River Basin Vietnam's extensive sedimentation occurs in the Mekong deltas and estuaries. One of the observable changes in the landscape is the development of mangroves species and accumulation of belowground carbon. Our preliminary measurements in Can Gio and Ca Mau districts show that the 35 year-old planted mangroves in Can Gio sites which are riverine have more tree and higher basal area compared with Ca Mau sites which are estuarine natural formation. The mean carbon stocks aboveground and belowground in Can Gio of 135 ± 52 Mg C/ha and 826 ± 245 Mg C/ha, respectively, are also higher than Ca Mau of 119 ± 44 Mg C/ha and 761 ± 190 Mg C/ha respectively. Although more samples are needed to confirm the fact that small trees in the estuaries are effective to trap sediment than large trees in the riverine.

Carbon Stocks in Mangroves within the Zambezi Delta, Mozambique. Trettin, C., Stringer, C. (*U.S. Forest Service, USA; ctrettin@fs.fed.us; christinaestringer@fs.fed.us*), Macomo, C. (*Universidade Eduardo Mondlane, Mozambique; celiamacamo@yahoo.com)*, Nicolau, D. (*World Wildlife Fund, Mozambique; dnicolau@wwf.org.mz*), Tang, W. (*Univiversity North Carolina – Charlotte, USA; wenwutang@uncc.edu*), Bandeira, S., Fatoyinbo, T.

Our objective was to estimate the carbon pools within the mangrove forest on the Zambezi River Delta. Canopy height data from NASA's space shuttle LiDAR measurements were used to stratify the mangrove area among five canopy height classes. A spatial decision support system was used to implement a stratified random sampling design to measure the aboveground and belowground carbon pools and soils that included operational constraints. Preliminary analysis showed that the average diameter of the stands ranged from 8 to 28 cm and the basal area ranged from 7 300 to 32 100 cm^2, with large differences in species composition among plots within the canopy height classes. Based in the 2012 samples, soil bulk density averaged approximately 0.7 to 0.8 g/cm^3 throughout the 200 cm sample depth without significant variation between plots. Initial measurements of carbon concentration data suggest relatively low levels (1.06–2.39%), however, analyses of the 2013 data will change the estimate. The vegetation biomass data combined with the soil data will be used to estimate carbon pools within each of the sampling strata and for the entire delta. Findings from this work will be used to establish baseline carbon levels for the Zambezi that could be used for REDD+.

Ecosystem carbon storage of Indonesia's peat swamp forests. Warren, M. (*U.S. Forest Service, USA; mwwarren.usfs@gmail.com*), Kauffman, B. (Oregon State University, *USA; Boone.Kauffman@oregonstate.edu*), Murdiyarso, D., Kurnianto, S. (*Center for International Forestry Research, Indonesia; d.murdiyarso@cgiar.org; s.kurnianto@cgiar.org*).

Indonesia's peat swamp forests have accumulated and stored organic matter for millennia, forming globally significant carbon reservoirs. Degradation and conversion of peatlands are Indonesia's largest source of greenhouse gas emissions, highlighting the climate mitigation potential of improved peatland management and the role of peatlands in incentive strategies such as Reducing Emissions from Deforestation and Forest Degradation (REDD+). Yet, there are significant uncertainties concerning the patterns of aboveground and belowground carbon storage in peatlands at local to national scales. Here we examine ecosystem carbon storage of Indonesian peat swamp forests based on surveys of 1ha stands throughout Sumatra, Indonesian Borneo, and Papua. Ecosystem carbon storage, including living biomass and soil organic carbon pools, ranged from 1 730 to 8 188 Mg C/ha, largely determined by peat thickness. These estimates are approximately 4–19 times higher than IPCC default values for tropical forest ecosystems (respectively), and organic peat layers accounted for approximately 87–98% of the ecosystem total. Carbon stored in the upper one meter of peat averaged 649.3 ± 100.9 MgC/ha, which exceeds default values for mature tropical rainforest on mineral soils. These results illustrate the immense capacity of tropical peatlands to store carbon and the high carbon value of relatively shallow peatlands.

C-29 Desertification, land degradation and drought

Organizer: Hoduck Kang (Dongguk University, Republic of Korea)

Assessment of current status of forest management on degradation in Myanmar with emphasis on social aspect to local people. Khaine, I. (*Ministry of Environmental Conservation and Forestry, Myanmar (Burma); inkyinkhainefd@gmail.com*), Woo, S. (*University of Seoul, Republic of Korea; wsy@uos.ac.kr*).

In Myanmar, rural livelihood development and their participation are essential for combating forest degradation because about two thirds of the population essentially rely on the wealth of forests for their livelihoods and cultural survival. This study aimed to investigate the socio-economic status of forest dependent community by comparing two rehabilitation techniques and environmental awareness of rural people. Questionnaire surveys by face to face interviews were carried out. The respondents were stratified as poor, medium, and better off, and the sample shape was defined as a triangle. The results showed that rehabilitation by means of remnant forest conservation gave much more tangible and intangible benefits than plantations although the greater income was given in the initial year of plantation establishment due to taung-ya system. Rural people used fuelwood the most, followed by the bamboo shoot. Poverty was strongly correlated with forest dependency since the poor households depended on the forests more than the better off. The educational level and livestock possessed had negative relationships to forest dependency, and the environmental awareness of the rural people was poor during that time. This study points out implementing rehabilitations and rural livelihood development in harmony is important for combating degradation.

Rehabilitation of degraded agroecosystem services through forestry in irrigated croplands of Central Asia. Khamzina, A., Djanibekov, U., Dubovyk, O. (*University of Bonn, Germany; asia.khamzina@uni-bonn.de; utkur@uni-bonn.de; desiderare@yandex.ru*).

Cropland degradation due to salinity jeopardizes agroecosystem services in irrigated drylands, threatening the economic development. This study in the lower Amudarya River Basin, Central Asia assessed the option of converting degraded landscape segments to tree plantations of salt-tolerant species. We examined provisioning services, impact on the agroecosystem carbon stock, and monetary value of these services. Depending on the species, 64–70 t C/ha was sequestered in woody biomass over 7 years. The increase in soil organic carbon ranged between 7–12 t/ha, peaking with N_2-fixing tree species. The net present value of afforestation ranged between 720–5 800 USD/ha due to production of nontimber products (including carbon) and exceeded profits from annual cropping on marginal lands. Due to the reliance on groundwater, afforestation would increase the irrigation water availability at the farm scale. This would enhance the cultivation of water demanding commercial crops on the productive farmland and consequently increase whole-farm income. The viability of afforestation option was further confirmed by the above-average suitability of degraded irrigated cropland for forestry, as assessed via GIS-based multi-criteria decision-making approach that considered biophysical landscape constraints under irrigated agricultural setting. The combined findings facilitate formulation of relevant policies to introduce forestry among farm activities for the landscape rehabilitation.

Estimation and mapping of desertification using Landsat imagery and correlation of some variables on a regional scale. Lamchin, M., Lee, W.-K. (*Korea University, Republic of Korea; naska_l@yahoo.com; leewk@korea.ac.kr*).

Desertification is a serious threat to the environment and social economy, and there is a pressing need to develop a reasonable and reproducible method to assess it at different scales. In this study, the Hugnu-Khaan protected area in Mongolia was selected as the research region and a quantitative method for desertification assessment was developed by using Landsat TM/ETM+ data

on a regional scale. In this method, NDVI, GSI (topsoil grain size index) and land surface albedo were selected as assessment indicators of desertification to represent land surface conditions from vegetation, landscape pattern, and micrometeorology. Based on considering the effects of vegetation type and time of images acquired on assessment indictors, assessing rule sets were built and a decision tree approach was used to assess desertification of Hugnu-Khaan protected area. In this study, to identify the degradation of land that can be a proxy of desertification, three variables, such as NDVI, Albedo, and GSI were examined. First, study area was classified by the level of desertification, and then the relation between level of desertification and the three variables was tested.

LiDAR-derived structural diversity indices as ecological indicators for managing semi-arid ecosystems at risk of desertification. Listopad, C., Batista, M., Silva, A., Branquinho, C. (*University of Lisbon, Portugal; cdlistopad@fc.ul.pt; mkobatista@fc.ul.pt; aprsilva@fc.ul.pt; cmbranquinho@fc.ul.pt*).

Climate change and increasing socio-economic pressure is placing many ecosystems of high ecological and economic value at risk. This is particularly urgent in semi-arid and arid ecosystems, such as the montado, shaped by centuries of human presence. Understanding how land management strategies impact the composition, structure, and ecological health is crucial in face of climate change and in face of the risks of desertification. We propose applying a LiDAR-derived structural diversity index (LHDI) as a surrogate of ecosystem health. This objective, quantifiable index, first developed for the highly dynamic pine-grassland woodland pine systems, can be rapidly obtained with reduced field effort and cost using a portable LiDAR system. This study validates the use of the LHDI in a cork-oak woodland site located within a long-term desertification study area, 25 km north of Lisbon, Portugal. We evaluate succession on structural and compositional diversity after grazing pressure was removed from the landscape at 15, 10, and 5 years post-cattle exclusion and contrast it with current moderate and heavily grazed plots. The 3-dimensional spatial arrangement of structural elements was used to assess changes in structural complexity, relating these to biodiversity, ecosystem resilience and cork oak health targets.

Growth performance of several woody species in afforestation site in dry steppe of Mongolia under different watering and fertilizer treatments. Nyam-Osor, B. (*National University of Mongolia, Mongolia; bnyamosor@yahoo.com*), Akhmadi, K. (*Institute of Geoecology, Mongolia; khaulenbek@yahoo.com*), Ochirbat, B. (*Institute of Geography, Mongolia; batkhishig@gmail.com*), Lunten, J. (*Institute of Geoecology, Mongolia; janchivdorj_mn@yahoo.com*), Byambadorj, S. (*National University of Mongolia, Mongolia; serko_2008b@yahoo.com*).

Mongolia is one of the countries which has a serious problem with deforestation and land degradation. Thus, numerous activities for rehabilitation had been conducted, but most of them showed poor results due to harsh climate and lack of understanding of the ecological characteristics. The objectives of this research were (1) to determine appropriate watering regime, (2) to determine effects of fertilizer on growth trees, and (3) to select suitable tree species for reforestation of dry regions. Seedlings (*Ulmus pumila* L; *Populus sibirica* L; *Caragana arborescens* Lam, *Caragana microphylla* Lam, *Hippophae rhamnoides* L, *Armeniaca sibirica* L, *Tamarix glasera* Ldb, *Elaeagnus moorcroftii* Wall.ex Schlecht) were transplanted at the research site of Korea-Mongolia Joint Green belt project located in the dry steppe zone of Mongolia. Seedlings were grown under different watering (control, 2 l/h, 4 l/h, 8 l/h) and fertilizing regimes (control, NPK, COMP-sheep dung), their growth performances were monitored for three growing seasons. All measured variables (root collar diameter, shoot height, leaf parameters, survival rate) significantly differed among treatments and species level. Monitoring results suggested that watering with 4 l/h and fertilized with COMP accelerated seedling growth compared with other treatments. Meanwhile height, diameter growth, and survival rate were higher in *P. sibirica* than the other species.

Effect of land use gradient on Sudanian woody vegetation layers in West Africa. Ouedraogo, O., Loyapin, B., Boussim, I. (*University of Ouagadougou, Burkina Faso; ouedraogooumar@yahoo.fr; loyapinbonde@yahoo.fr; ijboussim@gmail.com*).

In the Sudanian zones of West Africa, increasing climatic aridity and human land use pressure have provoked a considerable decline of woody vegetation cover. Many trees and shrubs are lost in the course of vegetation clearing. To understand the impact of land use on the dynamics and resilience of woody vegetation, different layers need to be considered. This study aims to determine the vegetation layer which is more negatively affected and highly vulnerable to land use. Dendrometrical data were collected along an anthropogenic gradient from near-natural vegetation to cultivated lands. Results indicated the sapling layer was more diversified than that of trees, regardless of land use type. In the both layers, plant populations were significantly denser in classified forest in comparison to fallows and cultivated lands. The anthropogenic gradient has a great impact on the diversity, density, and the population structure of the tree layer compared to the sapling one. In addition, the comparison of the IVI of species indicates in one side that the number of dominant species in the tree layer decreases with the increasing of environmental pressure while in the sapling layer; the pressure seems to favor the dominance of several species. Therefore, the tree layer of the Sudanian vegetation is more vulnerable to the land use patterns than sapling vegetation.

Strategies to improve Degraded Arid Rangelands in Rajasthan, India. Tewari, V., Arya, R. (*Arid Forest Research Institute, India; vptewari@yahoo.com; dr_ranjana@yahoo.com*).

Land degradation has recently been exacerbated in rangelands of arid Rajasthan in India by heavy grazing pressures. Local grazing pressures are surpassing the recommended stocking rates of the rangelands at an enormous pace. The carrying capacities of the rangelands were estimated several decades ago, however, qualitative evidence is available regarding changes in soil and vegetation patterns. There is need to evolve practices for improving the long-term productivity and sustainability of rangeland ecosystems adopting various options such as moisture conservation techniques, pre-monsoon sowing of grass seeds, and application of fertilizers. Mechanisms must be developed to fully involve range users (herders) in all aspects of project planning and implementation if sustainable productivity increases are to be achieved. It is suggested that a flexible stocking rate, dependent on seasonal and annual variation in feed availability must be a key element in any improved range and livestock management strategy. Various relevant issues like increasing livestock population, consequences of overgrazing, carrying capacity of pasturelands along with means for enhancing range productivity, measures for range improvement, and strategies for rangeland management are discussed and presented in this paper.

Causal effects of shelter forests and water factors on desertification processes during 2000–2010 in the Horqin Sandy Land region, China. Yan, Q., Zhu, J., Zheng, X. (*Chinese Academy of Sciences, China; qlyan@iae.ac.cn; jiaojunzhu@iae.ac.cn; zhengxiao303@163.com).*

There is little evidence to support the direct causal effects of driving factors on the desertification processes, since desertification is a complicated process affected by both vegetation factors (including vegetation cover and amount of shelter forests) and water factors such as precipitation and evapotranspiration. The objective of this study was to identify how each possible influencing factor, especially the establishment of shelter forests, affects desertification in Horqin Sandy Land (HSL). We found that the desertification was controlled. The total vegetation cover in HSL had both the most direct and indirect effects on desertification processes. The amount of shelter forests increased sharply, but only the shrub forests had the significant direct effect on the desertification processes. Due to the fact that the arbor species selection in the afforestation did not comply with water conditions, there was no close direct effect of the sharp increase of arbor forests on desertification control. The results indicate that the afforestation plays a role in the control of desertification for HSL, but the effect is far less than expected. Aiming to effectively control desertification in HSL, improving vegetation cover, and in particular selecting suitable arbor species in accordance with water conditions may be more important in the future.

C-30 Novel Ecosystems and intervention: Adaptation to climate change

Organizers: John Stanturf (U.S. Forest Service) & Palle Madsen (University of Copenhagen, Denmark)

Novel ecosystems resulting from altered fire regimes. Bradshaw, R. (*University of Liverpool, United Kingdom; Richard.Bradshaw@liv.ac.uk*).

Fire is an important driver of vegetation dynamics in several forest types but has varied in frequency and intensity in the past and will do so in the future. Fire can be influenced by appropriate management intervention to mitigate the impacts of climate change. Retrospective studies of fire using the palaeoecological record show significant variation in fire frequency and associated changes in European forest vegetation during recent millennia linked to both climatic change and human impact. Comparing past records with output from a dynamic vegetation model driven by climate and fire frequency provides mechanistic insight into the role of fire. Both model and data suggest that fire frequency alone can control community scale variability in Fennoscandia, with fire frequency thresholds able to explain the dominant vegetation types observed both now and in the past. Deciduous tree distribution has been primarily controlled by climate in the past, but under a warmer climate scenario the prevailing fire frequency is forecast to exert the dominant control. Modelling future climate scenarios combined with likely land-use change indicate substantial alteration in fire risk and fire season in the boreal zone with the consequent development of novel forest ecosystems.

Pushing the envelope: forest management strategies for adapting to a changing climate in Canada. Burton, P. (*University of Northern British Columbia, Canada; phil.burton@unbc.ca*).

Many land management approaches are founded on assumptions of statis and equilibrium with the abiotic environment. It is now clear that climate change is happening and that many species and ecosystems will not be able to persist in their current locations. We know that species assemblages have come and gone in the past and that many species today do not occupy the full range of locations to which they are suited. Some existing populations will experience greater stress, while the success of others will improve, so novel and transient ecosystems will become more apparent in the coming decades. Forests will persist, but their changes will challenge our ability to understand, interpret, and manage them sustainably. Canadian researchers and managers are exploring the implications of a changing climate on ecosystem classification systems, on silivicultural guidelines, on tree seed transfer rules, and on the risk of disturbance from insect outbreaks, forest fires and landslides. Such impacts cannot be negated, but are being accommodated through measures such as assisted migration, multi-species stand management, identifying climatic refugia, maintaining landscape connectivity, and reducing forest fuels. These actions represent a paradigm shift from efforts to optimize productivity to those which reduce risk of loss.

Role of assisted migration in forest ecosystems on the cusp of change. Dumroese, K. (*U.S. Forest Service, USA; kdumroese@fs.fed.us*), Williams, M. (*Michigan Technological University, USA; miwillia@mtu.edu*).

With respect to climate change, an overwhelming task in forestry is to develop an adaptive program that not only conserves the evolutionary potential of a species but also anticipates novel ecosystems (i.e., ecosystem assemblages not formerly known). Plant migration, movement to stay in sync with optimal climatic conditions for growth and adaptation to novel conditions through evolutionary processes occur simultaneously, however, the rate of contemporary climate change is predicted to far exceed both processes, thus having serious impacts on forest restoration. Plant species and populations at the edge of their distributions may be especially vulnerable to novel conditions. Assisted migration, the movement of species and/or populations in direct management response to climate change, is a novel approach to address forest ecosystems along the leading and trailing edges of their distribution. For example, modification of seed transfer zones to allow transfer of suitable genotypes to leading edges, planting species anticipated to migrate into trailing edges, and the broadening of seed collection guidelines to capture a diversity of genotypes from various environments within the population are options to increase a population's chance for survival, adaptation, and migration.

Can we predict the ecological implications for restoration of an extirpated forest tree species under global change? Jacobs, D. (*Purdue University, USA; djacobs@purdue.edu*), Gustafson, E., Sturtevant, B. (*U.S. Forest Service, USA; egustafson@fs.fed.us; bsturtevant@fs.fed.us*), de Bruijn, A. (*Purdue University, USA; adebruij@purdue.edu*), Dalgleish, H. (*College of William and Mary, USA; hjdalgleish@wm.edu*), Lichti, N. (*Purdue University, USA; nlichti@purdue.edu*).

Imminent, largely anthropogenic changes present unique challenges and opportunities for future forests. A legacy of direct and indirect human impacts have altered tree species composition in many regions, and this trend is likely to continue as new exotic

pests and pathogens spread throughout the world. Such changes may alter carbon storage capacity and the resilience of forests to new introductions and climate change. In the eastern U.S., the imminent reintroduction of the formerly dominant American chestnut (*Castanea dentata*) using blight-resistant germplasm represents a unique case scenario that may help to inform ecological implications of wide-scale restoration efforts. This species has potential to increase C storage and ameliorate declines in other tree genera because of its relative shade tolerance, rapid growth rate, large size, longevity, and decay resistance. We have forecast landscape scale ecological changes in eastern U.S. forests under a set of plausible alternative futures that include varying management scenarios, direct and indirect effects of climate change, existing and potential insect pests, and American chestnut restoration. Reintroduction of this extirpated keystone forest tree species presents promising ecological implications for future forests, yet this unprecedented effort is challenged in practice by the logistics of setting realistic restoration goals.

Paleoclimatic shifts and novel ecosystems. Millar, C. (*U.S. Forest Service, USA; cmillar@fs.fed.us*).

The concept of novel ecosystems can be investigated from the perspective of history. In paleoecology, non-analog ecosystems are recognized retrospectively as past assemblages comprising species not known to co-occur at present. Prospective changes can also be analyzed, where a point in history is assessed relative to changes that ensued subsequently. From both contexts I explore implications for species involved. When did novelty emerge (what environmental, climatic, and antecedent conditions)? Where were such conditions and situations likely to occur (geographic contexts)? What were the outcomes for species involved (adaptive evolution, range shifts, increased productivity vs. extirpation or extinction) and for the communities which they formed? Historic ecosystems reveal diverse conditions that comprise structural novelty, including changes in species diversity, species abundance, population demography, and community diversity. Non-analog changes in ecosystem process are also apparent, including novel disturbance regimes and response to invasion by non-native species. Historic analogs to fragmentation (opening and closing of geographic corridors) and to severe environmental reassembly of the land (volcanism, outburst floods) and air (rapid climatic shifts and changes in CO_2) also provide context for investigating when and where novelty might emerge, and what might be potential consequences for the species and communities involved.

Complex forest stand structures for risk reduction and adaptation. O'Hara, K. (*University of California – Berkeley, USA; kohara@berkeley.edu*), Ramage, B. (*Randolph-Macon College, Ashland, VA, USA; BenjaminRamage@rmc.edu*).

Complex stand structures are those with age class, species, or structural diversity. Forms of multi-aged silviculture are a primary means of creating complex stand structures that may emulate the natural processes that create these forests. Alternatively, the sequence of treatments may be outside the normal disturbance regimes and will create structures that are also outside the normal range of variation. These multi-aged treatments will not follow traditional forms of uneven-aged silviculture, but instead will provide flexible means for creating a great variety of stand structures. Some of these will be within and some outside natural ranges of variation. The presence of multiple age classes provides resistance and resilience to perturbations such as from disturbance or climate change. Variation in tree size provides varying levels of susceptibility to different disturbances and multiple age classes provide multiple pathways to post-disturbance recovery. These complex structures therefore serve to reduce risk as well as providing more options for managers. Potential benefits include more constant production of various ecosystem services and reductions in risk associated with investments in forest management.

The influence of climate change on forest ungulates: the paradox of restoring novel ecosystems. Rooney, T. (*Wright State University, USA; thomas.rooney@wright.edu*).

Grazing and browsing by forest ungulates shape the function, structure, composition, and successional trajectories of forest ecosystems. Climate change will alter forest ecosystems directly and indirectly by mediating ungulate – forest interactions. I present and examine scenarios in which climate change can amplify or weaken the effects of ungulates on forest ecosystems. At this time, it is impossible to predict which scenarios are more or less likely. The combination of altered biotic and environmental conditions will lead to novel forest ecosystems that have no current analog. These forests will retain some of the functions we associate with forest today, lose other functions (some restorable, some not), and gain novel functions we cannot yet predict. Management of these novel systems will include manipulating potential forest stressors, such as grazing or browsing intensity. Forest restoration will take on new meanings as climate change plays out, making forest management even more challenging in the future.

Novel and neo-native, native and exotic, restoration and intervention, oh my! Stanturf, J., Dumroese, K. (*U.S. Forest Service, USA; drdirt48@gmail.com; kdumroese@fs.fed.us*), Löf, M. (*Swedish University of Agricultural Sciences, Sweden; magnus.lof@slu.se*), Madsen, P. (*University of Copenhagen, Denmark; pam@ign.ku.dk*), Palik, B. (U.S. Forest Service*, USA; bpalik@fs.fed.us*).

As challenging as the present is, global climate change increases the critical need for restoration. Degradation will arise through increased climate variability and extreme events and altered mean conditions. The needs for restoration under climate change are fourfold: restoring already degraded lands in a manner that increases their adaptation to future climatic conditions, restoring forests catastrophically disturbed by climatic extreme events, reducing vulnerability of forests undergoing regeneration to altered climate (normal silvicultural adaptation), and the options of carbon sequestration and bioenergy for mitigating climate change. Responses to these needs may be incremental (reactive) or transformational (responsive or anticipatory). Incremental strategies focus on resistance and include doing nothing or doing slightly more of what is already being done (including ecological restoration and assisted population migration). Responsive strategies include assisted range expansions as well as managing emerging neo-native or novel ecosystems. Anticipatory strategies take a proactive approach and assist species to migrate beyond their native ranges, construct synthetic novel ecosystems comprised of new species assemblages, as well as introducing non-native species in order to restore ecosystem functions. Transformative strategies involving proactive intervention present multiple challenges of method and scale as well as governance, including redefinition of nativeness or acceptance of exotic species.

Theme D: Forest and Water Interactions

D-01 Long-term watershed studies: What have we learned about eco-hydrological functioning

Organizers: Shirong Liu (Chinese Academy of Forestry) & Xiaohua Wei (University of British Columbia, Canada)

Forests, land use change and the water regime over half a century in the Blue Nile Basin of Ethiopia. Bishop, K. (*Swedish University of Agricultural Sciences (SLU), Sweden; Kevin.Bishop@slu.se*), Gebrehiwot, S. (*Ethiopian Institute of Water Resources, Addis Ababa University, Ethiopia; solomon.gebreyohannis@slu.se*).

The relationship of forest cover change and hydrological regime was investigated in the Blue Nile Basin of Ethiopia, which is a sub-basin of the Nile Basin, based of 45 years (1960–2004) of gauged-river data using observational data analysis and community perception in 12 macro-scale watersheds (> 100 km^2 in area). Changes in hydrology and forest cover were analyzed through statistical methods, modeling, remote sensing, and community perception. Change detection analysis with both statistics and modeling revealed few significant changes in the hydrological regime. Despite the relatively stable hydrological regimes, there was dramatic forest cover change (from 90% cover to 45% in the 45 years period) in the watershed from the southern part of the Basin. The community perception summarized forest and hydrological relationship was complex. While other literature from the Blue Nile Basin suggests relationships between forests and low flows in the spatial dimension; there is no evidence to support this in the temporal dimension at the scale of river basins. Hillslope and farm level studies integrated with community participation may reveal a different picture at smaller scales.

Impacts of reforestation of denuded land on the streamflow regime in a weathered granite mountain area. Choi, H., Kim, S. (*Korea Forest Research Institute, Republic of Korea; choih@forest.go.kr; kimsj@forest.go.kr*).

From the 1960s, Korea began its reforestation in earnest led by the government. Now the total reforestation area reached 2.2 million ha, and it is almost a third of the total forest land. Therefore, most of the forest lands in Korea have experienced big changes in the hydrological regime. The objective of the study was to evaluate the impacts of reforestation on the streamflow regime in the denuded land of the weathered granite mountain area in the northern part of South Korea. The main tree species of the study site are pine and oak, reforested in 1974. The area is about 5 ha, and 30 years observed data sets were used in analysis. As the results of the flow duration curve analysis according to the elapsed year after reforestation, the flow duration period has rapidly increased from 90 days in 1980s to 310 days in 1990s. The medium and low flow discharges are also remarkably increased. In the 2000s, they are about 4 times bigger than the 1990s. This result implies that the reforestation of denuded lands can be of great assistance to increase the water supply and conservation.

The hydrologic impacts of long-term afforestation in an upland watershed in north-central Portugal. Hawtree, D., Feger, K., Tavares Wahren, F. (*Technische Universität Dresden, Germany; dhawtree@gmail.com; fegerkh@forst.tu-dresden.de; filipa.wahren@mailbox.tu-dresden.de*), Nunes, J., Rial Rivas, M., Santos, J., Jacinto, R. (*Universidade de Aveiro, Portugal; jpcn@ua.pt; m.rial@ua.pt; juliana.santos@ua.pt; jacinto.rita@ua.pt*).

Portugal has undergone significant afforestation since the early 20th century (primarily with *Pinus pinaster* and *Eucalyptus globulus*), which has raised concerns about the hydrologic impacts of this land-cover change in many areas of the country. This study considers these impacts within the humid Mediterranean climate zone of north-central Portugal, by examining finding from a study watershed which is a source of freshwater and nutrients for the coastal lagoon near the city of Aveiro. Over the afforestation period for which data is available (1935–2000), the variability of streamflow in terms of yield, magnitude, flow-partitioning (*i.e.* baseflow), and seasonality are examined. These findings indicate that at the watershed scale, there has been less impact on streamflow than would be expected from the observed magnitude of afforestation. The results of these finding are then contrasted against recent site-scale research conducted at the same location, which have shown hydrologic impacts from land-cover change. The contrasts between these findings are discussed and potential explanations are examined, which consider the specific characteristics and hydrologic processes dominant in the study watershed. In addition, other environmental impacts of afforestation in the study area are examined, and considered in the context of future potential land-use changes.

Effects of contemporary harvest practices on water yield and snowpack dynamics in the continental-maritime region of the USA. Hubbart, J. (*University of Missouri, USA; HubbartJ@missouri.edu*), Link, T. (*University of Idaho, USA; tlink@uidaho.edu*), Gravelle, J. (*PineOrchard, Inc., USA; jag@pineorchard.com*), Elliot, W. (*U.S. Forest Service, USA; welliot@fs.fed.us*), Du, E. (*Lawrence Berkeley National Laboratory, USA; edu@lbl.gov*).

Alterations to water yield and snowpack dynamics in post-forest harvest mountainous terrain of the western United States remains one of the greatest uncertainties in watershed management of the region. Streamflow data were collected since 1991 at the Mica Creek Experimental Watershed (MCEW) in northern Idaho. The effect of isolated treatments of road building and 100% clearcut and 50% partial cut on water yield and snow deposition and ablation dynamics were investigated. Water yield increased in excess of 270 mm/yr (P<0.01) after clearcut harvesting, and by more than 140 mm/yr (P< 0.01) after partial cut harvesting. Peak snow water equivalent (SWE) was approximately 57, 30, 17, and 34 cm in clearcuts, 50% partial cuts, undisturbed, and a riparian valley bottom forest, respectively. The number of days to melt out from peak SWE ranged from 53 to 36 days in the clearcut and full forest respectively. Clear cutting resulted in almost three times the snowpack as full forest, but prolonged snowpack depletion by only three weeks. Results suggest that assuming snow cover uniformity may lead to considerable errors in computed quantity and timing of runoff in pre- and post-harvest environments of physiographically diverse landscapes of the continental/maritime region of the USA.

Seventy-seven years variation of annual evapotranspiration in a small watershed with the forest restoration and succession on denuded hills. Kuraji, K. (*University of Tokyo, Japan; kuraji_koichiro@uf.a.u-tokyo.ac.jp*), Gomyo, M. (*Forestry and Forest Products Research Institute, Japan; gomyo@affrc.go.jp*).

To understand the magnitude of changes in evapotranspiration and the main controlling factors of such changes, in association with the long-term natural recovery of forests on denuded hills, we compared the mean annual evapotranspiration during the early 10-year period (initial stage of forest recovery) and late 10-year period (60 years after the early period; transition stage of forest recovery) as measured by the water balance method. The Ananomiya and Shirasaka watershed at the Ecohydrology Research Institute (The University of Tokyo Forests) was selected for this study, where the temperature, rainfall, discharge and forest stand volume have been monitoring since 1923. In Ananomiya Watershed, the 10-year mean annual loss, as calculated by the annual water balance for the late period was 89 mm larger than that measured for the early period. We propose a new method, based on the short term water balance method, to estimate of annual evapotranspiration and have applied this method to evaluate the relationship between annual evapotranspiration and mean annual temperature, annual precipitation, and annual number of days with precipitation. The mean annual evapotranspiration for the late period was 80 mm larger than that measured for the early period. We conclude that the main reason for higher evapotranspiration in the late period may have been the increase in canopy interception as a consequence of forest growth.

Rational density for balancing the water yield and other services of larch plantation in Liupan Mountains of northwest China. Wang, Y., Hao, J., Yu, P., Xiong, W., Xu, L. (*Chinese Academy of Forestry, China; wangyh@caf.ac.cn*; *haoyazitu@163.com; yupt@caf.ac.cn; xiongwe@caf.ac.cn; xulh@caf.ac.cn*).

Forests can supply multiple services and products. However, these functions are interacted in a complex way and influenced by stand structure. The mountain areas are important head-water areas in dryland regions with serious water shortage, and water yield should be the dominant function of the forest land there. But water yield competes with other functions since forests generally consume more water than other vegetation types. Thus, quantifying the relation among stand structure (e.g. density), water yield and other main functions is the basic requirement for a multifunctional management of head-water forest in stand scale. The objective of this paper is to determine the optimal stand density to balance the competing water yield and other functions, based on the eco-hydrological studies in middle-aged larch (*Larix principis-rupprechtii*) plantation at the Liupan Mountains of northwest China. Firstly, the individual relations among stand density and annual water yield, biomass and carbon sequestration, tree growth and timber production, undergrowth plant species diversity, and resistance against snow damage were established; then a rational density was determined for ensuring certain water yield without obvious injury of other functions. With this approach, the head-water forests can be managed for maximizing their total value/benefits for people.

Alteration of flow regimes caused by large-scale forest disturbances and its ecological implications. Wei, X., Zhang, M. (*University of British Columbia, Canada; adam.wei@ubc.ca; Mingfang.Zhang@ubc.ca*).

Flow regime determines the structures, functions and integrity of aquatic, floodplain and riparian ecosystems. The impacts of forest disturbances on flow regimes have been rarely investigated. We used a large severely disturbed watershed, the Baker Creek watershed in the central interior of British Columbia, Canada to study how forest disturbances can alter flow regimes and to discuss possible implications of these alterations. Flow duration curves (FDC) and time series cross-correlation analysis were used to detect the statistical significance of relationships between hydrological regimes (magnitude, duration, timing, frequency and variability of high flows and low flows) and forest disturbances (EDA: equivalent disturbance area). The results showed that the magnitude of high flows was significantly increased and the timing of high flows was significantly advanced by forest disturbances. After forest disturbances, the occurrence of high flows with greater return periods became more frequent with increased variations. In addition, forest disturbances significantly increased the magnitude of low flows but with reduced variability. On average, high flows and low flows in the disturbed period were increased by 31.4% and 16.0% compared with those in the reference period. Possible ecological implications of these hydrological alterations caused by forest disturbances were discussed.

Ecosystem dynamics controlled by the seasonal distribution of precipitation in forests of Interior Alaska. Yarie, J., Valentine, D. (*University of Alaska Fairbanks, USA; jayarie@alaska.edu; dvalebtube@alaska.edu*).

The seasonality of soil water recharge affects two key aspects of ecosystem function in the boreal forest of interior Alaska. We used a pair of studies to investigate the importance of seasonal precipitation on growth and decomposition in two permafrost-free landscapes (upland and floodplain) supporting mid-successional forest types. We excluded summer (15 May–15 September) precipitation events from six forested plots (3 upland, 3 floodplain) for the past 24 years and spring snowmelt from 6 nearby plots for the past 5 years. We monitored growth and mortality of all trees on the experimental and control plots. We estimated changes in total plot above-ground tree biomass. Individual tree growth was slowed by snowmelt removal but not by summer precipitation removal in the upland sites. Both treatments resulted in lower stand-level biomass growth which may be tied to the plot level mortality. On floodplain sites summer precipitation removal reduced white spruce tree growth while snowmelt removal had no significant effect. Neither treatment affected stand-level biomass growth. Summer rainfall exclusion increased forest floor thickness and mass in all stands while also reducing soil respiration, particularly in upland sites, suggesting that summer rainfall may be a key constraint on decomposition. Snowmelt exclusion caused no overall change in soil respiration.

D-02 Conceptual frames and research strategies for integrated studies of adaptation to drought

Organizers: Philippe Rozenberg (National Institute for Environmental and Agricultural Science and Research, France), Anne Griebel & Gregor Sanders (University of Melbourne, Australia)

The physiology of tree mortality from drought. Adams, H. (*Los Alamos National Laboratory, USA; adamshd@lanl.gov*).

The feedback of a dynamic terrestrial carbon sink is a major uncertainty in projections of global climate change. Forests, a major component of this sink, are potentially vulnerable to die-off in many regions due to increased drought expected with climate

change. For better projection of forest loss and associated effects on the climate system, improved information on how trees die from drought is needed. Here we synthesize results from around the world for >14 species from >15 experiments and observational studies on the physiological process of tree mortality from drought. We examined the role of hydraulic failure (xylem cavitation by air embolism) and non-structural carbohydrate depletion in tree mortality associated with drought. Hydraulic failure (defined as ~>75% loss of xylem hydraulic conductivity) was a universal aspect of mortality physiology, while carbohydrate depletion was not. However, reduced non-structural carbohydrates in at least one tree tissue at death (relative to surviving control trees) were as common a response as unchanged or increased carbohydrates. Coniferous gymnosperm species were more likely to exhibit carbohydrate reduction with mortality than angiosperm trees. We suggest that linking known tree drought mortality physiology with functional traits can provide for predictive capability of mortality mechanism in additional species.

The performance of ten Ghanaian tree species in response to drought and shade. Amissah, L. (*Wageningen University, Netherlands & Forestry Research Institute of Ghana; ewurakua.amissah@gmail.com*), Mohren, G. (*Wageningen University, Netherlands; frits.mohren@wur.nl*), Kyereh, B. (*Kwame Nkrumah University of Science and Technology, Ghana; kyerehb@gmail.com*), Poorter, L. (*Wageningen University, Netherlands; Lourens.Poorter@wur.nl*).

The distribution of many tropical species is determined by water availability and light. Over the last two decades annual rainfall has decreased in many tropical regions. If species are not able to acclimatize to these changes it will have large consequence for species persistence. Here, we present data on a greenhouse experiment in which seedlings of ten Ghanaian tree species were subjected to drought (continuous watering versus withholding water) and shade (5% irradiance= low light" and 20% irradiance=high light") for nine weeks. We asked how species respond to drought and shade effects in terms of 1) survival and growth, and 2) biomass allocation, morphology, and physiology and 3) how plasticity of morphological traits relates to species survival in drought. Drought survival in high light was 1.7 fold lower than in low light indicating that plants are hit harder by drought in exposed environments that are typical for forest gaps. Drought led to a stronger reduction in relative growth rate in high light than in low light. Drought survival was positively correlated to plasticity in leaf mass fraction, which suggests that plasticity in plant traits may play a role in species survival under changing global climate.

Hydraulic and ecophysiological traits related to tree drought mortality are linked to the aridity of the environment in eucalypts. Arndt, S., Sanders, G., Hirsch, M. (*University of Melbourne, Australia; sarndt@unimelb.edu.au; gregorjs@gmail.com; Mareike.Hirsch@hnee.de*).

Physiological traits have been proposed as possible tools to predict vulnerability to tree drought mortality but these traits have only been studied in a few tree species. We investigated the vulnerability to hydraulic cavitation in leaves (P50leaf), turgor loss point (TLP) and osmotic potential at full turgor (OPFT) in 16 different eucalypt species from different environments in south-eastern Australia (300 mm to 1500 mm of precipitation p.a.) in an arboretum. We observed strong correlations between all measured ecophysiological traits and the aridity of the environment of the origin of the species. The results indicate a strong genetic control over these physiological traits in eucalypts – trees from more arid environments lose turgor and hydraulic conductivity at lower water potentials and achieve these lower water potentials by having more osmotically active substances, even if they are not stressed. This is the first time these strong correlations between physiological traits and aridity of the origin of the species have been observed. This is likely related to the fact that eucalypts follow a similar strategy and growth form (broadleaf evergreen with sclerophyllous leaves), indicating that physiological traits may be used as thresholds within a genus or a group of species with similar drought tolerance strategies.

Response of piñon and juniper respiration to drought and warming. Collins, A., McDowell, N. (*Los Alamos National Laboratory, USA; acollins@lanl.gov; mcdowell@lanl.gov*), Ryan, M. (*Colorado State University, USA; Mike.Ryan@colostate.edu*), Pockman, W. (*University of New Mexico, USA; pockman@unm.edu*).

Drought and temperature-induced tree mortality is believed to be occurring globally, though the physiological mechanisms underlying documented mortality events are not well understood. Piñon pine (*Pinus edulis*) and oneseed juniper (*Juniperus monosperma*) are widespread Southwest U.S. species known to be susceptible to mortality due to altered precipitation and temperature. Respiration is a key component of the tree carbon budget and its response to abiotic stress is thought to play a role in mortality or survival. A careful examination of the response of piñon and juniper respiration to increased temperature and drought is thus a necessary step in predicting their future distribution in a changing environment. We established a rainfall and temperature manipulation experiment in a piñon-juniper woodland near Los Alamos, NM. In-situ trees were exposed to one of five treatments: Heat (+5° C), Drought (–40% rainfall), Heat+Drought, Ambient Control, and Chamber Control. CO_2 efflux measurements were conducted on the bole of each tree once per month between June 2012 and October 2013. In piñon, the Heat and Drought+Heat treatments showed the highest efflux. In juniper, the highest rates were in the Drought treatment. Conversely, piñon Drought+Heat showed thermal acclimation while juniper exhibited acclimation in both the Heat and Drought+Heat treatments.

Variability in biomass partitioning, growth and survival under water stress in seedlings from two populations and three breeding generations of *Pinus radiata* in Chile. Espinoza, S., Santelices, R. (*Catholic University of Maule, Chile; espinoza@ucm.cl; rsanteli@ucm.cl*), Magni, C. (*University of Chile, Chile; crmagni@uchile.cl*), Ivković, M. (*CSIRO Plant Industry, Australia; milosh.ivkovich@csiro.au*), Cabrera, A. (*Catholic University of Maule, Chile; acabrera@ucm.cl*).

Considering that rainfall and other climate factors are projected to change in the future, affecting establishment and early survival of radiata pine (*Pinus radiata* D. Don), identification of drought tolerant radiata pine genotypes is needed. To address this issue, early growth, survival and biomass allocation of radiata pine seedlings were studied in response to water stress. Three generations of breeding families from two populations in Central Chile, with different water holding capacity were analyzed. The seedlings were cultivated in a nursery for 100 days and after that subjected to two watering regimes for 45 days. Survival, growth, and biomass partitioning traits were estimated for each seedling at the end of the experiment. Two studied *P. radiata* populations

showed different strategies of response to drought with changes in root dry weight and root:shoot ratio significantly affected. Seedlings of sandy soils populations showed the highest investment in roots. First generation families originating from coastal populations showed the highest survival and root:shoot ratio when exposed to water stress (i.e. 60% and 1.8 respectively). However, in second and third-breeding generation both traits decreased. The opposite was observed in sandy soil populations, which may represent an important mechanism of their local adaptation to future climatic change.

Unraveling the adaptive meaning of wood in *Eucalyptus* species. Fernandez, M. (*Instituto Nacional de Tecnología Agropecuaria (INTA), Argentina; ecologia_forestal@yahoo.com.ar*), Rozenberg, P. (*French National Institute for Agricultural Research (INRA), France; philippe.rozenberg@orleans.inra.fr*), Monteoliva, S. (*Universidad Nacional de La Plata, Argentina; smonteoliva@yahoo.com.ar*), Martinez-Meier, A., Gyenge, J., Tesón, N., Salda, G., Licata, J. (*Instituto Nacional de Tecnología Agropecuaria (INTA), Argentina; martinezmeier.a@inta.gob.ar; javier_gyenge@yahoo.com; natateson@hotmail.com; gdsalda@hotmail.fr; julianlicata@hotmail.com*), Barotto, A. (*Universidad Nacional de La Plata, Argentina; josecuervo86@gmail.com*).

Lower vulnerability to xylem cavitation due to tension and/or freeze-thaw has been identified as key traits determining the resistance to drought and low temperature in woody species. However recent advances have highlighted the importance of wood capacitance, embolism repair capacity (related to carbohydrates dynamics and parenchyma function) and ionic regulation of hydraulic conductivity as alternative or complementary strategies to face abiotic stress. In several species, some of these traits are correlated or functionally related to wood density. *Eucalyptus* is one of the most important genera in forestry. However there is scarce knowledge about the functional role of its well-anatomically known wood in terms of abiotic stress resistance. An interdisciplinary project has been developed to address this topic using different commercial species introduced in Argentina (*E. grandis*, *E. globulus*, *E. viminalis* and *E. camaldulensis*), covering all the range of wood densities of the genus (400–1000 kg/m^3). Insight of wood anatomy, ecophysiology and quantitative genetics is jointly applied to evaluate the variability of strategies between and within species, aiming at providing reliable tools for selection of stress resistant genotypes. In particular, relationship between microdensity profiles and wood function is being explored. The first results of this study are presented and discussed.

Growth, water use and water use efficiency of Eucalyptus under different spacings and genotypes. Hakamada, R. (*University of São Paulo, Brazil; rodrigo_hakamada@yahoo.com.br*), Hubbard, R. (*U.S. Forest Service, USA; rhubbard@fs.fed.us*), Ferraz, S. (*University of São Paulo, Brazil; silvio.ferraz@usp.br*), Stape, J. (*North Carolina State University, USA; jlstape@ncsu.edu*), Lemos, C. (*International Paper, Brazil; Cristiane.Lemos@ipaper.com*).

Tree genetics and spacing are key factors regulating biomass production in Eucalyptus plantations but relatively little is known about the interactions of genetics and spacing on water use and water use efficiency in these forests. As part of the Tolerance of Eucalyptus Clones to Hydric and Thermal Stresses (TECHS/IPEF) project that covers 35 sites across Brazil and Uruguay, we are quantifying wood growth, water use and water use efficiency in four Eucalyptus clones that differ in their tolerance to drought at 8 planting densities (ranging from 500 to 3000 trees/ha). Seedlings were planted on February 2012 and Granier thermal dissipation probes were installed in four trees per treatment in August 2013. Daily estimates of tree water use and quarterly growth measurements will continue over a two year period. Initial results suggest that wood growth and tree water use are positively correlated with stocking for all four clones but differences among clones suggest distinct levels of water use efficiency. Here, we demonstrate how spacing and drought tolerance influence the interaction between wood growth and tree water use and discuss the relevance of our results in the context of sustainable plantation management.

Species response to drought and late frost is affected by within species diversity. Jentsch, A., Kreyling, J. (*University of Bayreuth, Germany; anke.jentsch@uni-bayreuth.de; juergen.kreyling@uni-bayreuth.de*), Warren, S. (*U.S. Forest Service, USA; swarren02@fs.fed.us*), Beierkuhnlein, C. (*University of Bayreuth, Germany; carl.beierkuhnlein@uni-bayreuth.de*).

Increasing frequency and magnitude of climatic extremes as a consequence of global warming are assumed to lead to stronger mortality of plants, in particular trees. However, ecotypic differention and intra-specific variability may be crucial for species sensitivities. We studied within-species variability in the response of two important tree (*Fagus sylvatica, Pinus nigra*) and four common grass (*Arrhenatherum elatius, Holcus lanatus, Festuca pratensis, Alopecurus pratensis*) species to warming, drought and frost events in a full factorial common garden experiment. For each species, within-species variability was represented by using seeds from populations differing in their native climate on a continental scale. Within all species, productivity differed between populations from contrasting origins and several species showed population-specific sensitivity to drought, warming or frost. Within-species variability exceeded among-species variability in some cases, yet variability was also high within populations. Mortality increased due to drought exposure, further exacerbated by additional warming. However, no local adaptation, i.e. increased tolerance of populations stemming from warmer and dryer origins, was detected. However, populations from warmer origins generally were more frost sensitive. Drought further stimulated increased frost tolerance. Within-species variability is important in the adaptation of species to environmental changes. Drought tolerance cannot be predicted from climatic origin.

Potassium and sodium supply effects on the adjustments to water deficit of Eucalyptus grandis trees: insights from a throughfall exclusion experiment in Brazil. Laclau, J. (*CIRAD, UMR Eco&Sols, France; laclau@cirad.fr*), Battie-Laclau, P. (*University of São Paulo-CENA, Brazil; placlau@cena.usp.br*), Christina, M. (*CIRAD, UMR Eco&Sols, France; mathias.christina@cirad.fr*), Gonçalves, J. (*University of São Paulo- ESALQ, Brazil; jlmgonca@usp.br*), Epron, D. (*Université de Lorraine, France; daniel.epron@scbiol.uhp-nancy.fr*), Moreira, R. (*University of São Paulo- ESALQ, Brazil; rmoreira@usp.br*), Le Maire, G., Bouillet, J. (*CIRAD, UMR Eco&Sols, France; guerric.le_maire@cirad.fr; jpbouillet@cirad.fr*), Cabral, O. (*EMBRAPA, Brazil; ocabral@cnpma.embrapa.br*), Nouvellon, Y. (*CIRAD, UMR Eco&Sols, France; yann.nouvellon@cirad.fr*).

Identifying management practices enhancing tree tolerance to drought and nutrient deficiencies is of primary interest to confront global change. A split-plot design with 3 blocks was set up to gain insight into the interactions between fertilization and water stress on carbon, water and nutrient cycling in *Eucalyptus* plantations on deep tropical soils. The main-plot factor was the water supply (undisturbed *vs* exclusion of 37% of throughfall) and the sub-plot factor compared 3 fertilization regimes (control, sodium supply, potassium supply). Biomass and nutrient accumulations in tree components, leaf area index (LAI), fine root development,

leaf gas exchanges, soil respiration, soil solution chemistry as well as soil water contents down to the water table at 17 m in depth have been measured over the first half of the rotation. The MAESPA model was used to estimate the contribution of water withdrawn in deep soil layers over 3 years. Carbon labelling for 12 trees at age 2 years showed a strong influence of potassium addition on phloem sap velocity and C allocation patterns. Although potassium supply improved stomatal sensitivity to water deficit, the great enhancement in growth exacerbated tree water deficit during dry periods. The behavior of sodium-supplied trees was intermediate. Fertilization regimes should be revisited in a context of climate change for optimizing the trade-off between safety and growth.

Defense allocation patterns are important to the drought-mortality risk of a semi-arid conifer. Macalady, A. (*University of Arizona, USA; amacalad@email.arizona.edu*), Bugmann, H. (*ETH Zurich, Switzerland; harald.bugmann@env.ethz.ch*), Klaey, M. (*Swiss Federal Office for the Environment (FOEN), Switzerland; MatthiasSimon.Klaey@bafu.admin.ch*), Gaylord, M. (*Northern Arizona University, USA; monica.gaylord@nau.edu*), English, N. (*James Cook University, Australia; nathan.english@jcu.edu.au*), Allen, C. (*U.S. Geological Survey, USA; craig_allen@usgs.gov*), Swetnam, T. (*University of Arizona, USA; swetnamt@email.arizona.edu*), McDowell, N. (*Los Alamos National Laboratory, USA; mcdowell@lanl.gov*).

Drought and insects frequently interact to produce widespread tree mortality, suggesting that tree defenses may play a key role in survivorship during drought. However there are few empirical tests of the importance of defense allocation versus other metrics of tree physiological stress. To investigate how allocation to defense affects mortality risk, we measured radial growth– a metric of tree carbon status – and resin ducts – critical to *Pinus* defense systems – in tree rings of *Pinus edulis* that died and survived the 2000s and 1950s droughts in New Mexico, USA. The number of resin ducts, their average size, and the ratio of resin duct to xylem area were significantly higher in surviving trees across sites and droughts. Recent growth was also higher on average, however this was inconsistent across space and time. Statistical models of mortality risk calibrated using both growth and duct variables had substantially more support than models based on growth or duct parameters alone, and correctly classified ~80% of trees. Accounting for tree allocation to resin ducts was more important for predicting mortality during the 2000s drought, suggesting amplified bark beetle pressure during recent, warm versus historic cooler drought. We conclude that accounting for defense allocation may improve predictions of drought-associated mortality.

Coordinated adjustments in xylem hydraulic safety, efficiency and capacitance across climatic gradients and axial gradients within trees. Meinzer, F. (*U.S. Forest Service, USA; rick.meinzer@oregonstate.edu*), Barnard, D. (*Colorado State University, USA; dave.barnard@colostate.edu*), Johnson, D. (*Duke University, USA; dj74@duke.edu*), McCulloh, K. (*University of Wisconsin, USA; kmcculloh@wisc.edu*), Woodruff, D. (*U.S. Forest Service, USA; david.woodruff@oregonstate.edu*).

Trees must maintain the integrity of xylem water transport from roots to leaves in order to sustain photosynthetic gas exchange and prevent lethal levels of dehydration. Much work has focused on the roles of static properties such as xylem vulnerability to embolism and hydraulic conductivity in determining the overall drought resistance of trees. However, xylem water transport occurs under dynamic conditions that could provoke runaway embolism and catastrophic hydraulic failure if stomatal control of transpiration is not adequately coordinated with overall tree hydraulic architecture. Hydraulic capacitance is a component of hydraulic architecture that acts to buffer fluctuations in xylem tension through transient discharge of water into the transpiration stream. Here we describe coordinated adjustments in sapwood capacitance, resistance to embolism and hydraulic conductivity that contribute to homeostasis of water transport in temperate and tropical forest trees. We suggest that stomatal regulation of transpiration, and therefore xylem tension, optimizes daily reliance on the buffering effects of capacitance. The interplay between dynamic and static components of hydraulic architecture must be taken into account when evaluating potential responses of trees to drought.

Identifying drought resistant lodgepole pine genotypes for a changing climate: growth and hydraulic response observed in genetic field trials. Montwé, D. (*Albert-Ludwigs-Universität Freiburg, Germany; david.montwe@iww.uni-freiburg.de*), Isaac-Renton, M., Hamann, A. (*University of Alberta, Canada; isaacren@ualberta.ca; andreas.hamann@ualberta.ca*), Spiecker, H. (*Albert-Ludwigs-University, Germany; instww@uni-freiburg.de*).

Drought has been identified as a major cause of tree mortality and may threaten the health and productivity of lodgepole pine (*Pinus contorta*), an important timber species in western North America. One effective effort to mitigate the impacts of an expected increase in the frequency and severity of extreme droughts includes the planting of adapted provenances. To target the most drought resilient and resistant genotypes for planting, we use tree ring and height increment analysis to retrospectively assess growth response and adjustments in the water conducting cell structure. More than 2,200 stem disks were collected from provenances tested in the comprehensive IUFRO Illingworth provenance trial series. Provenances were chosen to represent regions in the United States, and British Columbia's southern interior, central interior and north, while planting sites covering severe drought events were chosen to represent climate change scenarios. We expect that provenances from warmer and drier regions will outperform provenances from wetter and colder sites in drought years, and will also show faster growth rate recovery. We further expect that higher resistance and resilience of southern provenances are accompanied by a more safety orientated water conducting system. Preliminary results and potential policy implications are discussed.

Seedling establishment limited by water availability: understanding spatial and temporal limitations to maximize outplanting success. Pinto, J. (*U.S. Forest Service, USA; jpinto@fs.fed.us*).

Seedlings planted in forest and restoration settings face a myriad of challenges before they can become established and grow. These challenges are realized after a thorough site evaluation that includes spatial and temporal factors. Only then can the primary limitations to establishment be understood and consequently overcome. A model of seedling establishment furthers our understanding of how seedlings engage their surroundings and begin to survive and grow on a site. This model characterizes the physiologic, atmospheric, and edaphic process that factor into a target seedling's design and the supplemental appropriate mitigating measures that need to be employed. In most cases around the world, the primary limitation to seedling establishment is

moisture availability and this availability has significant effects on seedling physiological functions. This research illustrates the biophysical processes seedlings face when establishing, the physiological consequences, and mitigating measures to these limitations. Armed with this data, better choices can be employed in reforestation and restoration tactics, challenging old paradigms in artificial regeneration strategies, thereby increasing establishment success and restoration trajectories.

Oak forest decline in the Mediterranean environment: understanding the linkage of climatic drivers to physiological and dendro-anatomical variations. Ripullone, F., Colangelo, M., Gentilesca, T., Borghetti, M. (*University of Basilicata, Italy; francesco.ripullone@unibas.it; mcolangelo83@hotmail.com; tiziana.gentilesca@unibas.it*; *marco.borghetti@unibas.it*)**.**

Recent evidence highlights the vulnerability of forests around the world mainly due to the increased temperatures and water stress episodes. In particular, the Mediterranean region has been identified as a climate-change hotspot with major risks in the near future. At present, several cases of widespread decaying of *Quercus* spp. stands have been already reported in Southern Italy. In this regard, it is essential to enhance our knowledge on plant functional mechanisms responsible for forest decline. We applied a multidisciplinary approach, based on the combination of dendrochronological, wood-anatomical and stable isotopes analysis along tree rings to ascertain the effect, in the recent past, of environmental and climatic factors on physiological and wood anatomical behavior. To this aim, decaying and non-decaying trees have been selected at four different sites where oak stands are suffering from severe decline. We identified the drought episode occurred in 2000 (*i.e.* less than 400 mm of total precipitation) as the onset of forest decline. After this year wood properties and physiological activity changed significantly between decaying and non-decaying trees overall in terms of radial growth, number of vessels, parenchyma ray, latewood versus earlywood production, and water-use efficiency.

Do leaf adaptations to low water potential influence isohydric or anisohydric responses in a widely distributed genus? Sanders, G., Nitschke, C., Kasel, S., Arndt, S. (*University of Melbourne, Australia; gsanders@student.unimelb.edu.au; cnitschke@unimelb.edu.au; skasel@unimelb.edu.au; sarndt@unimelb.edu.au*).

Plant adaptation to drought depends on physiological traits that allow a reduction in water potential. The adaptation can produce a lower turgor loss point and also limit the loss of hydraulic conductivity under drought stress compared with poorly adapted species. It is unclear whether such adaptation or strong stomatal sensitivity to prevent hydraulic failure (isohydry) has biogeographical or ecophysiological significance at a continental scale. Adaptation in combination with limited stomatal response (anisohydry) allows continued transpiration during drought episodes, which may be crucial for leaf survival. This study has the aim of classifying stomatal sensitivity and physiological adaptation in leaves from arid and mesic climates across the Australian continent. Trees were selected in an arboretum to measure all species in a common environment across two seasons. To minimize phylogenetic differences, the study has been limited to *Eucalyptus* species. The patterns observed within this genus across such a wide climatic and geographic distribution are likely to have implications for the interpretation of drought adaptation and survival in other evergreen sclerophyllous species.

Tolerance of *Eucalyptus* clones to hydric, thermal and biotic stress across sites, stockings and rain-exclusion regimes. Stape, J. (*North Carolina State University, USA; jlstape@ncsu.edu*), Binkley, D. (*Colorado State University, USA; dan.binkley@colostate.edu*), Grattapaglia, D. (*Embrapa Cenargen, Brazil; dario.grattapaglia@embrapa.br*), Campoe, O., Alvares, C. (*Instituto de Pesquisas e Estudos Florestais, Brazil; otavio@ipef.br; clayton@ipef.com*).

Even the fastest growing forests in the world may be constrained by drought. Drought limitations on survival and growth vary with climate, site conditions, stocking, and genetics. The TECHS-IPEF project (Tolerance of Eucalyptus Clones to Hydric and Thermal Stress) is a collaborative research platform installed in 2012 that encompasses all these factors with 35 sites across a 3000-km gradient from the Equator to 33° S Latitude in Brazil and Uruguay. Over 26 forest companies are collaborating with universities and agency scientists across a gradient of temperature (15 to 30 °C), precipitation (800 to 2500 mm/yr) and soil types. At each site, a 5-ha trial contains 11 clones of fast-growing eucalyptus varieties, from a common pool of tropical or subtropical clones, and hourly meteorological stations. Rain-exclusion systems were installed to test the effect of removing 30% of rainfall, and density gradients examine the effects of competition on growth. Growth and leaf area index are measured twice a year and four sites are being measured in detail for water use, root growth and carbon budgets. The project intends to better understand the GxE interaction on eucalyptus and the physiological and genomic processes that control their responses.

D-03 Land use/land cover change and hydroecology: consequences at variable spatial scales.

Organizers: Latif Kalin (Auburn University, USA), Yusuf Serengil (Istanbul University, Turkey) & Xiaohua (Adam) Wei (University of British Columbia, Canada)

The effect of land use change on the ecosystem services provided by headwater wetlands in Alabama. Anderson, C., Barksdale, F., Alix, D., Kalin, L. (*Auburn University, USA; andercj@auburn.edu; barkswf@gmail.com; diane.m.alix@gmail.com; latif@auburn.edu*).

Conversion of forests to urban or agricultural use has the potential to severely change drainage patterns to headwater wetlands and reduce the services they provide. To evaluate land use change effects, a series of investigations were conducted using over 35 headwater wetlands across coastal Baldwin County, Alabama. Wetlands represented a range of watershed land use/land cover (LULC) (i.e., forest, urban, and agriculture) that was quantified and used to detect patterns in wetland functions. Monitoring a subset of 15 wetlands, we found that land use change increased runoff to wetlands which caused flashier water levels, higher energy flow, and reduced storage of forest floor litter. Reduced forest cover in watersheds correlated to greater invasive species cover in wetlands (particularly Chinese privet, *Ligustrum sinense*). Relationships between increased privet cover and reduced

recruitment of native species suggests that significant community shifts may result from land use change. Seasonal amphibian surveys showed that species richness was not related to land use however less disturbed wetlands (i.e., those in predominantly forested watersheds) had several sensitive species that were rarer and not found in more disturbed wetlands. Current work and early results relating land use, wetland hydrology and water quality enhancement are also provided.

Mind the gap: trees can improve groundwater recharge in the seasonally dry tropics. Bargués Tobella, A., Ilstedt, U. (*Swedish University of Agricultural Sciences, Sweden; aida.bargues.tobella@slu.se; ulrik.ilstedt@slu.se*), Bazié, H. (*Institut de l'Environnement et de Recherches Agricoles, Burkina Faso; baziehugues@yahoo.fr*), Bayala, J. (*ICRAF, Mali; J.Bayala@cgiar.org*), Verbeeten, E. (*University of Amsterdam, Netherlands; verbeeten@gmail.com*), Nyberg, G. (*Swedish University of Agricultural Sciences, Sweden; Gert.Nyberg@slu.se*), Sanou, J. (*Institut de l'Environnement et de Recherches Agricoles, Burkina Faso; josiassanou@yahoo.fr*), Benegas, L. (*Swedish University of Agricultural Sciences, Sweden; Laura.Benegas@slu.se*), Murdiyarso, D. (*Center for International Forestry Research, Indonesia; D.MURDIYARSO@CGIAR.ORG*), Laudon, H. (*Swedish University of Agricultural Sciences, Sweden; Hjalmar.Laudon@slu.se*), Sheil, D. (*Southern Cross University, Australia; douglas.sheil@scu.edu.au*), Malmer, A. (*Swedish University of Agricultural Sciences, Sweden; Anders.Malmer@slu.se*).

Tree planting is being promoted and adopted worldwide as a tool to restore or enhance the provision of ecosystem goods and services. Despite its benefits, tree planting in drylands has been largely questioned as the current paradigm in forest hydrology predicts that more trees lead to diminished water resources. This "trade-off theory" contrasts with the widespread view of forests functioning as sponges and sustaining dry season flows, but empirical support for the "sponge theory" is lacking. The trade-off theory is based on paired-catchment studies showing that afforestation dramatically decreases stream flow within few years of planting. However, such studies have neglected widespread areas of forests, woodlands and agroforests with open, non-continuous and mosaic-like tree cover on degraded tropical soils which strongly limits the applicability of their conclusions in most tropical drylands. In a West African agroforestry parkland, we show that an intermediate tree cover maximizes groundwater recharge. Below this optimum, more trees increase water yields, as their beneficial effects on soil hydraulic properties overweight their extra water consumption. Our "optimum tree cover theory" may reconcile the two existing views on forest hydrology and gives new perspectives for research and policy on the hydrological impacts of trees in the landscape.

How much do bark beetles change the annual water cycle of a spruce-fir forest? Frank, J., Massman, W. (*U.S. Forest Service, USA; jfrank@fs.fed.us*; *marilynmartynuk@me.com*), Ewers, B., Williams, D. (*University of Wyoming, USA; beewers@uwyo.edu; dgw@uwyo.edu*).

Bark beetle disturbances in the forests of western North America have been linked to anthropogenic changes in land use and climate and to disruptions in ecosystem function and alterations in the hydrologic cycle of forests. Spruce beetle (*Dendroctonus rufipennis*) outbreaks impact subalpine forests that contribute to the headwaters of many western US watersheds. These epidemics influence annual water vapor fluxes by two distinct processes: (1) transpiration is reduced as attacked trees experience hydraulic failure due to the beetle associated blue-stain fungus and (2) as dead trees drop their needles, canopy leaf area is reduced which alters the dynamics of snow interception and sublimation. In this study, we analyze eddy-covariance flux data collected during a spruce beetle outbreak in a subalpine forest dominated by Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) in southeastern Wyoming, USA. Results suggest that growing season and wintertime water vapor fluxes are equally important for the annual water cycle and that in the first years following the outbreak both evapotranspiration and sublimation were reduced by one-third. Our findings demonstrate that ignoring winter sublimation causes erroneous water budgets and ultimately streamflow predictions.

Floodplain forest restoration: rethinking management legacies for flood mitigation and consumptive water use in flood prone lands. Hubbart, J. (*University of Missouri, USA; HubbartJ@missouri.edu*), Zell, C. (*Geosyntec, USA; czell@geosyntec.com*), Kellner, E., Hooper, L. (*University of Missouri, USA; rekfh3@mail.missouri.edu; lwh356@mail.missouri.edu*).

Conversion of bottomland hardwood forest (BHF) to agricultural (Ag) and urban land uses in the 19th and 20th centuries altered the hydrology of streams, floodplains, and remnant BHF. Broadened and steepened stream channels lead to increased channel instability, accelerated erosion, and reduced floodplain hydrologic connectivity. A study was implemented in 2009 to investigate floodplain processes comparing remnant BHF and Ag sites. 120 m^2 grids were established to estimate soil characteristics up to 100 cm depth (n=302), and surface soil infiltration capacity (n=42). 80 m^2 grids (each site) were implemented with nine equally spaced piezometers to estimate shallow groundwater depth and flow. Results indicate average porosity (n=150) of 0.56 (SD=0.04) and 0.59 (SD=0.04) in agricultural and BHF sites, respectively. Average infiltration capacity was 44 cm/hr (SD=38 cm/hr) and 59 cm/hr (SD=54 cm/hr) in agricultural and BHF sites, respectively. Depth integrated calculations of equivalent depth of soil water (EDSW) were significantly different (CI=99%) at 33.3 cm/m (SD=2.24 cm/m) and 36.9 cm/m (SD=2.68 cm/m) between Ag and BHF sites, respectively. Modeled shallow groundwater (MODFLOW) flow and storage indicate an approximate 3-fold greater hydraulic conductivity, specific yield (40%), and cumulative accepted storage (59%) in BHF relative to Ag. Results demonstrate the benefit of restoring floodplain forests to mitigate flooding and stormwater runoff problems in rapidly developing and flood prone lands.

The impacts of forest changes on flow regimes in the upper reach of Poyang River basin. Liu, W. (*Nanchang Institute of Technology, China; liuwf729@126.com*), Wei, X. (*University of British Columbia, Canada; adam.wei@ubc.ca*).

Forest changes (deforestation or reforestation) in forested watersheds can greatly affect flow regimes, and consequently lead to the changes of aquatic functions and ecosystem integrity. Previous research mainly focused on the impacts of either deforestation or reforestation on flow regimes, with rare studies on both in a single watershed. This paper used the Meijiang watershed (6983 km^2), situated in the upper reach of the Poyang Lake basin as an example to quantify how forest changes (both deforestation and reforestation) consecutively affect flow regimes. Two breakpoints (1968 and 1985) with significant annual streamflow changes were detected, and they were then used to define three distinct periods including the control (1957 to 1967), deforestation (1968 to1984) and reforestation (1985–2006). The paired-year approach was applied to quantitatively assess the impacts of forest

changes on flow regimes. The results showed that the deforestation significantly increased the averaged magnitudes of high flows by 10.2%, increased high flows with greater return periods by 28.3%, advanced the averaged timings of peak flows by 26 days, and extended the durations of high flows over the thresholds by 4 days. In contrast, reforestation changed peak flows with the delay of 21 days in the averaged timings and the reduction of 5 days in the average flow durations and the averaged magnitudes of high flows were decreased by 7.4%. The deforestation has also affected the low flows with 18% reduction in flow magnitudes, 15-day advancing in the average timings, and 16-day longer in flow durations.

Role of land use/cover and water quality on West Nile virus incidence. Noori, N., Kalin, L., Lockaby, B., Magori, K. (*Auburn University, USA; nzn0004@auburn.edu; kalinla@auburn.edu; lockabg@auburn.edu; kmagori@auburn.edu*).

A growing human population accelerates urbanization, forest disturbance and other types of land use/cover (LULC) changes. Such land use changes modify the hydrological processes and water balance of river basins. In particular, the hydrologic and water quality changes often have negative implications for human health. Transmission of vector-borne diseases in urban environments, such as West Nile virus (WNV) fever, is an important global health concern. In this study, to control mosquito-borne diseases, changes in mosquito population under different environmental conditions were monitored. The risk factors underlying WNV incidences considered in this study are LULC changes and shift from forest to urban, and its impact on water quality and hydrologic features. To clarify which specific water chemistry is conducive to breeding the mosquitoes and to determine the mosquitos' reaction under different water quality conditions, a mesocosm experiment was designed. Results showed that phosphate is highly conductive to breeding the mosquitoes associated with WNV. Also, to examine the relationship between LULC and water quality parameters, a watershed scale model was developed in Atlanta metropolitan area, Georgia where an extensive dataset on WNV cases is available. The results from the watershed model and mesocosm experiment will be useful to enhance the ability of predicting WNV risk.

Prediction of channel erosion in watersheds along urban-rural transitions. Serengil, Y., Pamukçu, P. (*Istanbul University, Turkey; serengil@istanbul.edu.tr; pinarpamukcu86@hotmail.com*).

Channel erosion can occur on all land use types and is considered as one of the most challenging forms of erosion. The sediments caused by channel erosion immediately reach the streams and cause many problems in fluvial systems. Urbanization can cause deformation of riparian ecosystems and accelerate channel erosion. Because it is hard to determine the amount and state of channel erosion by physical methods, assessments based on land use and stream conditions is a practical way to make estimates. In this study we analyzed the stream corridor properties together with riparian zone land use and estimated susceptible stream segments with high accuracy (>50%) in 3 large watersheds of Istanbul. Considering that the major erosion processes take place during high flow events we used various rainfall intensities to simulate flow conditions. These simulation estimates were compared with data from stream erosion surveys on 66 channel profiles. We concluded that not the amount of erosion and sedimentation but the susceptible stream segments can be estimated by using riparian and stream conditions together with hydraulic parameters.

Effect of forest changes on river discharge and sediment in a large scale watershed. Zhou, P. (*Guangdong Academy of Forestry, China; zhoupinger@sinogaf.cn*), Liu, Z. (*Heidelberg University, Germany; zhiyong.liu@geog.uni-heidelberg.de*), Zhang, F., Zhang, W. (*Guangdong Academy of Forestry, China; fqzhang001@sinogaf.cn; happyzwq@sina.com*).

The hydrological effect of forest recovery is receiving renewed interest globally. Understanding how forest recovery may affect streamflow is important to both reforestation and long-term water sustainability. In this study, we analyzed 22 years of hydrologic data from 5 stations (1989–2011) and 51 years of meteorological data of 5 stations (1960–2011) located in the Dongjiang river watershed, South China. Time series analysis with Mann-Kendall statistical testing as well as long term data on vegetation cover and NDVI changes based on satellite images were used. Our results showed that no significant streamflow reduction as a result of forest restoration from about 30% forest coverage in 1989 to 57% in 2009. The average annual river discharge with size from 531 km^2 to 35 340 km^2 showed significant linear relationship with watershed area ($R^2 > 0.99$, $P < 0.001$). It also implicated that changes of vegetation cover had no impact on average annual stream flow. However, a more forested watershed showed lower runoff coefficient in wet season while higher runoff coefficient in dry season in addition to significantly reduced the sediments ($P < 0.001$), so forest recovery contributed to soil erosion control and river discharge redistribution from wet season to dry season in this subtropical area.

D-04 Hydroecological studies in the Mediterranean region

Organizers: Yusuf Serengil (Istanbul University, Turkey), Xiaohua Wei (University of British Columbia, Canada) & Ferhat Gokbulak (Istanbul University, Turkey)

Bringing water quantification into the management of semiarid forests: a need for implementing adaptive silviculture and watershed services programs. Del Campo, A., Gonzalez-Sanchis, M. (*Universidad Politécnica de Valencia, Spain; ancamga@upv.es; macgonsa@gmail.com*), Fernandes, T. (*Federal University of Acre, Brazil; tjgfernandes@yahoo.com.br*), Molina, A. (*IRTA, Spain; amolihe@gmail.com*).

Lack of forest management in semiarid forests is common because of the low economic incentives from conventional forest products. This leads to overstocking and consequently to potential biotic and abiotic perturbations such as wildfires, reduced growth, dieback, or unbalanced green/blue-water ratios. In these cases, quantifying silvicultural treatments in terms of water and incorporating this information into forest management would improve either their adaptation to reductions of available water (increase their resilience) or to maintain the ecosystem services such as water provision. This work presents the results of implementing hydrology-oriented silviculture in three semiarid forests of Spain, all of them showing lack of management: Holm oak coppice forest, 60 years old Aleppo pine plantation and dense postfire pine sapling regeneration stand. In all cases, thinning

was performed according to technical criteria and the water cycle (precipitation, interception, transpiration, soil moisture and run-off) monitored for at least one year and then compared with a non-treatment control. In all cases forest management increased both tree-water use (transpiration) and water delivery from the stand as deep infiltration or run-off (blue water). This change in the water cycle components was mainly done at interception's expenses, which decreased up to 25%.

Thinning effects on monthly runoff in a forested watershed. Gökbulak, F., Şengönül, K., Serengil, Y., Özhan, S., Yurtseven, İ., Uygur, B., Özçelik, M. (*Istanbul University, Turkey; fgokbulak@istanbul.edu.tr; sengonul@istanbul.edu.tr; serengil@istanbul.edu.tr*; *sulozhan@istanbul.edu.tr*; *ibrahimy@istanbul.edu.tr; uygurb@istanbul.edu.tr); msaid.ozcelik@istanbul.edu.tr*).

The objective of this study was to investigate the effect of forest thinning on water yield in a forested watershed by using paired watershed method. Two experimental watersheds with similar ecological conditions in Belgrad Forest of Istanbul were used for this purpose. Following a 6-year calibration period from December 2005 to October 2011, a simple linear regression equation was developed between monthly streamflows of two watersheds with a significantly high correlation coefficient (r = 0.95). After 18% of standing volume was removed from one watershed and the other was left untreated as a control, streamflow was monitored for 21 months starting from January 2012 in both watersheds. The change in the monthly runoff was determined as the difference between measured and predicted values using linear regression equation. Average monthly streamflow was about 18 mm and 14 mm in the control and 20 mm and 17 mm in the treatment watersheds for pre- and post-treatment periods, respectively. Paired watershed analysis showed that monthly streamflow was not significantly increased both for the first (3 mm) and the second year (1.5 mm) after harvest. The results revealed that low thinning intensity increased water yield significantly in this forest ecosystem.

Mediterranean vegetation-water interactions: a model comparison at different scales. Ruiz-Pérez, G., Medici, C., Pasquato, M., Gonzalez-Sanchis, M. (*Universitat Politècnica de València, Spain, Spain; guruipr@cam.upv.es; chme1@dihma.upv.es; marpas@posgrado.upv.es; macgonsa@gmail.com*), Molina, A. (*IRTA, Spain; amolihe@gmail.com*), Fernandes, T. (*Federal University of Acre, Brazil; tjgfernandes@yahoo.com.br*), del Campo, A., Francés, F., García Prats, A. (*Universitat Politecnica de Valencia, Spain; ancamga@dihma.upv.es; ffrances@hma.upv.es; agprats@upvnet.upv.es*).

In Mediterranean ecosystems, the catchment water balance is directly affected by land use. Type, density and structure of vegetation determine important hydrological processes. In recent years, considerable efforts have been made to adequately reproduce and predict the interaction between the vegetation and the water cycle under different scales. The present study compares the capability of two models in reproducing the interaction between vegetation and water of a Mediterranean catchment. The models are BIOME-BGC and LUE, and both are validated using field data and satellite imaginary. The comparison shows a better performance of BIOME-BGC reproducing vegetation dynamics. However, BIOME-BGC shows also limitations: the scale, which can be too detailed for watershed studies; the initial physiological parameters, which can be difficult to estimate both spatially and temporary; and the lack of a proper hydrological representation. On the contrary, LUE performs better under watershed scale and it needs less information, but since it is a parsimonious and conceptual model, some vegetation processes are neglected. According to the models comparison, the best model can be selected depending on the scale and the objective of the study. A proper combination of both models would lead to a more suitable model that reproduces accurately vegetation-water interaction.

Improvement of forest management towards optimizing water production in Marmara region of Turkey. Serengil, Y. (*Istanbul University, Turkey; serengil@istanbul.edu.tr*), Tekin, H. (*General Directorate of Forestry, Turkey; hayatitekin@ogm.gov.tr*), Şengönül, K., İnan, M., Yurtseven, İ., Uygur, B., Pamukçu, P. (*Istanbul University, Faculty of Forestry, Turkey; sengonul@istanbul.edu.tr; inan@istanbul.edu.tr; ibrahimy@istanbul.edu.tr; uygurb@istanbul.edu.tr; pinarpamukcu86@hotmail.com*).

One of the major issues in forest-water interactions concerns the management of forest ecosystems to optimize water production in a watershed. In this study we present the results of a regional study towards this objective in Marmara region of Turkey. The region is characterized by rapid urban sprawl together with industrialization that accelerates water demands. The major forest types in the region are broadleaved stands that lay over mild topography. The precipitation is between 600–1200 mm and runoff coefficients of the watersheds in the region are quite variable, ranging from 20 to 60 percent. The reservoir or lake watersheds that we classified as significant cover a substantial portion of the region. In the field phase of the study we determined sampling points and measured water related stand parameters like leaf area index, litter layer properties, and standing timber volume. We also conducted stream corridor assessments to determine the stream conditions in relation with forest ecosystems. The NDVI calculations were made on SPOT images of 2.5 meters resolution. With this data we delineated the subregions where there is potential to increase water yield up to 10 percent.

Timber harvest effects on selected physical water characteristics in a forested watershed. Uygur, B., Gökbulak, F., Serengil, Y., Şengönül, K., Özhan, S., Yurtseven, İ., Özçelik, M. (*Istanbul University, Turkey; uygurb@istanbul.edu.tr; fgokbulak@istanbul.edu.tr; serengil@istanbul.edu.tr; sengonul@istanbul.edu.tr; sulozhan@istanbul.edu.tr; ibrahimy@istanbul.edu.tr; msaid.ozcelik@istanbul.edu.tr*).

The purpose of this study was to investigate thinning impact on physical water quality parameters with a paired watershed study in a broadleaf forest ecosystem. After a 70 months monitoring period starting from December 2005, calibration equations were established between control and treatment watersheds for stream water parameters including pH, color, turbidity, electrical conductivity, suspended sediment concentration, water and air temperatures, after which 18% standing timber volume was harvested from treatment watershed. Streamflows were also monitored for the same parameters in both watersheds during the 21 months treatment period from January 2012 to September 2013. Changes in the mean monthly streamwater values were determined as the differences between measured and estimated values derived from calibration equations. Results showed that forest thinning caused 11.6 μS/cm increases in the average monthly electrical conductivity, 5 NTU in turbidity, 0.02 mg/l in suspended sediment concentration, and 1.1 °C in the maximum air temperature and 0.5 °C decrease in the minimum air temperature but did not influence average monthly pH, color, and temperature values in stream water. Results reveal that forest management activities have important impacts on stream flow characteristics in the forested watersheds.

D-05 Managing forests and forest uses to protect and provide clean water

Organizers: Richard Harper (Murdoch University, Australia) & Jean-Michel Carnus (INRA, France)

Quantifying tradeoffs of water and carbon among PES-sponsored reforestation strategies in seasonally-dry Costa Rica. Abelleira, O. (*University of Idaho and CATIE, USA; ojabelleira@gmail.com*), Gunter, S. (*Thünen Institute of International Forestry and Forest Economics, Germany; sgunter@catie.ac.cr*), Marshall, J. (*University of Idaho, USA; jdm@uidaho.edu*), DeClerck, F. (*Bioversity International, France; f.declerck@cgiar.org*), Fremier, A. (*University of Idaho and Washington State University, USA; alex.fremier@wsu.edu*).

In seasonally-dry Costa Rica, reforestation with secondary forests and *Tectona grandis* plantations are eligible for Payment for Ecosystem Services (PES) yet their relative capacity to provide or not limit actual ecosystem services is unclear. Plantations generate income and sequester carbon but they consume soil water. This tradeoff with water use may be undesirable to residents due to seasonal water scarcity. We aim to quantify ecosystem service tradeoffs of water and carbon in secondary forests and *Tectona grandis* plantations. We are using six paired secondary forest and plantation sites to conduct plot-level measurements of tree transpiration water fluxes with heat-ratio method sap flux sensors, and of woody biomass accumulation by tree basal area increment. Across all sites, we have found the highest sap velocity rates in *Tectona grandis* compared to all 24 secondary forest species except for *Caesalpinia eriostachys*, an N-fixing species exhibiting comparable rates (~40 cm/hr). Plot-level transpiration estimates will be used to parameterize the InVEST water yield model, where contrasting scenarios of forest cover will be used to assess concomitant changes in catchment water yield. Scaling results from plot to catchment-level will improve our capacity to inform policymakers about ecological and social impacts of PES in the seasonally-dry tropics.

Importance of forests to water quality in the United States. Brown, T., Froemke, P. (*U.S. Forest Service, USA; tcbrown@fs.fed.us; pfroemke@fs.fed.us*).

Water quality is a continuing national concern in the United States, in large part because containment of pollution from nonpoint (diffuse) sources remains a challenge. Our previous work on the risk of water quality impairment across the over 15 000 fifth-level watersheds in the contiguous 48 states of the U.S. shows the importance of forests, and especially protected forests, in maintaining high water quality. We summarize those findings and then take a detailed look at the 3160 sixth-level watersheds in the State of Colorado. For those watersheds, we show the location of water quality stressors (including roads, mines, housing, livestock grazing, and agricultural cultivation) in relation to the presence of forest cover. We then evaluate the impact of land cover and water quality stressors on downstream water quality for a series of water quality measurement points located throughout the State. Further, we address trends, showing that although recent trends in some stressors are encouraging, the prospect of further substantial population and housing growth indicates continued pressure on water quality, thus highlighting the importance of maintaining forest vegetation.

Optimising water co-benefits from forest carbon mitigation. Harper, R., Sochacki, S., Ruprecht, J. (*Murdoch University, Australia; r.harper@murdoch.edu.au; s.sochacki@murdoch.edu.au; jruprecht01@gmail.com*).

Forests can contribute to climate change mitigation through (1) protection and enhancement of existing carbon stocks, (2) increasing carbon stocks and (3) substituting forest products for energy production or energy intensive building materials. Payments for forest carbon mitigation are occurring under various arrangements in different jurisdictions and the scale of future activity could be large. The likely impacts of broad-scale forest-mitigation on water yield and quality are not understood. Various approaches to water management using carbon mitigation have been examined in south-western Australia, a region with a drying Mediterranean climate and limited potable water supplies. The impacts on water yield and water quality of (1) deforestation and thinning of natural forests, and (2) reforestation of farmland have been studied. Approaches to reforestation have concentrated on *Eucalypts* and *Pinus* spp. and include total reforestation of watersheds, integration of strips of trees with farmland and 3–5 year rotations of trees interspersed with cereal cropping. Mitigation has been through both sequestration and bioenergy production and has occurred on both productive and abandoned land. Forest cover profoundly affects water yield and quality, not only through changes in watershed water balance, but also on the release of dissolved salts into the landscape.

Intensified forestry in Sweden: How will it affect the sustainability of forest soils and waters? Laudon, H. (*Swedish University of Agricultural Sciences, Sweden; Hjalmar.Laudon@slu.se*).

Intensified forestry through additions of nutrients, faster growing tree varieties, more intense harvest practices, and a changing climate all have the potential to increase forest production in Sweden, thereby mitigating climate change through carbon sequestration and fossil fuel substitution. However, the effects of management strategies for increased biomass production on the soil resources and water quality at landscape scales also have the risk to affect the long-term sustainability of soils and waters. This includes effects of fertilization on the long-term weathering and supply of base cations, consequences of changing mineral availability for future forest production, and effects on the landscape hydrology. Also, because soils and surface waters are closely connected, management efforts in the terrestrial landscape will potentially have consequences on water quality and the ecology of streams, rivers, and lakes. Here, I will discuss some of the most pertinent questions related to how an increased forest biomass production in Sweden could affect soils and surface waters, and how contemporary forestry goals can be met while minimizing the loss of other ecosystem services. The main conclusion of this is that the development of management plans to promote the sustainable use of soil resources and water quality, while maximizing biomass production, will require a holistic ecosystem approach, and needs to be placed within a broader landscape perspective.

Long-term forest planning taking stream water quality into consideration. Lundström, J., Öhman, K., Ågren, A., Tiwari, T., Laudon, H. (*Swedish University of Agricultural Sciences, Sweden; johanna.lundstrom@slu.se; karin.ohman@slu.se; anneli.agren@slu.se*; *tejshree.tiwari@slu.se; Hjalmar.Laudon@slu.se*).

Forestry has fundamental impacts on water quality in the boreal landscape. As a consequence it is important to consider how to reach water quality goals as well as how to achieve economic goals. Water chemistry in a stream is strongly affected by the

environment in the immediate surroundings, which means that forestry actions in the riparian zone have a large influence on water quality. The objective of this study is to develop a practical tool that can be used to make trade-off analyses between the economic values related to timber production and the effect that different forestry measures such as retaining buffer zones in the forest closest to the streams have on water quality. We will present data from a case study located in northern Sweden where we determined the effects of different buffer zone management scenarios on forest economics by using new insights from wet area maps. Since we considered hydrological information we were able to design more effective buffer zones both from an ecological and economical perspective. The decision tool could be used to evaluate the economic consequences of different forestry restrictions.

Forests and water: contemporary science and its relevance for community forestry in the Asia-Pacific region. Pairojmahakij, R., Mohns, B., Gritten, D., Bampton, J. (*The Center for People and Forests (RECOFTC), Thailand; regan@recoftc.org; bernhard.mohns@recoftc.org; david.gritten@recoftc.org; james@recoftc.org*).

There is long running and continuing discussions on the hydrological impact of forest management. In the context of intensifying competition between different land-uses throughout Asia, growing impacts of climate change, and increased devolution of forest management, water management is becoming an important consideration in the field of community forestry. Through a comprehensive literature review and field-based assessments the paper seeks to consolidate the hydrological impacts of forest management with a view to informing both policy makers and local communities on management strategies of forest landscapes for optimal water yields. In addition to presenting best practices, the paper also explores tradeoffs between afforestation/reforestation activities and potential negative impacts on water yields. The paper highlights where 'popular narratives' related to reforestation and increased water flows have been pervasive in regional policies and not only are unsupported by hydrological science, but may be in contradiction to it, with implications for policy and local ecologies and rural communities. These communities are often highly dependent on rural landscapes to meet livelihood needs. The paper proposes recommendations for policy makers and practitioners regarding hydrological aspects of community forestry in order to ensure livelihoods and adaptive capacities of local communities are supported by appropriate policies.

After the smoke clears: evaluating post-fire erosion risk and rehabilitation options. Robichaud, P., Elliot, W. (*U.S. Forest Service, USA; probichaud@fs.fed.us; welliot@fs.fed.us*), Wagenbrenner, J. (*Michigan Technological University, USA; jwwagenb@mtu.edu*).

The number, size, severity, and cost of wildfires worldwide continue to increase in part due to climate change. More people are living in wildland areas thus increasing the risk to public safety, homes, roads, infrastructure, water quality, and valued natural resources from fire and secondary fire effects like flooding and erosion has also increased. Major advancements in our knowledge of postfire assessments, risk analysis and rehabilitation treatment effectiveness have improved our ability to understand the consequences and outcomes that occur in the postfire environment. Various governments have modeled their postfire risk assessment based on the United States "Burn Area Emergency Response" program. To make the best use of limited rehabilitation resources, an assessment of fire effects on soils is needed to identify those burned areas that are most prone to increased flooding and erosion. Justifying these treatments is necessary to obtain government funding for installing postfire hillslope and road treatments which will protect public safety and valued resources from probable damage or loss. The tools include field guides, protocols, predictive soil erosion models and syntheses which are appropriately scaled, accessible, and formatted for ease of use in decision-making and assessment reports.

In-stream *E. coli* bacteria loading from forest and pasture land uses in the Attoyac River, East Texas, USA. Schwab, S., McBroom, M. (*Stephen F. Austin State University, USA; schwab.sarahe@gmail.com; mcbroommatth@sfasu.edu*).

Escherichia coli bacterial monitoring of the Attoyac River in East Texas, USA was conducted. Bacteria source tracking was employed to differentiate potential *E. coli* sources. Once sources were identified, loading by land cover type was allocated using the SELECT model. Since wildlife species were the predominate source (particularly from invasive wild hogs, *Sus scrofa*), this lead to the somewhat counterintuitive conclusion that greater bacterial loading may result from forested areas than pastures where cattle are grazed. This in part highlights the efficacy of grazing best management practices. However, additional analysis reveals that the parameter assumptions in the SELECT model may not adequately account for wildlife dynamics. This further illustrates the potential impacts of wildlife, especially invasive species, on water quality. Finally, the utility of *E. coli* as a water quality standard is evaluated, given the potential for bacterial longevity re-suspension within the water column.

Long-term response of streamflow and groundwater to timber harvesting and declining rainfall in a small forest catchment in south-western Australia. Stoneman, G., Kinal, J. (*Department of Parks and Wildlife, Australia; geoff.stoneman@dpaw.wa.gov.au; joe.kinal@dpaw.wa.gov.au*).

The hydrologic impact of thinning was investigated using a paired-catchment study over 39 years from 1975 to 2013 in a small *Eucalyptus marginata* forest catchment. Thinning reduced forest density by about two-thirds, with subsequent recovery such that by 28 years after thinning forest density was slightly less than before thinning. Streamflow increased from 1 per cent of rainfall before thinning to a peak of 13 per cent of rainfall 9 years after thinning and progressively declined to 0.4 per cent of rainfall 30 years after thinning. Groundwater level at a midslope location increased, relative to a control, by a maximum of 12.5 m 11 years after thinning and then progressively declined to be 10.5 m higher 30 years after thinning. Groundwater level at a valley location increased, relative to a control, by a maximum of 6.9 m 23 years after thinning and then progressively declined to be 6.1 m higher 30 years after thinning. The increase in streamflow in response to thinning this catchment persisted for longer than in other *Eucalyptus marginata* forest catchments and is attributed to herbicide treatment of coppice. The period of streamflow increase was coincident with the period where groundwater level in the valley was elevated and supports earlier research on the role of groundwater in amplifying streamflow generation.

Conversion of tropical rainforests to oil palm and rubber increased flooding in Peninsular Malaysia. Tan-Soo, J., Vincent, J., Pattanayak, S. (*Duke University, USA; jt65@duke.edu; jrv6@duke.edu; subhrendu.pattanayak@duke.edu*), Ahmad, I., Adnan, N. (*Forest Research Institute Malaysia, Malaysia; ismariah@frim.gov.my*; *norliyana@frim.gov.my*).

Programs that seek to protect hydrological services by paying landowners to conserve forests have proliferated. Yet, the ability of tropical forests to mitigate flooding continues to be debated. Our analysis of comprehensive flood data from 35 river basins in Peninsular Malaysia indicates that converting tropical forests to oil palm and rubber during 1984–2000 increased the number of days flooded during the wet season. Prior difficulty in detecting flood mitigation by tropical forests may have resulted from use of datasets that included only large floods instead of the full range of floods. Oil palm and rubber are lucrative crops, but assessments of their net economic benefits must consider the reduced value of forest ecosystem services associated with biodiversity loss, carbon emissions, and, evidently, increased flooding.

Modelling the effects of forest management on water quality in Sweden. Zanchi, G., Akselsson, C., Belyazid, S., Yu, L. (*Lund University, Sweden; giuliana.zanchi@nateko.lu.se*; *cecilia.akselsson@nateko.lu.se; salim@belyazid.com; lin.yu@cec.lu.se*)**.**

Forest management strategies affect the nutrient cycling in forest ecosystems. As a consequence, the chemistry of the soil solution and the nutrient loads in streams draining from forests change with the management activities in place. This study evaluates the effects of forest management practices on water chemistry in the soil solution and runoff of forests in Sweden by using the mechanistic model ForSAFE. The model simulates water chemistry as a balance between plant uptake, decomposition, immobilization, weathering, cation exchange and nutrient input and outputs through water flows. The recent inclusion of lateral water flows in the model allows a better understanding of the changes of runoff chemistry at the small-catchment level. Model results are validated against long-term measurements. The study shows that forest management can affect nutrient leaching, export of dissolved organic matter and water acidification. For instance, increased nutrient loss is simulated after clear-cuts while residue removals can reduce nutrient export. The study also highlights that the effect of management on forest water resources varies in different regions in Sweden. Moreover, the study shows how dynamic modelling can support the identification of management strategies that comply with environmental goals.

Forestry reserves and the regulation of water quality and algae structure of ponds in a sub-saharan region of Africa. Zongo, B., Boussim, I. (*University of Ouagadougou, Burkina Faso; azongo@hotmail.fr; ijboussim@gmail.com*).

Biodiversity conservation is a communal concern for humanity according to Convention on Biological Diversity. In Burkina Faso, several created forestry reserves contribute to the conservation of biodiversity in the country. Ponds of reserves as well as those outside reserves are numerous and their resources are particularly used by rural populations and cattle in sub-saharan regions of Africa. This study has been conducted in the soudano-sahelian zone of Burkina Faso, particularly in ponds of protected areas and those of unprotected areas. Investigations have been carried out during rainy seasons (July to September) of 2007 and 2008 and consisted to measure physico-chemical parameters and algae community structure in the two kinds of areas in order to evaluate the contribution of "forests" to the maintaining of water quality. Results show ponds in "forests" have lower sizes and higher transparency than ponds located out of the "forests". Salinity, nutrients and water pH were rather low in reserves. Diversity and biomass of algae were higher out of the reserves. Forests management and diversity conservation is extremely important for water quality regulation and then contribute to enhance goods and services of tree plants. More actions involving local people are also needed for better biodiversity conservation.

Posters

Towards optimized buffer zones – digital terrain indices as a tool for predicting the most sensitive areas. Ågren, A. (*Swedish University of Agricultural Science, Sweden; anneli.agren@slu.se*), Kuglerova, L. (*Umeå University, Sweden; lenka.kuglerova@emg.umu.se*), Arp, P., Ogilvie, J. (*University of New Brunswick, Canada; arp2@unb.ca; jae.ogilvie@unb.ca*), Laudon, H. (*Swedish University of Agricultural Sciences, Sweden; Hjalmar.Laudon@slu.se*).

Forestry practice affects water quality in several ways and hence forests should be managed such as to minimize the effects on surface waters. Heavy vehicles on forest soils can cause soil disturbance, i.e. rutting, which in turn can lead to leakage of unwanted substances leaking into the surface waters. The wet, riparian soils along streams and lakes have a lower bearing capacity and are therefore more susceptible to rutting. A new high resolution digital elevation model enables us, for the first time, to model and map the riparian wetlands. In a Swedish case study we have calculated several digital terrain indices, in different scales, to predict the wet areas along streams and lakes. The newly developed cartographic depth-to-water index could predict the distribution of the wet riparian soils in high resolution (4 m^2) with an accuracy of ca. 90%. The case study showed that the optimum scale for the calculations depended on local conditions, especially soil texture. Recently, it has also been shown that seepage areas along stream channels are hotspots for plant species richness. These hot-spots can also be mapped using this new technique. Using the new maps of riparian soils, buffer zones can be optimized to protect the most sensitive areas.

Interception loss, throughfall and stemflow in Tamaulipan thornscrub at species level in northeastern Mexico. Cantu Silva, I., Gonzalez Rodriguez, H. (*Universidad Autonoma de Nuevo Leon, Mexico; icantu59@gmail.com; humberto.gonzalezrd@uanl.edu.mx*), Kubota, T. (*Kyushu University, Japan; kubot@agr.kyushu-u.ac.jp*).

Throughfall and stemflow measurements in six thornscrub species plantations and in an undisturbed thornscrub plot were carried out between 2005–2013 in northeastern Mexico. Troughs and spiral-type stemflow gauges were used for throughfall and stemflow measurements. Interception losses of the canopy were estimated at 15, 18, 22, 25, 33, 34 and 38% for *Acacia rigidula*, *Acacia berlandieri*, *Diospyros texana*, *Prosopis laevigata*, *Helietta parvifolia, Ebenopsis ebano* and the Thornscrub plot, respectively. Linear regression analysis for interception loss in the seven canopy types showed correlation coefficients from r=0.967 (Thornscrub) to r=0.61 (*A. rigidula*). Stemflow values ranged from 0.23% (*P. laevigata*) to 3.29% (*E. ebano*), and the canopy storage values varied from 0.03 mm (*H. parvifolia*) to 0.19 mm (*A. berlandieri)*. The architectural features of the canopy and leaf

traits are different between species and may influence the interception loss. *A. rigidula* and *A. berlandieri* have the most permeable canopies and therefore the interception losses are lower. The *E. ebano* and Thornscrub intercept more than twice in relation to the *Acacia* canopies. Results suggest that the management of thornscrub, as a resource for water conservation, may play an important role in semiarid regions where water is a limiting factor.

Priority areas for water recharge in temperate forest ecosystems in Mexico. Chávez-González, H., González-Guillén, M., Hernández de la Rosa, P., Escalona-Maurice, M. (*Colegio de Postgraduados, Mexico; chavez.honoria@colpos.mx; manuelg@colpos.mx; pathr@colpos.mx; mescalona@colpos.mx*)**.**

Deforestation and degradation of forest ecosystems put at risk their productivity and permanence, decreasing the ability to recharge aquifers and other environmental services. This, coupled with the limitation of resources and high costs for conservation of large areas, requires the identification of priority areas for conservation. In light of the observed fragmentation of the forestry areas in the Sierra Norte of Puebla at the central region of Mexico, this study was conducted to determine priority areas of water recharge through: (1) detecting land use changes (1986–2010) and the biophysical, social and economic patterns that determine such changes using satellite images, GIS and a probabilistic model. The model, together with demographic information, allowed project changes (2010–2030) of land use in the study area; (2) Identify areas with potential for aquifer recharge throughout criteria and indicators, spatial information and Multicriteria Analysis; and (3) identify priority areas subject to be conserved with the use of GIS. Promote payment schemes for environmental services and land-use planning, are two of the viable management and conservation strategies. The priority areas should be the basis for the implementation of public policies for conservation of natural resources in the studied region.

The effect of plant cover on alimentation areas on spring water chemistry in South of Poland. Małek, S. (*University of Agriculture in Krakow, Poland; rlmalek@cyf-kr.edu.pl*), Żelazny, M. (*Jagiellonian University, Poland; miroslaw.zelazny@uj.edu.pl*), Astel, A. (*Pomeranian University, Poland; astel@apsl.edu.pl*), Siwek, J. (*Jagiellonian University, Poland; janusz.siwek@uj.edu.pl*), Jasik, M., Krakowian, K. (*University of Agriculture in Krakow, Poland; michal.jasik@op.pl; krakowian.k@gmail.com*), Wolanin, A. (*Jagiellonian University, Poland; anna.wolanin@uj.edu.pl*).

In the Western Carpathians (southern Poland), where Norway spruce dieback and changes of plant species composition have occurred, it was expected that the plant cover changes might affect spring water chemistry. Direct fieldwork was done on catchments: in the Silesian Beskid Mts, in the: Gorce, Świętokrzyski and Tatra National Park with different bedrock and plant species composition. Measurements were made of pH and electrolytic conductivity of spring water, and samples were transported to the laboratory, where they were filtered and the content of cations and anions determined by means of the Dionex 320, 2000 and 5000 gas chromatographs. The data obtained were verified and treated by the use of multidimensional data mining techniques in order to recognize mutual dependence between spring water chemistry and forested as well as deforested areas. Results showed that the presence of mixed stands caused an increase in pH values and an increase in calcium and magnesium concentrations compared to the spring waters of Norway spruce monocultures growing on the same geological bedrock. Higher content of base cations were noted in spring waters on afforested areas compared to samples obtained from deforested sites as well as from mountain meadow.

Effects of historic forest disturbance on water quality and flow in the Interior Western U.S. Matyjasik, M. (*Weber State University, USA; mmatyjasik@weber.edu*), Moisen, G. (*U.S. Forest Service, USA; gmoisen@fs.fed.us*), Combe, C., Hathcock, T., Mitts, S., Hernandez, M. (*Weber State University, USA; chelseycombe@mail.weber.edu; teborama@gmail.com; stephmitts93@hotmail.com; mhernandez@weber.edu*), Frescino, T., Schroeder, T. (*U.S. Forest Service, USA; tfrescino@fs.fed.us; tschroeder@fs.fed.us*).

Water quality and flow is affected my many complex factors in the Interior Western U.S. While many studies focus on individual water parameters response to a limited number of changing conditions, little work looks at long term effects of diverse forest disturbances on a broader array of water quality and flow metrics. The U.S. Forest Service Forest Inventory and Analysis program (FIA) is responsible for inventorying status and trends in forested ecosystems nationwide. FIA is currently partnered with NASA and others to develop nationwide maps of forest disturbance annually using the historic Landsat data record. Historic forest disturbance maps have the potential to provide new insights into water resources problems. In this paper, we synthesize the existing literature relating water and forest disturbances. Using temporally dense water samples analyzed by both the Environmental Protection Agency and U.S. Geological Survey in several focus areas in the Interior West, we indicate spatial temporary trends illustrating how forest disturbances affect surface water concentrations of nitrogen, phosphorus, potassium, magnesium, total dissolved solids and suspended solids in conjunction with stream flow dynamics. Presented trends are used to make recommendations of possible use of historic forest disturbance maps coupled with FIA data to predict future effects of forest disturbance on water.

Environmental fragility of the Iguaçu River watershed, Paraná, Brazil. Melo, L., Dalla Corte, A., Klein Hentz, Â., Sanquetta, C., Doubrawa, B. (*Federal University of Paraná, Brazil; laracmelo@gmail.com; anapaulacorte@gmail.com; angelakhentz@gmail.com; carlos_sanquetta@hotmail.com; betaaa_d@yahoo.com.br*).

This work aimed to evaluate the degrees of fragility potential (FP) and emerging fragility (EF) at the Iguaçu River watershed, Paraná, Brazil. The following variables were used to determine the fragility: slope class, soil class, soil use and the presence of riparian strips, according to the methodology proposed by Ross (1994). The thematic maps were analyzed in a Geographic Information System (GIS) and their combinations using ArcGis software. The result was expressed in classes of fragility: very low, low, moderate, high and very high. It was determined that 76% of the watershed fell under the FP very low, low and moderate, while 21.95% are areas of high or very high FP. For the FE, a similar pattern of distribution was observed. The sum of very low, low and moderate corresponds to 90% of the area and 7.5% represents the high or very high classes. It was noted that the very high class of FE was distributed mainly on floodplains, limiting condition for the use of the soil, because of the unstable structural features, with significant erosion from water. Enhancement of vegetation cover or soil conservation practices are recommended, considering the higher propensity to vulnerability.

Riparian forests in Pitangui River: a highly heterogeneous landscape in southern Brazil. Moro, R. (*UEPG, Brazil; moro.uepg@gmail.com*), Pereira, T. (*Federal University of Paraná, Brazil; tkpereira@live.com*), Lima, C. (*Ponta Grossa State University (UEPG), Brazil; chrisnied@gmail.com*)**.**

Landscapes in Paraná Sate, southern Brazil, are marked by highlands delimited by escarpments that forced antecedent rivers to carve their courses against the emerging plateaus. The Pitangui watershed (927 km^2) presents a typical heterogeneous landscape of foodplains in the First Plateau (FP) that turns into canyons and waterfalls in the Second Plateau (SP). To create a riparian landscape model, native forests along the flooding limits of the lotic channel were analyzed by means of SPOT 5 orthoimages (2005) with a 5 meter spatial resolution, and by ArcGIS 9.3, Envi 4.7, Guidos 1.3, and Fragstats 2.0 software. Landscape metrics and statistical treatment were used to characterize landscapes and patches. Both FP and SP riparian areas include a large number of small rounded patches and relatively few large linear areas. In FP there are 91 core areas linked by 69 corridors, plus 19 islets, while in SP there are 60 core areas linked by 14 corridors, plus 145 islets. Assuming a 30 meter buffer, forests under edge effect perform 60% in FP and 75% in SP. These patterns differ in relation to relief ($p < 0.44$) and the SP patches isolation are notable. Landscape analyses such as this can be used guide watershed conservation strategies.

Restoring the eco-hydrological function of the forest on a small karst island: case study on Nusa Penida Island, Bali (Indonesia). Narendra, B.H., Setiawan, O. (*Ministry of Forestry, Indonesia; budihadin@yahoo.co.id; o_setiawan@yahoo.com*).

This paper describes the potential of reforestation to restore forest eco-hydrological function on a degraded karst island based on land characteristics and field trial experiences. Nusa Penida, a small karst island lying off the southeastern coast of Bali, formerly was covered by primary forest and marshland but gradually it becomes barren and dry agriculture land because of community activities. The conversion effects on the decline of forest eco-hydrological function in absorbing and storing the rain water indicated by increased incidence of water scarcity and flash flood. The survey showed that the capability of the land was low associated with Mediterranean soil type, hilly topography, and dry climate with low annual rainfall. To recover the forest-land productivity and its eco-hydrological function, those barren lands are urgently needed to be reforested. Small scale trials done using neem *(Azadirachta indica)* tree as famous local species showed that organic matter enrichment through cattle manure treatment was an effective way to improve the soil condition and resulting better tree growth. Water constraints during application on a wide scale potentially can be overcome by applying rain water harvesting technologies, soil and water conservation, and establishing underground water tapping and constructions to utilize the abundant underground karst stream flows.

Enabling environmental excellance in Alberta through LiDAR derived wet areas mapping. White, B. (*Government of Alberta, Canada; barry.white@gov.ab.ca*), Ogilvie, J., Arp, P. (*University of New Brunswick, Canada; jae.ogilvie@unb.ca; arp2@unb.ca*).

Alberta continues to face unprecedented land use challenges due to an ever increasing population and an ever increasing demand for energy and forest resources. Sustainability of Alberta's aquatic habitats and forests is at risk. Innovative planning solutions that ensure positive outcomes are actively sought by Albertans. Accordingly, the province has partnered with researchers at the University of New Brunswick since 2004 to develop and test the effectiveness of a depth-to-water table mapping tool. This initiative, recently honoured for innovation excellence by the Alberta Science and Technology Foundation and the Alberta Emerald Foundation, is led by Alberta Environment and Sustainable Resource Development and spans 22 million hectares. Spatially explicit data-sets predict locations of small water bodies and wet, saturated soils which are currently not known to resource planners. Data-sets also identify drought prone areas where soil moisture may limit ecological processes including those that define forest productivity. Alberta's process relies upon airborne LiDAR data to produce maps with a resolution of 1 m. This initiative is transformational by influencing government policy and contributing to industry competitiveness and social license. Wet areas data-sets are also making a significant contribution to research in the areas of biodiversity, growth and yield, forest structure and reclamation.

D-06 Role of disturbance in maintaining and stimulating aquatic biological diversity in temperate forest ecosystems

Organizer: Robert Danehy (National Council for Air and Stream Improvement, USA)

Aquatic responses to forest disturbances: stream chemistry from U.S. Forest Service Experimental Forests. Argerich, A. (*Oregon State University, USA; alba.argerich@oregonstate.edu*), Johnson, S. (*U.S. Forest Service Research, USA; sherri.johnson@fs.fed.us*).

Water quality is a major influence on aquatic ecosystems, species composition and the complexity of their interactions. Forest disturbances, a result of natural events, forest management practices, or their interactions, have been shown to impact stream processes with implications for downstream water quality, local habitat, and therefore, biological diversity. Here we present water quality responses to differing types of disturbances in forested headwater streams at USFS Experimental Forests spanning the United States. Specifically, we examine whether stream chemistry responses to natural disturbances and forest harvest are similar in magnitude and duration, and consider the extent to which these responses might affect aquatic biota and aquatic processes such primary production. Overall, stream nitrate concentrations immediately increased after disturbances however the magnitude and duration of the responses varied across the continent and with type of disturbance. Elevated nitrate concentrations lasted years to decades, possibly responding to speed of vegetation recovery, geology and to differing background levels of nitrogen availability. This provides foundational knowledge to inform management practices and to help managers and policy makers understand and compare responses from managed and naturally disturbed basins.

Natural and anthropogenic disturbance influences on aquatic biological diversity in Western Oregon. Danehy, R. (*National Council for Air and Stream Improvement, USA; bdanehy@ncasi.org*), Moldenke, A. (*Oregon State University, USA; moldenka@science.oregonstate.edu*), Owen, S. (*Terra Aquatica Environmental, LLC, USA; sara.owen@swbell.net*), Lester, G. (*EcoAnalysts, Inc, USA; glester@ecoanalysts.com*), Justice, T. (*Weyerhaeuser Company, USA; Tiffany.Justice2@weyerhaeuser.com*).

We examined aquatic insect diversity in small streams of forested landscapes in western Oregon using published work and three data sets. Two comprehensive studies are the likely upper end of richness in this ecoregion with aquatic insect richness of 325 (1 site) and 425 taxa (small watershed). We investigated two disturbance types: one natural, debris flows, and one anthropogenic, canopy removal. The three studies had overall richness of 159, 165, and 192 taxa with site richness from 34 to 80 taxa. Taxonomic resolution was similar with the inclusion of Chironomidae to genus or species. Rare species were significant contributors as 20–30% of taxa were found at only one site within each study. We paired eight disturbed sites with a neighboring site. In all pairs, disturbed sites had higher overall and Chironomidae richness. EPT richness was also higher at disturbed sites in all but one pair. We conclude, due to the predominance of rare species, efforts to measure landscape aquatic richness, when targeting small streams, needs to be both intensive and extensive. Secondly, richness is not the best indicator to evaluate disturbance impacts, as assemblage trophic organization and function provide a more comprehensive representation of disturbance effects and recovery.

How does confounding impacts of flood and forest thinning alter benthic macroinvertebrate communities in Japanese headwater streams. Gomi, T., Watanabe, Y., Sakai, M. (*Tokyo University of Agriculture and Technology, Japan; gomit@cc.tuat.ac.jp; 50012539007@st.tuat.ac.jp; boundary.0008@gmail.com*).

We investigated that hydrological response and benthic macroinvertebrate communities in pre-, during-, and post-thinning periods in three headwater catchments draining 20 to 50 yrs Japanese cypress *(Chamaecyparis obtusa*) and cedar (*Cryptomeria japonica*) plantation. The drainage areas ranged from 2.5 to 17.1 ha with 18% of mean stream gradient and < 1 m of wetted channel width. One catchment was subjected to 50% stripe thinning, while the other catchments were remained as references. We monitored runoff and suspended sediment transport in nested catchments. We also collected three benthic samples at pools and riffles within 50 m channel reaches of each stream. Both base flow and peak flow increased some of the nested catchments depending on dominant runoff pathway. Total density of benthic invertebrates in all streams during the thinning period decreased 53 to 90% compared to that in the pre-thinning period. Meanwhile in the post-thinning period, the density of benthic invertebrates in the thinning catchment was 2 to 5 fold greater than that in the reference streams. Changes in runoff and riparian forest due to forest thinning altered benthic macroinvertebrate community structures depended on the timing of the disturbances and the life cycle of benthic invertebrates.

Emulating natural disturbance in riparian forests to enhance shoreline and aquatic biodiversity. Kreutzweiser, D. (*Canadian Forest Service, Canada; dave.kreutzweiser@nrcan.gc.ca*), Sibley, P. (*University of Guelph, Canada; psibley@uoguelph.ca*), Naylor, B. (*Ontario Ministry of Natural Resources, Canada; brian.naylor@ontario.ca*), Muto, E., Gunn, J. (*Laurentian University, Canada; emuto@shaw.ca*); *jgunn@laurentian.ca*), Richardson, J. (*University of British Columbia, Canada; john.richardson@ubc.ca*).

The emulation of natural disturbance (END) is a leading paradigm for modern, ecosystem-based forest management in North America. Applying END principles to forest watersheds will have implications for aquatic ecosystems because varying levels of intentional riparian (shoreline) harvesting are promoted as a management tool to emulate natural shoreline forest disturbance patterns. Until recently, the primary goal of creating shoreline disturbance by harvesting has been to increase riparian habitat complexity in support of terrestrial biodiversity. But our understanding of land/water linkages in forest watersheds combined with general disturbance ecology suggests that periodic large-scale forest disturbances, including riparian (shoreline) forests, may be required for long-term sustainability of aquatic ecosystems. We provide a theoretical basis and empirical example of how watershed and riparian forest disturbances have implications for aquatic habitats and their biotic communities. We use responses to natural disturbances (fire in boreal forest catchments) as ecological targets and benchmarks for emulation strategies. Low-order streams in 12-year post-burn catchments had distinct water chemistry, higher sediment loads, denser, more diverse riparian vegetation, and supported richer invertebrate communities than streams in reference catchments. Streams in logged catchments with riparian buffers tended to be intermediate. We discuss implications for applying END principles to boreal forest watershed management.

The post-wildfire response of Fishtrap Creek, British Columbia: lessons for emulation of natural disturbance as a forest management approach. Moore, D., Eaton, B. (*University of British Columbia, Canada; dan.moore@ubc.ca; brett.eaton@ubc.ca*).

In August 2003, the Maclure Fire burned an area of over 260 km^2 north of Kamloops, British Columbia. The burned area included over 60% of the catchment area for Fishtrap Creek, which drains an area of 170 km^2 at the location of a hydrometric weir. The fire burned a substantial portion of the upland plateau that dominates the catchment; the fire also killed almost all of the trees in the riparian zone of the mainstem channel. Following the fire, a substantial portion of the plateau area was subjected to salvage logging. Detailed monitoring of Fishtrap Creek began in autumn 2003, and has continued to present. Studies have documented the responses of streamflow, stream temperature, suspended sediment concentrations, bedload transport, in-stream wood and channel morphology. This presentation will review these responses to date, and also provide an update on the development and application of numerical models for predicting the longer-term response of the catchment to both natural disturbance and forest management. The presentation will conclude by examining the implications for the use of the END (emulation of natural disturbance) paradigm in forest management, particularly in relation to forest management in the riparian zone.

D-07 Impacts of forest roads on water resources and aquatic habitat

Organizers: Charles Luce (U.S. Forest Service) & Artemio Cerdà (University of València, Spain)

The relationship between forest roads and aquatic habitat conditions in western Montana, USA. Black, T. (*U.S. Forest Service, USA; tblack@fs.fed.us*), Al-Chokhachy, R. (*U.S. Geological Survey, USA; ral-chokhachy@usgs.gov*), Rieman, B. (*U.S. Forest Service, USA; brieman@blackfoot.net*), Carlson, A. (*The Wilderness Society, USA; anne_carlson@tws.org*), Thomas, C., Luce, C., Hendrickson, S. (*U.S. Forest Service, USA; cathomas@fs.fed.us*; *cluce@fs.fed.us; shendrickson@fs.fed.us*).

Forest roads can degrade aquatic ecosystems by altering hydrologic, wood, and sediment regimes, degrade water quality, and reduce habitat suitability for aquatic biota. Often sedimentation is singled out as a dominant contributor to degradation. There are currently over a million kilometers of low volume road on public lands in the United States, but declining timber harvest has reduced the capacity to maintain these systems. We address the need for prioritizing road restoration by merging two proven monitoring approaches to develop a new understanding of road impacts on aquatic ecosystems. First, we apply an empirical methodology known as the Geomorphic Roads Analysis Inventory Package (GRAIP) to locate and estimate fine sediment generation on road surfaces and delivery to streams. We link the GRAIP monitoring with stream channel monitoring using the PACFISH-INFISH Biological Opinion (PIBO) protocol to develop local relationships of road effects with in-channel responses. Early results from an investigation of 4 sub-watersheds in Montana support conceptual models linking high road densities with increased fine sediment within streams, but indicate a small percentage of roads are responsible for the majority of fine sediment delivered from road surfaces. Preliminary results support strategically improving necessary roads and removing unneeded legacy roads when appropriate.

Assessing controls on sediment delivery from forest roads. Luce, C., Black, T. (*U.S. Forest Service Research, USA; cluce@fs.fed.us; tblack@fs.fed.us*).

Not all sediment generated on forest roads reaches streams. The high infiltration capacity and roughness of the forest floor help trap sediment on slopes below roads. In assessing the contribution of roads to stream sediment, accounting for delivery is an important step for which there is limited theory and observation. Observations of delivery and non-delivery from road drainage features were collected across 6 basins in Northwest Forests, each with several thousand drain points. We used local logistic regression to estimate conditional probabilities of delivery to compare multiple hypotheses regarding controls on sediment delivery from forest roads, including distance to stream, slope, contributing segment length, estimated sediment load, and slope position. Distance to stream consistently provided the strongest model across the diverse range of basins examined, with strongly non-linear reductions in delivery with distance. Different basins yielded different parameters for the relationship. Insights from this work may be helpful in better design of road networks to reduce delivery to streams.

GRAIP-Lite: a tool for large scale assessment of road erosion. Nelson, N., Luce, C., Black, T., Cissel, R. (*U.S. Forest Service, USA; nnelson@fs.fed.us*; *cluce@fs.fed.us; tblack@fs.fed.us; rcissel@fs.fed.us*).

The objective of this paper is to describe a new tool for efficiently modeling the road sediment impact to streams at a broad scale. GRAIP-Lite provides the ability to describe the general effects of road location, maintenance, and design on road-derived sediment across sub-watersheds at relatively low cost and effort. The model requires a Digital Elevation Model, a GIS road line feature, and a calibration dataset, to predict the amount of sediment production on road segments, sediment delivery to streams, and sediment accumulation across the stream network. GRAIP-Lite results were validated against inventory and modeling done with the Geomorphic Inventory and Analysis Package (GRAIP) in 46 sub-watersheds in the Northwestern US across a substantial range of geology, topography, and weather. Early results indicate good agreement between the two approaches with a Nash-Sutcliffe of 0.80 for sub-watershed scale sediment delivery and 0.80 for specific sediment. Further analysis in streams with contributing areas of 10–15 km^2 have Nash-Sutcliffe scores of 0.73 for sediment delivery and 0.71 for specific sediment. Prioritizing areas for restoration work based on the simple tool provides added value beyond road density, which treats all roads equally and may result in sub-optimal project selection.

An unusual suspect – the threat posed by unpaved roads to coral reefs of the Eastern Caribbean. Ramos-Scharron, C. (*University of Texas-Austin, USA; cramos@austin.utexas.edu*), Gray, S. (*University of San Diego, USA; sgray@sandiego.edu*), Hernandez-Delgado, E. (*University of Puerto Rico, Rio Piedras, USA; coral_giac@yahoo.com*).

The multi-decade long decline in live coral cover throughout the Insular Caribbean is perceived by many to be partly linked to increases in terrestrial sediment delivery associated to coastal development. Even though the islands of Culebra (Puerto Rico) and St. John (U.S. Virgin Islands) contain some of the best remaining coral reef resources of the U.S. Caribbean, their reef ecosystems are being threatened by land-based erosion from continuously expanding unpaved road networks. Research indicates that in this dry sub-tropical setting, unpaved road erosion represents up to a four-order increase in hillslope erosion relative to background rates and that road networks are responsible for up to a tenfold increase in sediment yields and marine sedimentation rates. In addition, the efficient runoff-generating capacity of unpaved roads relative to the intermittent nature of streams signifies a potential for enhanced and more frequent delivery of highly turbid and nutrient-rich runoff to the otherwise clear and oligotrophic dominant water quality conditions. Curtailing erosion and sediment delivery from unpaved roads by the implementation of best management practices with various levels of documented cost-effectiveness ratings have become pivotal to coral reef restoration and monitoring on both islands.

Road sediment production and delivery: effects of management activities and climate change. Stafford, A. (*Water Quality Control Division, State of Colorado, USA; all.stafford@state.co.us*), MacDonald, L. (*Colorado State University, USA; lee.macdonald@colostate.edu*).

Unpaved roads are often the major source of anthropogenic sediment in forested watersheds. This study in the southern Sierra Nevada in California evaluated the changes in road sediment production and delivery due to: 1) graveling, grading, and waterbar

construction; and 2) the projected shift from snow to rain. Sediment production was measured from nearly 100 road segments over 2–5 years in the rain-dominated José Basin and the higher elevation, snow-dominated Kings River Experimental Watershed (KREW) study area. Detailed road surveys assessed segment characteristics and road-stream connectivity. Mean sediment production from native surface roads in José Basin was 1.8 kg m^{-2}/yr versus 0.13 kg m^{-2}/yr at KREW. Thirty percent of the roads in José Basin were connected to the stream network as compared to just 3% of the roads in KREW. Gravel had little effect on road sediment production in José Basin due to the poor quality and coverage of the rock and higher rainfall intensities, but significantly reduced sediment production at KREW. Grading increased sediment production by 3–8 times. The results show a wide divergence in the effects of different management strategies, and that road sediment production and delivery may increase by orders of magnitude as precipitation changes from snow to rain.

Plot-scale hydro-geomorphological response on gravelly roadbed, a case study from southern Brazil. Thomaz, E. (*Universidade Estadual do Centro-Oeste (UNICENTRO), Brazil; edi_thomaz@yahoo.com.br*), Ramos-Scharron, C. (*University of Texas-Austin, USA; cramos@austin.utexas.edu*).

Unpaved roads are recognized as important sources of Hortonian overland flow and sediment in both forested and agriculturally-active rural areas of the State of Paraná in southern Brazil. The objective of this study is to assess the effect of micro-catchment scale, slope, and ground cover on runoff and sediment generation of a graveled roadbed under 30-minute long simulated rainfall conditions. For our purposes, a micro-catchment is defined by the pre-existing cross-slope drainage pattern of each road segment. Fifteen replication experiments were performed at rather constant rainfall intensities (42.9 + 8.8 mm/hr), on roadbeds with variable micro-catchment drainage areas (~3–7 m^2), slopes (6.5±2.5°), and gravel ground cover (82 + 22%). The size of the contribution area was the most important physical characteristics affecting runoff response and sediment production as statistical analyses indicated it had an influence on time to runoff, total runoff, and sediment loss. Neither slope nor the proportion of the ground surface covered by gravel proved to be as statistically correlated with runoff and sediment response as micro-catchment size. Our study indicates that road runoff and sediment production is scale-dependent and these findings could be used to improve road drainage design to minimize impacts on downstream water resources.

Posters

Monitoring the hydrologic and geomorphic effects of forest road decommissioning and road improvements. Black, T., Luce, C., Cissel, R., Nelson, N., Staab, B. (*U.S. Forest Service, USA; tblack@fs.fed.us*; *cluce@fs.fed.us; rcissel@fs.fed.us; nnelson@fs.fed.us*); *brianstaab@fs.fed.us*).

The objective of this study was to assess the effectiveness of several road treatments used by the U.S. Forest Service in reducing the hydrologic and geomorphic impacts of forest roads on streams. The treatments were road storm damage risk reduction (SDRR), road decommissioning, and road storage. We assess the effectiveness of treatments for reducing: 1) road-stream hydrologic connectivity; 2) fine sediment production and delivery; 3) mass wasting; and 4) stream crossing failure risk. Roads were inventoried before and after treatments, focusing on the condition of the road drainage system. We use the GRAIP (Geomorphic Road Analysis & Inventory Package) model to predict improvements in outcomes based on implemented treatments. Ultimately we return to the roads to observe the response of treated vs. untreated control roads to large storms. Data collection was collected on over 50 sites in the western US and monitored for 5 years. Preliminary results indicate that roads decommissioned by recontouring the hillslope had a 77% reduction in sediment delivery and a 79% reduction following a storm event while control segments exhibited variable responses. SDRR treatments had a reduction of 35% following treatment and 66% following the storm event while the control roads had a post storm decrease of 31%.

The impact of ground based timber harvesting on soil hydrophysical properties: a case study in Hyrcanian forest. Hayati, E., Abdi, E. (*University of Tehran, Iran; hayati_fe@ut.ac.ir; abdie@ut.ac.ir*), Moghadamirad, M. (*University of Agricultural Sciences and Natural Resources-Gorgan, Iran; mostafa_119_g@yahoo.com*).

Although skid trails are the only route for off-road transportation of timber in Hyrcanian forest, where ground-based skidding systems are the main log extraction system, they are also a major source of sediment and runoff in forest ecosystems. In this research, soil infiltration has been studied on the soil in wheel ruts, center of skid trail and undisturbed forest as control in Kuhmiyan Forest as a part of Hyrcanian forests. A double-ring infiltrometer was used to measure soil infiltration in a 65 minutes period at the three different treatments. Results of this study showed that both cumulative infiltration rate and the infiltration at different measuring times at the wheel ruts (67 mm) were significantly lower than that at control treatment (270 mm). Considering the huge reduction of soil infiltration on the skid trails, forest managers will be able to estimate the declined capability of soil for absorption of precipitation reaching it (which was only 67 mm for the skid trail of our study area), and thus potential of runoff regarding a long-term return period.

Water and sediment behavior on rolled grade roads. Muneoka, H., Suzuki, H., Yamaguchi, S., Tanaka, Y. (*Forestry and Forest Products Research Institute, Japan; hirokomuneoka@affrc.go.jp; hidesuzu@affrc.go.jp; syamaguc@affrc.go.jp; tanakay@affrc.go.jp*).

Road surface water transports sediment, which then drains onto hill slopes. The transported sediment may reach the streams beneath the road and impair water quality. Drainage with rolled grade seems to be one of the methods which can reduce the impacts on the hill slope and the water quality beneath the road. Rolled grade means a longitudinal gradient with gentle undulations like wavy lines. Here, the water on the road surface is expected to flow into concaves and drain onto the hill slope. The amount of sediment discharged from concaves is expected to be smaller than that of cross ditches because the water is expected to spread shallowly on concaves and slow down before draining, hence the transported sediment deposits. Conversely, the decelerated water may stand on the concaves and impair the characteristics of the road prism. This study aims to show the water and sediment behavior on concaves depending on the shape of the concaves and suggest an appropriate shape which can reduce sediment discharge and prevent the water from standing on the concaves.

Quantification and modeling of foot trail surface erosion in a dry subtropical forest setting in the Eastern Caribbean. Ramos-Scharron, C. (*The University of Texas-Austin, USA; cramos@austin.utexas.edu*), Reale-Munroe, K. (*The University of the Virgin Islands, USA; krealem@uvi.edu*), Atkinson, S. (*The University of Queensland, Australia; scottconsaulatkinson@gmail.com*).

Anthropogenic disturbance often increases surface erosion with its potential detrimental downstream effect on aquatic resources. Foot trails are often overlooked as they represent only a small fragment of the landscape, but they can be important sources of sediment, particularly in pristine areas. Concern over the potential for trail erosion to stress nearshore coral reefs of the East End Marine Park on the island of St. Croix, U.S.Virgin Islands led to trail reconstruction and restoration. The objectives of this study were to: (1) quantify trail erosion; (2) identify key factors controlling erosion; and (3) develop an empirical trail erosion model. Measured trail erosion rates ranged from 0.6 to 81 Mg/ha/yr. The lower values were from abandoned trails with a dense vegetation cover, while highest rates were from unvegetated trails immediately following construction. Trail erosion rates are one- to three-orders of magnitude higher than erosion from nearby undisturbed hillslopes. The absence of rills suggests that traditional parametric or transect monitoring may greatly underestimate actual trail erosion rates. The new empirical trail erosion model may serve as a tool to assess the effects of trail construction and restoration activities in the generation of sediment from small catchments in other similar dry-forest settings.

Effectiveness of road decommissioning. Sosa Perez, G., MacDonald, L. (*Colorado State University, USA; gsosa@lamar.colostate.edu; lee.macdonald@colostate.edu*).

Road decommissioning is an expensive method to reduce sediment delivery to streams, and studies are needed to quantify its effectiveness. The objectives of this study were to: 1) measure sediment production and road-stream connectivity before and after decommissioning; and 2) quantify the costs and benefits. The study is taking place on the Arapaho-Roosevelt National Forest in Colorado. Sediment fences were installed in summer 2013 on 18 segments to be decommissioned and 10 control segments. Between 11 June and 7 September there was 116 mm of rainfall, and road sediment production varied from zero to 3.0 kg/m^2. Sediment production appeared to be related to segment slope, active area, percent bare soil, and a qualitative traffic variable, but there were no consistent relationships. Only 12% of the 14 km to be decommissioned was connected to the stream network. An unusual 206-mm storm from 10–16 September occurred after the roads were ripped but before mulching; mean sediment production for the decommissioned segments was only 34% of the previous total, but 117% for the controls. Monitoring will continue for 1–2 years, and models will be calibrated or developed to predict the effectiveness of road decommissioning and unit costs for reducing sediment delivery.

Quantitative and qualitative investigation of road construction standards in Arasbaran forest, Iran. Talebi, M., Majnounian, B., Abdi, E. (*University of Tehran, Iran; m_talebi90a@yahoo.com; bmajnoni@ut.ac.ir; abdie@ut.ac.ir*).

Forest roads are an essential infrastructure and prerequisite in management of forested areas. Sustainable management of roads depends on regular and timely forest road maintenance. Road inventory is the first step in forest road management, control of construction standards and maintenance operation. The purpose of this study was to obtain the required information to assess existing roads standards by road inventory and using the results to schedule maintenance operation. To do this a part of the road network from Kaleibarchay watershed in Arasbaran forest was inventoried, and cross sectional components were measured and compared to standard ones. Culverts and bridges along the road were also investigated. Road components, problems of surfacing and slope stability were analyzed in ArcGIS9.3 software. The results showed that there were significant differences between existing parameters and standard ones and the exceptions were side ditch depth and roadbed. Road segment only had one culvert. Cross-slope has the highest consistency with standard values. Among surfacing problems, rutting had the highest abundance and cutslope had more stability problems than fillslope. This research can be used in maintenance operation for the roads studied and also as a model to study and collect required inventory data.

D-08 Sustaining riparian biodiversity and ecosystem services in a changing climate

Organizers: Kathleen Dwire (U.S. Forest Service), Michael Pollock (National Oceanic and Atmospheric Administration, USA) & Chris Frissell (University of Montana, USA)

Streamside buffers moderate effects of forest thinning on riparian microclimates and stream temperatures in western Oregon, USA. Anderson, P. (*U.S. Forest Service, USA; pjanders@peak.org*), Eskelson, B. (*Oregon State University, USA; bianca.eskelson@oregonstate.edu*).

Riparian areas of the mesic forests of western Oregon, USA are biodiversity hotspots providing critical fisheries habitat and water quality services. Uncut vegetative buffers are commonly used to moderate upland timber harvest impacts on aquatic and riparian habitats and functions. In an operational-scale experiment begun in 1993, we examined three buffer types: streamside, variable width and one-tree-height in young, 35–45 year-old Douglas-fir forests originally thinned to 200 trees per hectare. Through ten years, near-stream microclimates for the variable width and one-tree-height buffers were minimally altered from the uncut reference conditions. In 2012, following re-thinning 88 trees per hectare, summer daily maximum air temperatures near the stream were elevated 2.1–4.1°C in the streamside and variable width buffers. Regardless of increased air temperature, maximum stream temperature for the two narrow buffers was indiscernible from the untreated reference. Within buffers and thinned stands, maximum air temperatures exceeded maximum soil temperatures by 11–16°C for all buffer types. Our new results reinforce the effectiveness of variable width and one-tree-height buffers in moderating effects of heavy thinning on water temperature and riparian microclimates in small streams. Differential air, soil and water temperature responses indicate that factors other than shade influence the thermal energy budget of riparian forests and streams. Flexible, context specific delineation of buffers may promote a beneficial balance between competing objectives.

Fuels and fuel-reduction treatments in riparian conifer forests: challenges of maintaining streamside and aquatic habitats. Dwire, K. (*U.S. Forest Service, USA; kadwire@fs.fed.us*), Frissell, C. (*University of Montana, USA; leakinmywaders@yahoo.com*), Pollock, M. (*National Oceanic and Atmospheric Administration, USA; michael.pollock@noaa.gov*).

Riparian conifer forests provide structurally complex aquatic and terrestrial habitat and dispersal corridors, maintain streamside microclimates and stream water quality, and buffer streams from upland activities. In the interior west of North America, riparian forests frequently occur as narrow linear features in the forested landscape mosaic and are influenced by the same natural disturbances, notably insect outbreaks and fire. Although limited data are available for riparian stands, fuel reduction treatments are being widely implemented throughout the region to manage fire risk. Here, we present results from a recent study comparing forest attributes and fuel loads in paired riparian and upland stands in watersheds impacted by beetle infestation (southern Wyoming, northern Colorado). Sampled stands were generally similar, although riparian forests had higher live basal areas, more large diameter snags, and greater shrub diversity. Standing fuels (trees) were similar across stand types. However, fuel distribution (structural complexity) differed. Also, some riparian habitat features may change as stands respond to overstory mortality, as well as predicted shifts in precipitation patterns, lower stream flows, and more frequent fires. We will discuss the role of fuels treatments in management of streamside forests, and challenges of sustaining valued riparian ecosystem services in a changing climate.

Historic and current fire patterns in Sierra Nevada riparian forests. North, M., Lydersen, J., Van de Water, K. (*U.S. Forest Service, USA; mnorth@ucdavis.edu*; *jmlydersen@fs.fed.us; kvandewater@fs.fed.us*).

Recent wildfires in the Sierra Nevada suggest that, if left untreated, riparian forests can burn at high severity and may accelerate the spread of fire through a watershed. We examined historic forest structure and fire return intervals, and compared these to current stand conditions and burn severity patterns. In the past many riparian forests of first and second order streams burned frequently at low severity and had similar stand conditions to upland forest. Due to higher productivity, current riparian fuel loads often exceed adjacent areas, resulting in large patches of high severity after wildfire. Unlike historic conditions, we did not find a stream size or shape threshold that reduced fire severity or patch size patterns in modern wildfires. This reduction in fire effects heterogeneity could negatively impact biodiversity and ecosystem services of riparian forests.

Climate change and forest thinning with riparian buffers: relationships to shrinking headwater stream habitat. Olson, D. (*U.S. Forest Service, USA; dede.olson@oregonstate.edu*), Burton, J., Puettmann, K. (*Oregon State University, USA; julia.burton@oregonstate.edu; Klaus.puettmann@oregonstate.edu*).

Headwater streams and their associated riparian areas provide habitat for many forest-dependent species, especially amphibians. In the U.S. Pacific Northwest, salamander species of concern occur in spatially discontinuous or intermittent streams in moist coniferous forests west of the Cascade Range crest. We hypothesized that spatial intermittency of these streams would be associated with annual climate metrics, and this association might have interaction with riparian forest management scenarios such as thinning and riparian buffers. Using retrospective analyses (ordination, regression) of headwater stream reach (N=109) and climate conditions over a 16-year time span, we assessed the relationship of the stream intermittency with climate, with the prediction that more dry channel would occur during warm, dry years. Then we included riparian management regime in the model, with the null hypothesis of no change. In sum, we found support for our "shrinking headwaters" prediction with percent dry channel related to summer heat:moisture index. Inclusion of riparian management did not improve the models. Using climate projections, we assessed potential futures on headwater stream lengths, with examples drawn from forested watersheds in the western Cascade Range, showing effects on overland amphibian connectivity.

Riparian forest conservation and restoration: a few examples from eastern France. Piegay, H. (*École normale supérieure de Lyon-CNRS, France; herve.piegay@ens-lyon.fr*).

The implementation of the Water Framework Directive (WFD) in Europe requires improvement of the ecological status of rivers by 2015. Restoration actions focusing on riparian environments are of particular interest because they are less costly than other actions and provide ecological and social benefits associated with landscape improvement. WFD not only requires repair of ecological damages, but also promotes mitigation and conservation strategies to preserve river segments in good ecological condition. This talk will introduce case-studies from Eastern France and provide lessons from them, specifically: i) design of erodable corridors for conserving bank erosion as a critical process for forest rejuvenation and biodiversity conservation, ii) modification of vegetation maintenance/clearing practices to minimise impacts on riparian forest and associated aquatic habitats; iii) restoration strategies along the Rhône and Rhine rivers, regulated during the 19th and 20th centuries, for recreating pioneer stages and self-maintained riparian forests, iv) experiments and monitoring to assess the responses of riparian species to changes in drier conditions. A key-issue is also how to strategically locate restoration and conservation actions to maximise benefit at a minimum cost. Characterisation of riverine corridors at network scales (ca 50000 km^2) using remote sensing information for targeting actions will be illustrated.

Does thinning restore late-successional forest structure? Pollock, M. (*National Oceanic and Atmospheric Administration, USA; michael.pollock@noaa.gov*), Frissell, C. (*University of Montana, USA; leakinmywaders@yahoo.com*), Dwire, K. (*U.S. Forest Service, USA; kadwire@fs.fed.us*).

Throughout much of the northern hemisphere, old, complex and biologically diverse riparian and upland conifer forest ecosystems have been cleared and replaced by structurally simple, species poor forests. In such ecosystems, much of the decline in biodiversity has been attributed to the loss of large trees, large dead wood (snags or down, decomposing wood on the forest floor and in streams). Biodiversity declines have led to experimental efforts to accelerate the restoration of old forest structure. A common experimental restoration technique is to thin young stands. In this paper, we examine the hypothesis that over the long-term, thinning will accelerate the development of large live trees and large dead wood important to numerous aquatic and terrestrial species. Projecting such changes over the long term requires the use of a forest growth model, as long-term studies are lacking.

We used such a model to project the production of live and dead wood under different thinning regimes for young conifer stands in western Oregon, USA. Our results suggest that there are long-term structural tradeoffs associated with restoration thinning, and that passive restoration may often be the best strategy for restoring late-successional forest structure.

Effects of wild ungulate herbivory on riparian restoration for salmonids. Rowland, M., Wisdom, M. (*U.S. Forest Service, USA; mrowland@fs.fed.us; mwisdom@fs.fed.us*), Endress, B. (*Institute for Conservation Research-San Diego Zoo Global, USA; bryan.endress@gmail.com*), Parks, C., Coe, K. (*U.S. Forest Service, USA; Cparks01@fs.fed.us; khcoe@fs.fed.us*).

Intensive herbivory by domestic and wild ungulates can dramatically affect riparian vegetation. In western North America, these effects are of particular concern in riparian systems, where long-term ungulate herbivory can substantially reduce or eliminate deciduous, highly palatable species such as aspen (*Populus tremuloides*) and cottonwood (*Populus* spp.). These species are vital components of riparian forest and shrubland systems that support healthy salmonid populations. Thus, most riparian restoration targeted for salmonid conservation includes silvicultural practices that include planting thousands of deciduous seedlings, often in protective exclosures. Despite recognition that herbivory can dramatically affect success of riparian restoration, knowledge is scarce about effects of domestic versus wild ungulates on restoration plantings for effective recovery of riparian systems. We report results of the initial phase of a long-term study in northeastern Oregon, in which we examined effects of wild ungulate (deer, *Odocoileous* spp. and elk, *Cervus elaphus*]) herbivory on intensive riparian plantings in the absence of cattle (*Bos taurus*). We describe effects of deer and elk herbivory on deciduous seedling survival and growth to year one, both within and outside exclosures. We also discuss implications of our results for integrated ungulate management and current silvicultural practices for salmonids in riparian ecosystems.

The critical role of fluvial disturbance for riparian forest development along large rivers in dry regions (California, USA). Stella, J., Riddle, J. (*SUNY College of Environmental Science and Forestry USA; stella@esf.edu*; *jess.riddle@gmail.com*), Battles, J. (*University of California, Berkeley, USA; jbattles@berkeley.edu*).

Understanding how riparian forests coevolve with past fluvial disturbance is especially important for predicting future dynamics in semi-arid regions undergoing climate change. We conducted an extensive forest inventory and chronosequence analysis in remnant riparian forest stands along the meandering, 160-km middle reach of the Sacramento River (California, USA) to quantify how abiotic conditions and forest structural characteristics such as tree density, basal area and biomass vary with floodplain age. We inventoried 431 fixed-area plots within vegetation patches ranging in age from 4 to 107 years. Two successional trajectories were evident: (1) rapid tree species shifts, from pioneer willow/cottonwood to mid-successional hardwoods; and (2) patches of shrub willow that persisted many decades. Sediment accretion was reduced in the persistent willow plots compared to the successional forest stands, suggesting an association between higher flood energy and arrested succession. Forested stands 40–60 years old were the most extensive in terms of floodplain area, and supported the highest biomass, species diversity, and functional wildlife habitat. These stands were dominated by Fremont cottonwood (*Populus fremontii*) and reached their maximum biomass within 50 years. In this river system, sediment morphodynamics are integrally tied to the development of multi-aged forest structure, especially ecologically important middle-aged stands.

D-09 Ecology and management of coastal forests and mangroves

Organizer: Ariel E. Lugo (U.S. Forest Service)

Monitoring forest change analyzing change in resistant Z-score using Landsat data : case studies from Bangladesh and Montana. Biswas, T., Maus, P., Megown, K., Chastain, R. (*Remote Sensing Applications Center, USA; tanu.biswas@gmail.com; pmaus@fs.fed.us*; *kmegown@hotmail.com; rchastain@fs.fed.us*).

Woody draws and upland deciduous tree communities are unique and ecologically important component of Eastern Montana, USA. They provide significant habitat to many species in the landscape. A pixel based change in resistant Z-score of NDVI was used to monitor the change within these small and rare occurence deciduous communities on the Custer National Forest, Montana (USA) using Landsat TM data from 1985, 1990, 1995, 2000, 2005, 2009, and 2011. Resource photography from contemporary time period was used to confirm the observed changes. The change in resistant Z-score highligted the areas within the deciduous forest landscape that underwent change (2% or 5%) due to different disturbances and required further monitoring. In a separate study change in resistant Z-score was used to monitor change within four mangrove forest canopy cover classes within Bangladesh. The mangroves of Bangladesh contribute to 60% of their natural forest and require efficient monitoring than possible through traditional field methods. Landsat images from 1989, 1999 and 2009 was used for the study. The Z-score analysis identified subtle changes within the landscape and informed the REDD+ initiatives within the Sundarban mangrove forest, Bangladesh. In this paper we present the resistant Z-score analysis and demonstrate how it can be used to provide an assesment of forest change from different disturbances based on Landsat data.

Botanical surveys in Awat-Awat mangrove forest, Sarawak, Malaysia. Gandaseca, S., Imam Aritanto, C., Haruna Ahmed, O., Muhamad Majid, N. (*Universiti Putra Malaysia, Malaysia; seca@upm.edu.my; chan2_himura@yahoo.com; osumanu@upm.edu.my; nik@upm.edu.my*).

The objective of this study is to determine the present status of species diversity in Awat-Awat mangrove forest (AAWF), Sarawak, Malaysia. Six lines transect, each one is 500 m long were randomly established from seaward edge to the landward edge of the forest. Twelve random plots (10 × 10 m plot) were used in transect lines for detailed vegetation study. All of available mangrove species were recorded and identified specimens were made into herbarium specimens and kept at the Herbarium Laboratory, UPM Bintulu Sarawak Campus. About 10 families and 18 species were identified at twelve random plots from seaward edge to landward edge of the forest, including species from the families Avicenniaceae, Meliaceae, Combretaceae, Arecaceae, Rhizophoraceae, Rubiaceae, Sonneratiaceae, Pteridaceae, Acanthaceae and Malvaceae. The average height and DBH

were 12.16 m and 14.45 cm respectively. *Rhizophora apiculata* was the dominant and most abundant distributed species, while *Schypiphora hydrophyllaceae* was the least dominat species. In term of species distribution and zonation of mangrove species, *R. apiculata* and *Nypa fruticans* were found abundantly distributed in all of plots.

Species and functional diversity of mangrove forest for conservation planning of Alibijaban Wilderness Island in San Andres Quezon, Philippines. Pampolina, N. (*University of the Philippines Los Baños, Philippines; nelsonmanguiatpampolina@yahoo.com*), Rozaldo, R. (*Department of Environment and Natural Resources, Philippines; roncyn74@yahoo.com*).

The sustainable management of island ecosystems in the Philippines is a high priority for conservation and ecotourism where species composition and ecological function play important role. This research presents attributes of biodiversity resources in Alibijaban Wilderness Area of San Andres Quezon for its designation as protected landscape and seascape. The island is mangrove-rich zoned with mean density, wood volume, and carbon stocks of 1361 trees/ha, 43.4 m^3/ha, and 58.7 Mg/ha, respectively. It includes 37 mangrove species dominated by Rhizophoraceae with critically endangered *Xylocarpus rumphi*i. It provides habitat for 38 avian species where an endemic bird species (*Megapodius freycinet pusillus*), favored macrobenthos (Annelida, Arthropoda, Chordata, Echinodermata Mollusca), and endangered bats (*Pteropus vampyrus, Aceredon jubatus*) reside. Abundance of avifauna and arthropods are strongly correlated with tree basal area in all zones, suggesting important functions of mangroves as food source and habitat. However, regeneration was reduced with abundance of arthropods, indicating their balancing role. Biodiversity was found to be very low to moderate due to threats (extraction, migration, land conversion, wildlife collection, climate change) that necessitate conservation planning to sustain the island.

Impact of climate change on the nipa palm of Sundarbans. Rahman, M. (*Chandpai-IPAC, Sundarbans, Bangladesh; mizan_peroj@yahoo.com*), Vacik, H. (*University of Natural Resources and Life Sciences, Austria; harald.vacik@boku.ac.at*).

Nipa palm (*Nypa fruticans*) is a multipurpose indicator species of the Sundarbans, the home of aquatic animals; amphibians including crocodile; reptiles, mammals including the Royal Bengal Tiger; crustaceans; and birds. It works as a dune stabilizer, windbreaks or shelterbelts. To understand the climate change impacts on this UNESCO World Heritage and Ramsar site, the dynamics of nipa palm over the last decade was studied in the fresh and the mixed fresh-brackish swamps. The abundance of the species has been affected by increased salinity, infrequent inundation, accretion of silt and extensive coastal erosion. Declining trends in Nypa abundance has been observed in the mixed fresh-brackish swamps in forest areas at Karamjal, Jongra, Mora Passur, Nandobala, Harbouria, Choraputia, Andharmanik, Tamulbunia, Supoti and Kochikhali. The inland nipa palm populations have already been disappeared from many fresh swamps. Due to increased salinity, fresh swamp is being converted into mixed fresh-brackish swamp while mixed fresh-brackish swamp into brackish swamp. The changes in the composition and abundance of this sensitive indicator plant species provide the specific biological signal of the climate change impacts on this mangrove. Conservation, mitigation, monitoring and further researches are essential to adapt to the climate change impacts.

Effects of climate change on coastal forest ecosystems and marine environment of Cameroon. Suka, E. (*Ministry of Environment, Protection of Nature and Sustainable Development, Cameroon; emmanuelsuka@yahoo.com*).

The coastal zone of Cameroon is affected by climate change caused by extensive land use changes through agricultural production and massive deforestation, pollution, industrial development and infrastructural construction amongst oil refineries. Impacts include decline in fisheries, biodiversity loss, ocean level rise and floods, degraded coastal forest ecosystems and marine environment, altered water quality and impoverished natural resource base thereby increasing poverty and food insecurity. There is no coastal management policy, as well as lack of knowledge and capacity to mitigate effects. The objectives of this research were to identify causes, evaluate impacts and level of compliance with environmental treaties and propose sustainable coastal management policies. Research methods included participatory interactive ecosystems approach, rapid assessment field survey and evaluation comprising structured and semi-structured interviews, empirical and statistical analysis of affected coastal forest ecosystems and environment compared to standing forests, as well as review of multilateral agreements, documents related to coastal management and physical data collected from national archives, libraries, CDC meteorological stations, and natural resources management institutions. The results of this study were used to draft an Integrated Coastal Zone Management policy for sustainable coastal development.

Local mangrove forest management of cyclone-affected areas in Myanmar. Thinn, T., Takeda, S. (*Kyoto University, Japan; thinn07@gmail.com; takeda@asafas.kyoto-u.ac.jp*).

This paper evaluates local forest management in the Ayeyarwady Delta, one of the mangrove forests in Myanmar that has been most degraded by the expansion of agriculture. Data were collected in December 2012 via fieldwork for GIS/RS through interviews using semi-structured questionnaires in one village which was seriously affected by the cyclone Nargis in May 2008. 70 households were asked about their livelihoods, land use practices and the motives behind their agriculture in the mangrove forests. About 80% of the respondents were engaged in agriculture and fisheries. Although the respondents still relied on some mangroves for their fuel, the commercial logging of the mangroves has slowed considerably in the years since the cyclone. It was difficult to regenerate the abundant mangrove forests that had been converted into paddy fields. However, mangrove cover increased after the local people kept the remaining trees near their homes. Local people also began to conserve mangroves to protect their homes from the storm. Their attitudes and perceptions regarding mangrove management have changed. This kind of local forest management system can influence community forestry programs in cyclone-affected areas. However, since coastal populations have increased in recent years, alternative sources of fuel need to be considered.

Theme E: Forest Biomass and Bioenergy

E-01a Sustainable biomass for energy and industrial raw materials: biomass potentials

Organizers: Viktor Bruckman (Commission for Interdisciplinary Ecological Studies, Austrian Academy of Sciences), Sanjeev Kumar Chauhan (Punjab Agricultural University, India) & Robert Jandl (Federal Research and Training Centre for Forests, Natural Hazards and Landscape, Austria)

Forest energy in West Africa: situation and future scenarios for Burkina Faso and Sierra Leone. Arevalo, J., Pelkonen, P. (*EduSilva, Finland; javier.arevalo@uef.fi; paavo.pelkonen@uef.fi*).

More than 80% of Sub-Saharan people depend on traditional forms of biomass as their energy source, mainly fuelwood and charcoal. Despite the different socioeconomic and ecological conditions between the semi-arid Burkina Faso and the humid Sierra Leone, deforestation and forest degradation related to the dependence on traditional biomass are vast. With some of the highest annual population increments and lowest indexes of human development in the world, these countries are among the most vulnerable to climate change. Despite many efforts in the form of policies and development projects implemented in recent times, dependence on biomass is likely to continue and even increase in the next decades. Lately, efforts have focused on increasing the supply by means of afforestation (including wood energy lots) and forest management plans, and in reducing the demand by improving efficiency in charcoal production as well as in fuelwood and charcoal use (e.g., distributing improved cookstoves). The authors review the policies and plans related to forest energy in Burkina Faso and Sierra Leone and, after presenting various scenarios for wood energy demand and supply within the next decades, provide recommendations for a coordinated wood energy strategy.

Biochar application in forestry: a multinational approach to assess the potential for negative carbon emissions. Bruckman, V. (*Austrian Academy of Science, Austria; Viktor.Bruckman@oeaw.ac.at*), Liu, J. (*Pukyong National University, Republic of Korea; jayliu@pknu.ac.kr*), Uzun, B., Apaydin Varol, E. (*Anadolu University, Turkey; bbuzun@anadolu.edu.tr; eapaydin@anadolu.edu.tr*).

Biochar is widely used in agriculture to improve soil properties, with particular success under tropical conditions. A multinational project, consisting of partners in South Korea, Turkey, and Austria, tries to assess the potential of biochar to realize negative carbon emissions. Three main aspects of the process-chain are studied: (1) Sustainable biomass availability and competition with other markets, (2) optimization of pyrolysis process in regard to energy production and char quality and the influence of woody, forest-based feedstock materials, and (3) the effects of biochar application in a forest ecosystem, which is being studied for the first time. The aim is to jointly review the current status across disciplines via a series of dedicated workshops in combination with field and laboratory experiments. Preliminary results reveal that the major knowledge gaps are mainly in the areas of long-term effects of biochar in the soil, and practical issues, such as application methods. Product standards have to be developed, especially regarding pollutants, in order to facilitate the formulation of guidelines for safe and efficient biochar application. Field studies suggest that 10 tons/ha is a suitable amount with no immediate negative effects on vegetation. Characteristics of biochar obtained from *Picea abies*, in addition to results from application trials on *P. abies*-dominated, acidic stands will be presented.

Biomass yields from first rotation periods in commercial short rotation forestry (SRF) plantations in Bavaria prove to be higher than those from previous field trials. Hauk, S., Wittkopf, S., Knoke, T. (*Weihenstephan-Triesdorf University of Applied Sciences, Germany; s.hauk@wz-straubing.de; stefan.wittkopf@hswt.de; knoke@forst.wzw.tum.de*).

Beside prices, biomass yields are the factors with the greatest influence on the economic profitability of short rotation forestry (SRF) systems. But yields are largely dependent on site conditions. Field trials have been conducted worldwide to quantify the yields of various SRF tree species under given site conditions. Yet it is not clear if these yield levels are achievable on field sites managed by practitioners, where suboptimal management is anticipated. Therefore, the authors measured biomass yields from 30 SRF stands on sites representative of Bavarian (southern Germany) conditions, and managed by commercial practitioners. These biomass yields were then compared with yields from field trials in Bavaria and Germany in general. Contrary to expectations, the yields on field sites were higher than those on field trials. These higher yields are due to sound management, consistent weed control, and disproportionally frequent use of sites with moist soils. Hence, SRF cultivation on moist marginal lands seems to be economically competitive, with low opportunity costs and comparatively high productivity and therefore revenues. Furthermore, competing demands for the cultivation of food crops are rare on these moist soils. Use of these synergies can help create more efficient land use systems.

Energy crops and trees as a sustainable feedstock from marginal lands. Jacobson, M. (*Pennsylvania State University, USA; mgj2@psu.edu*).

Dedicated energy crop plantations are recognized as a preferred option for scaling up energy production, especially if grown on the potentially large areas of marginal land. These short rotation crops and trees such as shrub willow, hybrid poplar, other numerous tropical woody legumes, and warm season grasses can be grown on marginal lands and have the capacity to produce large volume of biomass, have high energy potential, and sequester carbon. “Marginal land” has many connotations and in the literature is not clearly defined. The term should include not only biophysical factors but also the agro-economic context. An estimated 60 million ha of land is available in the United States and 757 million ha in the world to grow bioenergy crops. But to date, what is the status of energy crop plantations in terms of their success in meeting feedstock requirements for biorefineries? A critical knowledge gap is evident when countries such as Sweden and UK are retreating from expanding energy crop production

of species such as willow. This paper examines energy crop plantations not only in terms of production yields and harvest logistics but also in terms of their socioeconomic and financial feasibility. Case studies are described from Europe, North America, Brazil, Africa, and Asia.

Demonstrating potential for commercial production of some biomass fuels for bioenergy application in Kenya. Onchieku, J. (*Kenya Forestry Research Institute, Kenya; onchieku@gmail.com*), Ondieki, C. (*Multi Media University, Kenya; charlesondieki@gmail.com*), Arckermann, K. (*Deutsche Gesellschaft für Internationale Zusammenarbeit* (*GIZ), Germany; klaus@giz.org*), Chikamai, B. (*Kenya Forestry Research Institute, Kenya; director@kefri.org*), Oballa, P. (*Kenya Forestry Research Institute, Kenya; poballa@yahoo.com*).

The purpose of this study was to identify and estimate the quantities of various biomass residues and determine their suitability as fuels for biogasification for electricity generation. Biomass energy accounts for more than 80% of the total renewable energy supply globally. Most is used in developing countries as traditional biomass for cooking and heating homes. However, there is rapidly emerging global interest in biomass for modern energy applications. Optimum utilization of biomass fuels depends on current sustainable supply and their suitability, which is based on their physical, chemical, and thermal properties. In this study, empirical methods for determination of quantities of residues generated in Kenya as well as methods for determining their suitability for utilization as fuels for bioelectricity generation are provided. Biomass residues generated in Kenya annually are estimated and their suitability evaluated. The potential for commercial production of these residues using low-cost screw presses is discussed and recommendations given for piloting briquette production as a small-scale enterprise in Kenya.

Sustainable urban forest maintenance: re-thinking *satoyama* as a biomass resource for small-scale wood energy utilization. Terada, T., Yamamoto, H. (*University of Tokyo, Japan; terada@k.u-tokyo.ac.jp; yama@k.u-tokyo.ac.jp*), Yin, W. (*Beijing Forestry University, China; maximusinjapan@gmail.com*), Uddin, M. (*Government of Bangladesh, Bangladesh; nz_post@yahoo.com*), Jarzebski, M. (*University of Tokyo, Japan; jarzebski@sustainability.k.u-tokyo.ac.jp*), Fujieda, J., Yokohari, M., Fukuda, K.

Most urban forests in Japan are former *satoyama*, woodland which was historically maintained by local people to obtain firewood and other organic materials. In the 1960s, the economic viability of *satoyama* as a source of biofuels drastically declined with the introduction of fossil fuels. Many *satoyamas* have since been developed for housing needs, and the remaining ones were simply abandoned. Currently, harnessing locally produced energy is gaining prominence in Japan especially, after the nuclear crisis following the wake of the disaster on 11 March 2011. However, reestablishing *satoyama* woodlands as a biomass source has been progressing slowly, due to a lack of empirical data on the biomass supply potential. The purpose of this research is to estimate the sustainable biomass yield from an urban forest and former *satoyama* in peri-urban Tokyo (*Oaota* forest). First, biomass stock was estimated using both aerial photos and results of tree measurements, and then the sustainable biomass yield was estimated using the growth rate of forest stands approximated by stem analysis. The authors used the results to propose appropriate biomass utilization scenarios in urban areas which meet the sustainable yield from *Oaota* forest, to argue for the need for a renewed forest-human relation in urban areas.

Survey of guidelines for intensive forest biomass removals from around the world: lessons and recommendations. Titus, B. (*Canadian Forest Service, Canada; btitus@nrcan.gc.ca*), Helmisaari, H. (*University of Helsinki, Finland; helja-sisko.helmisaari@helsinki.fi*), Bruckman, V. (*Commission for Interdisciplinary Ecological Studies of Austrian Academy of Science, Austria; Viktor.Bruckman@oeaw.ac.at*), Stupak, I. (*University of Copenhagen, Denmark, Denmark; ism@ign.ku.dk*), Vanguelova, E. (*Centre for Forestry and Climate Change Forest Research, UK; elena.vanguelova@forestry.gsi.gov.uk*).

Environmentally sustainable forest management (SFM) has evolved to the point that it is now a basic tenant of modern industrial forestry. Concomitantly, governance mechanisms to encourage and ensure SFM have evolved and include (1) mandatory regulations, and (2) voluntary recommended guidance (or best management practices). SFM for the traditional forest products sector includes environmentally sustainable harvesting practice. However, increased need for bioenergy feedstock can lead to utilization of harvesting residue left after felling for traditional products, and sometimes stumps; ameliorative practices such as ashing or fertilization are also sometimes used to replace site nutrients removed in harvested residue. The potential for incremental impacts with increased removals has resulted in some jurisdictions' refining of their SFM governance to address emerging practices, either within their current SFM systems or as new regulations or guidelines specific to biomass harvesting. The authors review current regulations and guidelines specific to biomass harvesting (i.e., harvesting residue removal, stump removal, ashing) from more than 20 jurisdictions from around the world that are designed to protect soil, biodiversity, and water values. The authors draw lessons for consideration by those interested in developing or revising regulations and guidelines, and by those generating the knowledge needed to underpin them.

Eucalyptus plantations in Florida (USA): economic analysis of current and potential uses. Wright, J. (*ArborGen Inc., USA; patula.wright@gmail.com*).

The introduction of *Eucalyptus* in Florida (USA) began in the 1870s. During the decade of the 1960s, with the advent of large-scale eucalypt plantations for pulping in Spain, Portugal, Brazil, South Africa, and other countries, there was a large effort to achieve success with eucalypt plantations in Florida. Cold temperatures, lack of adequate eucalypt plantation culture techniques, and limited availability of improved seed or clones made these early efforts largely unsuccessful. The first years of the 21st century brought renewed interest in eucalypt plantations in Florida, especially for bioenergy. Developments in national and international bioenergy markets for wood pellets, biofuel, combined heat and power, and cogeneration have promoted the use of short rotation and coppice management in eucalypts in Florida. The eucalypt species showing promise have been *E. benthamii*, *E. macarthurii*, *E. grandis*, *E. amplifolia*, and the hybrid *E. urograndis* (*E. grandis* x *E. urophylla*). Eucalypt plantation wood yields in Florida are lower in the northern part of the state (MAI 9–18 green tonnes/ha/yr with a rotation of 8–10 yr) compared to the southern part of the state (MAI 18–36 green tonnes/ha/yr with a rotation of 6–8 yr).

E-01b Sustainable biomass for energy and industrial raw materials: evaluation of bioenergy systems

Organizers: Viktor Bruckman (Commission for Interdisciplinary Ecological Studies, Austrian Academy of Sciences), Sanjeev Kumar Chauhan (Punjab Agricultural University, India) & Robert Jandl (Federal Research and Training Centre for Forests, Natural Hazards and Landscape, Austria)

Biomass partitioning and fuel characterization of short rotation tree species. Chauhan, S., Soni, R., Singh, B. (*Punjab Agricultural University, India; chauhanpau@pau.edu; rajsoni@pau.edu; balkaransandhu@rediffmail.com*).

The increasing problem of wood shortage in the developing world can be reduced by promoting short rotation forestry outside traditional forest areas, including agricultural lands. This approach can help to conserve the wealth of natural forests. However, trees on agricultural lands are acceptable only if they are more remunerative than traditional farming rotations. Resource allocation into tree components is of fundamental importance in understanding the marketing strategy of on-farming trees. There are different buyers of a single tree and therefore partitioning of biomass is essential so that the tree adopters are not put at a disadvantage. Biomass as a source of renewable energy is gaining importance. The timber component from short rotation species involves less than 50% of the total tree biomass and the rest of the biomass is used for energy purposes. Although biomass for energy does not command as high a price as timber, it is equally important when its environmental value is counted. This paper will share information on the potential role of short rotation forestry in sustaining society and the environment. Allocation of biomass allocation in different components (stem, branch, leaf, bark, and root) of short rotation species will be presented along with the fuel value to account for optimum economic and environmental benefits.

Opportunities to design sustainable bioenergy systems. Dale, V. (*Oak Ridge National Laboratory, USA; dalevh@ornl.gov*).

Effective indicators can help quantify the sustainability attributes of bioenergy options. Major environmental categories of sustainability were identified to be soil quality, water quality and quantity, greenhouse gases, biodiversity, air quality, and productivity; 19 indicators in those categories are discussed. Also identified were 16 socioeconomic indicators that fall into the categories of social well-being, energy security, trade, profitability, resource conservation, and social acceptability. Together, this suite of indicators is hypothesized to reflect major environmental and socioeconomic effects of the full supply chain for bioenergy. The context of an application strongly affects the choice, measurement, and interpretation of sustainability indicators. An example from the southeastern United States shows how context considerations include the purpose of the analysis, the specific fuel production and distribution system, policy influences, stakeholders and their values, baseline attributes, available information, and spatial and temporal scales of interest. Knowing the context is essential for setting priorities for assessment, defining the purpose, setting the temporal and spatial boundaries for consideration, and determining practicality and utility of measures. Adoption of more sustainable practices entails defining sustainability, developing easily measured indicators of sustainability, moving toward integrated forestry systems, and offering incentives or imposing regulations to influence management.

Impact of commercial poplar and willow short rotation forestry stands on water, soil, and phytodiversity. Dimitriou, I. (*Swedish University of Agricultural Sciences, Sweden; ioannis.dimitriou@slu.se*), Bolte, H. (*Thünen Institute of Forest Ecosystems, Germany; andreas.bolte@ti.bund.de*), Baum, S. (*Thünen Institute of Rural Studies, Germany; sarah.baum@ti.bund.de*), Weih, M. (*Swedish Univ. of Agricultural Sciences, Sweden; martin.weih@slu.se*).

Short rotation forestry (SRF) using poplars and willows for production of biomass for heat and electricity is expected to increase in the short term in Europe and other parts of the world. SRF is usually carried out on agricultural soils. Because of differences between annual and perennial systems in terms of management and physical traits, SRF on agricultural land will have implications on various environmental issues related to water, soil, and biodiversity. This paper presents results from experiments conducted in a large number of commercial SRF stands of poplar and willow compared to adjacent fields of common agricultural practices in Sweden and Germany. The results focus on differences between SRF and agriculture in groundwater quality in terms of nitrate-N and phosphate-P, organic C and trace elements in topsoil and subsoil, and phytodiversity. The results indicate differences in ecosystem services provided between land uses potentially competing in future landscapes (agriculture for food or fodder vs. SRF for energy) but also between energy production systems of different intensities, rotations, and management (SRF poplar vs. SRF willow).

Ecohydrological impacts of feedstock production for bioenergy across the Americas: a multidisciplinary study to assess long-term sustainability. Gutierrez Lopez, J. (*University of New Hampshire, USA; gutloja@gmail.com*), Pypker, T. (*Michigan Technological University, USA; tgpypker@mtu.edu*), Licata, J. (*National Agricultural Technology Institute – EEA Concordia, Argentina; julianlicata@hotmail.com*), Asbjornsen, H. (*University of New Hampshire, USA; heidi.asbjornsen@unh.edu*).

As the demand for alternative sources for energy increases, the sustainable production of bioenergy feedstock becomes a major challenge for researchers, policy-makers, and land managers. Research comparing petroleum- and bio-based fuels has focused on differences in CO_2 and other emissions, while less attention has been given to ecohydrological impacts. Understanding of these impacts in fast-growing woody feedstocks (e.g., aspen and eucalyptus) and palms is lacking. The objective of this research is to assess the impacts of producing woody feedstock on water balance across the Americas, focusing on *Populus tremuloides* (Wisconsin, USA), *Eucaliptus globulus* (Corrientes, Argentina), and oil palm (Pará, Brazil, and Tabasco, Mexico). Water balance is calculated based on measurements of transpiration (sapflow), canopy evaporation (throughfall), and stemflow, and precipitation and other climatic variables. Here the authors present their current findings and future directions for assessing the ecohydrological implications and long-term sustainable production of woody biomass for energy in four different environmental, socioeconomic, and cultural contexts. The findings of this study will provide a baseline for the development of sustainable production of crops for

bioenergy, quantify its effects on the water balance, and provide policy-makers, land managers, and researchers with unique information relevant for future development of alternative sources of energy.

How much is too much? Katzensteiner, K., Eckmüllner, O. (University of Natural Resources and Life Sciences (*BOKU), Austria; klaus.katzensteiner@boku.ac.at; otto.eckmuellner@boku.ac.at*).

Mountain forest soils derived from calcareous substrates are frequently characterized by high humus content or even consist solely of organic surface layers. The vegetation pools of carbon and sometimes of macronutrients exceed soil stocks. Even selective timber harvesting has been shown to significantly reduce carbon and nitrogen pools of such soils in the long run. Utilization of residual biomass may have negative feedback on future productivity. To provide a tool for the assessment of biomass extraction on humus dynamics and growth, a modeling environment combining site-specific growth and yield models with a carbon balance model has been developed for a study region in the Calcareous Alps (Austria). Empirical growth models have been derived from standard data of the Austrian forest inventory and additional surveys combined with high-resolution digital surface and terrain models, site maps, and soil information. Allometric functions for the assessment of carbon and nutrient distribution in tree components are based on stratified analyses of trees along chronosequences for predominant site types. Soil carbon and nitrogen dynamics are modeled by a simple mechanistic model based on litter/residue input, and empirically determined moisture and temperature sensitivity of mineralization. Scenarios for different harvest intensities are presented.

Carbon, water, and nutrient balances of a *Eucalyptus grandis* plantation in Brazil over 5 years. Nouvellon, Y. (*CIRAD, Brazil; yann.nouvellon@cirad.fr*), Stape, J. (*North Carolina State University, USA; jlstape@ncsu.edu*), Bonnefond, J. (*National Institute for Agricultural Research* (*INRA), France; bonnefon@bordeaux.inra.fr*), Le Maire, G., Christina, M. (*CIRAD, France; guerric.le_maire@cirad.fr; mathias.christina@cirad.fr*), Campoe, O., Hakamada, R., Loos, R., Bouillet, J., Laclau, J.

Eucalyptus grandis plantations in Brazil are among the most productive forests of the world, reaching mean annual increments of about 50 m^3/ha/yr over short (6 yr) rotations. Carbon, water, and nutrients budgets in one of these plantations were investigated through continuous eddy-covariance measurements of water vapor and CO_2 fluxes over a 5-yr period encompassing two successive rotations (2 yr before and 3 yr after harvesting and replanting), with measurements of water table depth, soil water content to a depth of 10 m, and concentrations of nutrients in soil solutions. Before clearcutting, fine roots were found to a depth of 16 m. No seepage occurred below 5 m. Actual evapotranspiration (AET) was approximately equal to annual precipitation (1350 mm). Clearcutting resulted in a strong decrease in AET, a recharge of deep soil layers, and a rise in the water table. By the third year after replanting, the rapid increase in AET supported by the fast expansion of roots led to soil water depletion to a depth of 10 m. Clearcutting turned the forest from a strong C sink (net ecosystem productivity of about 1 tonne C/ha/month) into a C source, but the plantation turned back to a C sink from 7 months after replanting onwards.

Evaluation of invasives species characteristics and rural people's views on introduced species *Prosopis juliflora* (SW.) DC. in dry zone of Myanmar. Than, W. (*Forest Research Institute, Myanmar; waiwaikyaw2007@gmail.com*).

Prosopis juliflora (mesquite) was introduced into Myanmar around the 1950s for dry zone greening. This research evaluated mesquite distribution using GIS, coppicing, soil and climate conditions, seed germination, and chemical composition of thorn and pod. In addition, a questionnaire survey was conducted to collect data on different societies' use of mesquite and their views. Nine villages were investigated in 2012. Four blocks (East, West, South, North) were laid out in each village. Total tree population and height and coppicing of 10 randomly selected trees were recorded in each block. No correlation was found between height, coppicing, and population. Seed germination was 58–73%. Minerals and feedstuffs of dry pod had a suitable composition for cattle although some samples had a less suitable composition than that of other pasture vegetation. Terpenoids and saponins in thorns may be toxic and painful. Soil sandy loam was dominant with mostly high alkalinity and some acidity. Rainfall between 460 and 940 mm and temperatures between 15.9 and 43 ˚C were observed. Differences in views between occupations (farming, animal husbandry, and forestry) were not significant except for housewife. Expenditures and income from woodcutting; production of charcoal, toddy candy, pots, and kitchen stoves; and brick baking were estimated. Use of mesquite firewood and earnings from these occupations were assumed to be sufficient to support these rural people. Respondents' attitude toward mesquite, "like it for no choice," is the absolute proper answer for inhabitants of the dry zone.

Harnessing green energy from green gold: case study from Peninsular India. Viswanath, S. (*Institute of Wood Science and Technology, India; syam.viswanath@gmail.com*), Renganathan, V. (*PoinTec Pens & Energy Pvt. Ltd, India; pointec94@gmail.com*).

Some of the tropical sympodial bamboo species have high specific gravity and calorific value, which are prerequisites for energy plantations. Such bamboo plantations have an inherent advantage over tree species in energy plantations as the culms can be harvested every year after clump establishment. Pilot studies in Mundurgi and Attebele, Karnataka, in Peninsular India, have shown that intensively managed bamboo species like *Bambusa balcooa* can be a clean energy source. About 1.5 MW of power could be generated from a plantation of around 80 ha through the gasification process. The authors present their clean energy generation model wherein the discarded nodal segments of bamboo are used in conjuction with other fast-growing woody species with high calorific value for power generation, while the internodal segments are utilized for incense stick production. "Biochar," a byproduct of this gasification process, is ploughed back into the soil along with the in situ compost generated from copious bamboo litter to replenish the C stock of captive bamboo plantations. Another byproduct of the gasification process is heat, which can be harnessed for applications like cold storage, chilling applications, and drying of agriculture produce. This holistic carbon negative process presents a unique opportunity for mitigating climate change through carbon sequestration besides generating clean energy.

E-02 Environmental impacts of intensive management of forest soils for timber and bioenergy production

Organizers: Deborah Page-Dumroese (U.S. Forest Service), Peter Clinton (Scion, New Zealand), Liisa Ukonmaanaho (Finnish Forest Research Institute, Finland) & Hailong Wang (Zhejiang Agricultural and Forestry University, China)

Short- and long-term ecological consequences of removal of harvesting residues for bioenergy from forests in Norway. Clarke, N., Eldhuset, T., Hanssen, K., Hietala, A., Kjønaas, O. (*Norwegian Forest and Landscape Institute, Norway; nicholas.clarke@skogoglandskap.no; toril.eldhuset@skogoglandskap.no; kjersti.hanssen@skogoglandskap.no; ari.hietala@skogoglandskap.no; janne.kjonaas@skogoglandskap.no*), Lange, H., Nordbakken, J., Økland, T. Røsberg, I.

In conventional stem-only timber harvesting (SOH), where branches and tops are left in the forests, organic material decays onsite and nutrients are returned to the biogeochemical cycle. In whole-tree harvesting (WTH), branches and tops are largely removed, together with their nutrients. In the longer term, such harvesting might increase the risk for nutrient imbalances and reduced forest production, as well as changes in species composition and biodiversity. Thus, there is potential for conflict between increased use of forest resources for bioenergy and rural employment on the one hand, and protection of ecosystem services together with long-term site sustainability on the other. Although numerous studies have been carried out, there are few in which the various effects are integrated and in which both short- and long-term aspects are considered. In two recently established field experiments at sites with different climatic conditions in Norway, the authors compared effects of WTH and SOH on soil, soil fungi, ground vegetation, and regeneration. The authors show how results from these experiments and from long-term experiments on effects of whole-tree vs. stem-only thinning on soil and ground vegetation can be used in further development of management guidelines to minimise the risk for negative effects of harvest residue removal.

Manipulating forest soils for greater productivity: Are there limits? Clinton, P. (*Scion, New Zealand; Peter.Clinton@scionresearch.com*).

There is an increasing recognition of the productivity gap in the agricultural sector and the need to close this gap to increase the supply of products. In the light of the future demands on forests, the extent of the productivity gap for forests also needs to be identified. The long-term nature of the forest cycle provides the potential to manipulate both the productivity of existing forests and also that of the future forests that will be planted following the harvest of current forests. Manipulation of forest soils offers many possible options for increasing the productivity and value of mid-rotation stands. Simply put, achieving larger logs, and more of them with better wood characteristics will increase both the value and productivity of existing forests. One way to do this is to increase the sophistication of fertiliser use in forestry and to bring it into line with state-of-the-art fertiliser technology while adopting a systems biology approach to match plant nutrition with forest soil resources. If we recognise that in addition to being nutrients, P, B, and particularly N can act as signals that regulate plant gene expression, physiology, and growth and development, we could aim to transform fertiliser use in forestry.

Variables of soil, plant and productivity related with age and site index in *Gmelina arborea* plantation in north Colombia. Escobar Quemba, L., Cadena Romero, M. (*Universidad Distrital Francisco José de Caldas, Colombia; hojyann@yahoo.com; mecadenar@udistrital.edu.co*), Henao Toro, M. (*Universidad Nacional de Colombia, Colombia; mchenaoto@unal.edu.co*).

The productivity of plantations of *Gmelina arborea* in Colombian tropical dry forest is lower than that in other countries, and many trees do not express all their genetic potential. To understand the effects of soil on yield, some properties of soils planted with *G. arborea* were examined, with the objective of relating them to site index (SI), nutrient status, and productivity. Soil samples were taken in nine plantation sites of 1 ha, corresponding to three SI (high, medium, and low) and three planting ages (3,7, and 10 yr). Nine trees in each plot were selected for nutritional analysis on leaves and measurement of growth variables. The soils have clay content between 32 and 60%, slightly acidic to neutral pH, low content of organic carbon and nitrogen, high levels of exchangeable bases, and a moderate level of phosphorus. Foliage analysis showed low levels of nitrogen in only two plots, whereas the others nutrients were adequate in all plots. There was no correlation with growth variables, however. Plots with the high SI had higher exchangeable calcium and lower sodium than the medium- or low-SI plots. An inverse relationship between exchangeable sodium and volume of trees was observed, suggesting that this element negatively influences plant development.

Biomass harvesting in Fennoscandian boreal forests—nutrient removals and nutrient status. Finér, L. (*Finnish Forest Research Institute, Finland; leena.finer@metla.fi*), Palviainen, M. (*University of Helsinki, Finland; marjo.palviainen@helsinki.fi*).

Intensive forest biomass harvesting for energy production is increasing in Fennoscandia and may have impacts on the nutrient status of forests. Existing data and new and published equations on biomass and nutrient contents in different tree stand components (crowns, stems, stump, and coarse roots) were used for quantifying the impacts of different harvesting intensities on nutrient removals. The results demonstrate that nutrient removals per m^3 of harvested stem differ between the tree species cultivated in Fennoscandia, and are smaller in Scots pine than in Norway spruce or birch stands. Furthermore, nutrient removals can be reduced by harvesting energy wood from mature stands instead of thinning young stands with a high proportion of nutrient-rich crowns. Traditional stem-only harvesting can already lead to negative phosphorus, potassium, and calcium balances during one-stand rotation on sites where the deposition and weathering of these nutrients are unable to compensate for the removals by harvesting and leaching. When the harvesting intensity is increased to encompass branches or even stumps and coarse roots, nutrient balances become even more negative and also include nitrogen. By taking into account the species- and site-specific nutrient pools and fluxes when planning harvesting intensities, negative nutritional impacts can be minimized.

Environmental sustainability of intensive forest biomass removals: results of a global meta-analysis. Fleming, R., Titus, B. (*Canadian Forest Service, Canada; rob.fleming@nrcan-rncan.gc.ca; bdtitus@gmail.com*).

A range of field trials have been established in various parts of the world to assess the environmental impacts of intensive biomass removals. Although some trials were designed to address bioenergy-related questions, others have different objectives but include some relevant treatments (e.g., Long-Term Soil Productivity trials in North America). Meta-analysis increases the amount of information that can be extracted from a range of field trials, and can be used (within the limits of the data available) to test hypotheses and generate empirical results to feed into our scientific understanding. The authors present results of meta-analyses using site-level mean data from publications and unpublished plot-level data from trials around the world to test hypotheses that tree growth response to intensity of biomass removals is dependent on factors such as tree species (conifer vs. hardwood, genus and genus groups, fast-growing vs. slow-growing), ecosystem type, climate, site index, soil properties (time since glaciation, texture, soil moisture, major nutrients, base cations, acidity), and surficial and bedrock geology.

Linking forest soils and ecophysiology to improve sustainable management of forest plantations. Fox, T. (*Virginia Polytechnic Institute and State University, USA; trfox@vt.edu*).

In order to address the complex problems facing foresters throughout the world, forest soils research must link empirical research with an improved understanding of ecosystem processes. In pine plantations in the southern United States, improved silvicultural practices over the last 50 years have more than doubled productivity and reduced rotation lengths by 50%. Until recently, the links between forest soil properties and ecophysiological processes controlling these changes were poorly understood. Thus it was difficult for managers to develop plantation management regimes that were well suited to the various climatic regimes and forest soil types in the region. This paper will describe how the physical and biochemical properties of forest soils affect water and nutrient availability and in turn tree growth. It will show how silvicultural treatments can influence resource availability that in turn affects leaf area, growth efficiency, and ultimately productivity of plantation forests. It will emphasize how management practices can improve or degrade forest soils and thus impact long-term forest productivity.

Hydrological constraints in harvest scheduling models for eucalyptus plantations. Gimenez, J. (*Research Group "Economics for a Sustainable Environment," Spain; jcfernan@unex.es*), Diaz Balteiro, L. (*Polytechnic University of Madrid, Spain; luis.diaz.balteiro@upm.es*), Bertomeu, M. (*University of Extremadura, Spain; bertomeu@unex.es*).

An important topic in the forest management literature is the temporal and spatial arrangement of harvests. Timber harvesting remains an important component of natural resource management, but it must be approached in such a way that other considerations are not sacrificed. Forest managers are increasingly being required to include spatial restrictions in their harvest schedules because of concerns about water quality and erosion control, among others. There are several examples of harvest scheduling models that use adjacency constraints to limit the size of harvests, but none of them uses the concept of hydrological neighborhood. This paper presents an attempt to incorporate hydrological constraints into harvest-scheduling mixed integer programming models for eucalyptus plantation management planning. Hydrological constraints are formulated so that connected cells (belonging to the hydrological neighborhood) cannot be harvested within the same time period. In this case, the most important issue is not the harvest size but the topographical harvest pattern. The authors applied this approach to a *Eucalyptus globulus* Labill. plantation in Galicia (Spain).

Negative effects of stump harvest and deep soil cultivation on the soil carbon pools are mitigated by enhanced tree growth. Jurevics, A. (*Swedish University of Agricultural Sciences, Sweden; arnis.jurevics@slu.se*).

Demand and supply of biomass for energy from forests is rapidly developing. Carbon balance is, however, questioned when stumps are harvested. Stump harvest has a negative impact on the soil C pool because of the removal of the slowly decomposing biomass with its C. Additionally, it increases the nutrient loss from the site with the potential to decrease growth of the next generation of trees. However, loss may be compensated for by a stimulated mineralization and reduced competing vegetation as a result of the soil disturbance caused by the stump harvest. C pools were estimated in soil and trees in two field experiments in boreal Sweden 22 and 25 yr after stem and stump harvest and deep soil cultivation (SS-DSC), in comparison to conventional stem harvest and manual patch scarification (S-PS). The soil C pools were 10 and 25% lower 22 and 25 yr, respectively, after SS-DSC, but not significant. The tree biomass C pool increased significantly by 18 and 47% following SS-DSC. The total C pool (soil and tree biomass) was unaffected by the treatment. It was concluded that statements on the carbon balance have to be based on both the soil C pool and the tree biomass C pool.

Stump harvest at final felling – impact on soil surface disturbance, and carbon and nitrogen dynamics. Kaarakka, L. (*University of Helsinki, Finland; lilli.kaarakka@helsinki.fi*).

As a result of changes in international and national energy policy, silvicultural treatments, which involve extensive biomass removal from forest stands, are becoming more common in Scandinavia. Stump harvest, often combined with mounding, causes severe soil disturbance, such as mixing and relocation of the organic material and the mineral soil within the soil profile. Due to lack of research, the possible environmental effects of stump extraction are uncertain and their time-scale unknown. The effects of stump harvesting on soil C and N pools, C and N mineralization, and soil surface disturbance were studied at three different clear-felled Norway spruce stands in Southern Finland. The study used a paired design, based on time since final felling and site fertility. Soil samples were systematically collected from the different soil surfaces found at stump harvest sites: mounds, excavation pits, and the undisturbed surfaces. The extent of soil surface disturbance was visually estimated using a quadrat. Preliminary results indicate that stump harvest can cause extensive soil surface disturbance.

Assessment of forest logging influence on soil environment. Marchi, E., Cambi, M., Certini, G., Paffetti, D. (*University of Florence, Italy; enrico.marchi@unifi.it; martina.cambi@unifi.it; giacomo.certini@unifi.it; donatella.paffetti@unifi.it*), Picchio, R. (*University of Tuscia, Italy; r.picchio@unitus.it*), Vettori, C.

Mechanized ground-based logging methods are widely used today because they generally provide a safe work environment and high labor productivity. However, forest soils, which often are characterized by rich, soft humus and biologically active top

horizons, are particularly prone to compaction during logging operations and, as a consequence, other forms of degradation. This work evaluated the effects of logging on the physical and biological properties of soil. Two areas were investigated in central Italy. In the first one, a stand of umbrella pine growing on sandy soils, impacts from heavy machinery in clearcuts carried out in 2006 or 2011 were compared. In the second area, a conifer mixed stand growing on clay loam soils, impacts of wheeled and tracked tractors on soil were compared during thinning in 2013. In both the study sites and in both trafficked and control areas, soil samples were collected to determine bulk density and porosity. In the field resistance of soil to penetration and shear strength was measured. Other soil samples were studied in terms of specific and quantitative composition of soil microbial communities by molecular approaches. The results showed significant differences in soil physical and biological characteristics between the trafficked areas and the control, which underline the necessity to carefully plan and monitor such logging operations.

A sustainability index for improving nutrient management in short rotation bioenergy systems. Sochacki, S., Harper, R. (*Murdoch University, Australia; s.sochacki@murdoch.edu.au; r.harper@murdoch.edu.au*), Smettem, K. (*University of Western Australia, Australia; keith.smettem@uwa.edu.au*), Dell, B. (*Murdoch University, Australia; b.dell@murdoch.edu.au*).

Short rotation energy crops have the potential to provide sustainable sources of biomass, but the efficient use of nutrients will be crucial to ensure that these systems are sustainable. In dryland environments 3- to 5-yr rotations of tree crops integrated with agriculture represent a major potential bioenergy feedstock and a means to restore landscape hydrologic balances, while maintaining food production. In soils with low natural fertility, the long-term viability of these systems is critically affected by site nutrient status and subsequent cycling of nutrients. A nutrient assimilation index (NAI) was developed to allow comparison of the nutrient assimilation between tree species and tree components, to optimise nutrient management, and to quantify different strategies to manage nutrients. Biomass, nutrient export, and nutrient use efficiency were assessed for three short rotation tree crop species (Eucalyptus globulus, *E. occidentalis*, *Pinus radiata*). Component NAI was generally in the order of leaf<twig<bark< root<twig<bark<root.

Sustainable forest harvest requires nutrient supply from soil pools: ecosystem budgets for second-growth northern hardwoods in New Hampshire, USA. Yanai, R. (*State University of New York, USA; rdyanai@syr.edu*).

Nutrient cycling budgets in northern hardwood stands in the White Mountains of New Hampshire (USA) indicated that young stands were accumulating Ca in the forest floor and the vegetation and that leaf litter was more Ca-rich in young (<30 yr old) than in older stands. Stream concentrations of Ca remain elevated for decades in young stands. This research explored the possibility that accelerated apatite weathering could explain the high rate of Ca mobilization in young stands. Measurement plots were established in replicate stands of 3 ages (14–19 yr, 26–29 yr, and > 100 yr) at Bartlett Experimental Forest. Calcium in aboveground and belowground biomass averaged 1 102 kg/ha in mature stands. The amount of Ca in exchangeable form in soils was only 287 kg/ha in the mature stands, clearly not enough to supply Ca to forest regrowth. The young and mid-aged forests contained 375 and 540 kg Ca/ha in living biomass. Exchangeable Ca in the young and mid-aged stands was 230 and 184 kg/ha, not significantly different from the pre-harvest (old) condition. Thus the exchangeable pool is neither sufficient to explain forest growth nor is it depleted by forest growth. The sustainability of repeated forest harvest depends on weathering rates of Ca and other elements.

E-03 Evaluation of environmental Impacts of production and use of wood products and wood energy

Organizers: Richard Bergman (U.S. Forest Service) & Adam Taylor (University of Tennessee, USA)

GHG profile of an advanced pyrolysis unit using woody biomass. Bergman, R., Gu, H. (*U.S. Forest Service, USA; rbergman@fs.fed.us; hongmeigu@fs.fed.us*).

Biomass pyrolysis systems for producing syngas or biofuel have drawn worldwide attention for their environmental benefits and sustainability. Biochar as an additional product from these systems has also generated interest within the forest product industry and forest management research communities. Science-based assessments of new energy technologies and new products are essential tools for policy-makers working to expand renewable energy production. Evaluating the environmental impacts from changing to biomass-derived products provides decision-makers with the negative and positive consequences of selecting one product over another. In this study, emissions from a 200 kW_e modular advanced pyrolysis unit consuming about 250 kg/hr of woody biomass were categorized for their environmental impacts, including global warming potential (GWP), from cradle-to-production gate using life-cycle assessment standards. The unit generated 0.14 kg of biochar and 0.65 kg of synthesis gas (syngas) as its main products from 1 kg of woody biomass. Using a mass allocation approach, results showed GWP for biochar and syngas production of 0.072 and 0.34 kg CO_2-eq per kg of woody biomass, respectively. The next step will be to develop emissions profiles for secondary products such as activated carbon and electricity and compare these results to those of commercially available products.

Life cycle assessment of a fuel switch to biomass: the case of a direct-fired boiler gasification energy system. Mahalle, L. (*FPInnovations, Canada; lal.mahalle@fpinnovations.ca*).

This study presents a comparative assessment of a fuel switch from natural gas to wood biomass, using the direct-fired wood boiler gasification technology invented by Nexterra Systems Corporation. The study was conducted at Kruger Tissue Mill located in New Westminster, British Columbia, Canada, which was using natural gas to generate process steam for tissue production before the switch. The study scope included all the cradle-to-grave processes, starting from resource extraction through burning in boilers to produce steam. The primary goal of this exercise was to evaluate the greenhouse gas (GHG) emissions performance of the gasification energy system against burning natural gas as the base case. The U.S. Environmental Protection Agency's Tool for

the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) method and the European-based "Cumulative Energy Demand" (CED) method were applied to calculate global warming impacts and primary energy consumption by energy sources, respectively. The study finds that the wood biomass gasification system could mitigate 134–162 kg of CO_2 eq. of GHGs and displace 2 754–3 140 MJ of fossil fuel on a per tonne of steam basis.

Local air quality impacts of advanced biofuels in the Pacific Northwest: a consequential life cycle assessment approach. Ganguly, I., Eastin, I., Bowers, C. (*University of Washington, USA; indro@nararenewables.org; eastin@uw.edu; taitb@uw.edu*).

Typical forest harvest operations in the Pacific Northwest (USA) leave considerable volume of unused woody biomass in the forest. Given limited economic feasibility of extracting these harvest residues, the residual woody biomass is collected, piled, and burned in the forest or is simply left on the forest floor to decompose. The Northwest Advanced Renewables Alliance (NARA) research project is exploring the potential of converting residual woody biomass into drop-in biojet fuel within the region. Removing woody biomass derived from forest harvest operations greatly reduces the need to burn slash piles. Similarly, conducting forest thinning operations to remove dead and dying trees from the forest improves forest health and leads to a reduced risk of catastrophic forest fires caused by an overaccumulation of fuels. Using a consequential life cycle assessment framework, this paper highlights the positive and negative local air quality impacts associated with the NARA biofuels project. Although the harvest and residue extraction activities contribute to regional air pollution, the emissions avoided because of reduced slash pile burning and fewer and less intense forest fires enhance the regional air quality. The life cycle impact assessment (LCIA) results predict a net beneficial local environmental impact of the NARA biofuels project for communities across the Pacific Northwest.

Incorporating carbon sequestration into the feedstock life cycle assessment for residual woody biomass. Pierobon, F. (*University of Padua, Italy; francesca.pierobon@gmail.com*), Ganguly, I., Eastin, I. (*University of Washington, USA; indro@u.washington.edu; eastin@u.washington.edu*), Anfodillo, T. (*University of Padua, Italy; tommaso.anfodillo@unipd.it*), Bowers, C. (*University of Washington, USA; taitb@uw.edu*).

The renewability of wood plays an important role in evaluating the overall carbon footprint of producing energy from woody biomass. This renewability comes from both avoided carbon emissions during energy production and from carbon sequestration in the growing forest. Currently there is no consensus on the appropriate methods for incorporating carbon sequestration into the life cycle assessment (LCA) framework. This study proposes a methodology for incorporating carbon sequestration within the bioenergy LCA framework. Forest types, species mix, and silvicultural treatments play an important role in the development of the proposed carbon sequestration methodology. This paper evaluates the proposed carbon sequestration model for temperate mountain systems based on a 75-yr harvest cycle. The types of forest management scenarios considered in the analysis are: (1) privately owned dry forests, (2) state-owned and privately owned moist forests, and (3) dry-moist-cold national forests. The Lashof Accounting methodology has been used to evaluate the temporal environmental impacts associated with the emission and sequestration of carbon during the forest life cycle. The results suggest that forest type, species mix, and forest management systems all influence the level of environmental benefits derived from woody biomass based bioenergy.

Landscape-level net GHG analysis of forest-based material and energy systems. Gustavsson, L., Haus, S., Dodoo, A. (*Linnaeus University, Sweden; leif.gustavsson@lnu.se; sylvia.haus@lnu.se; ambrose.dodoo@lnu.se*).

There are multiple climatic aspects of forest products, such as fossil fuel substitution, material substitution, and carbon stock changes in biomass and soil. The efficiency of replacing different fossil fuels and materials in different sectors with forest biomass can vary widely. The authors estimate and compare time profiles of greenhouse gas (GHG) emissions of different forest and reference systems. The forest-based systems include wood-frame buildings and bioenergy systems; the reference systems include non-wood frame buildings and fossil energy systems. Conventional Swedish forest management is considered from stand and landscape levels, starting with managed mature forest, and forest land use without harvest is included in the reference systems. A life cycle perspective is used for technical systems, which include all significant elements of both the forest-based systems and the reference systems, including GHG emissions along the full material and energy chains. The difference in time-profiles of GHG emissions is then calculated between the forest-based systems and reference systems and the resulting cumulative radiative forcing over 300 yr. The results show greatest climate mitigation when forest biomass is used for construction materials and for heat and power production, replacing concrete and fossil coal. The methodological framework provides a tool to help determine strategies for forest management and use of forest biomass to mitigate climate change.

Modeling the effects of forest management and wood products use on carbon budget in the context of climate change. Jochheim, H., Brunet-Navarro, P. (*Leibniz-Centre for Agricultural Landscape Research (ZALF), Germany; hubert.jochheim@zalf.de; Pau.Brunet@zalf.de*), Mues, V., Olschofsky, K. (*University of Hamburg, Germany; volker.mues@uni-hamburg.de; konstantin.olschofsky@ti.bund.de*), Janott, M. (*Leibniz-Centre for Agricultural Landscape Research (ZALF), Germany; michael.janott@zalf.de*), Koehl, M.

Forest ecosystems store large carbon stocks in vegetation, coarse woody debris, and soil. Additionally, carbon is accumulated in harvested wood products. Climate change may influence carbon fluxes in forest ecosystems and may also affect total carbon sequestration. Forest management as well as wood utilization options are discussed to reduce atmospheric CO_2 concentrations and therefore mitigate climate change. The authors present results of a simulation study for different European forests using BIOME-BGC (BioGeochemical Cycles) model extended by a management module and a wood products module. Alternative management strategies in order to maximize harvested wood or carbon pools within the ecosystem are compared with the "business as usual" option. The management strategies vary in thinning intensity, exported fraction from forest, and rotation length. Additionally, effects of wood product use are investigated. The mitigation potential of the management and wood utilization options will be evaluated against simulated climate change effects.

Effects of forest management on timber and energy biomass production and climate change mitigation potential in Norway spruce. Kilpeläinen, S. (*EduSilva, Finland; antti.kilpelainen@uef.fi*).

The net exchange of CO_2 in the continuum of ecosystem, technosystem, and atmosphere should be taken into consideration when addressing the role of forests in climate change mitigation. It is mainly affected by forest management, which defines the

potential of biomass for carbon sequestration, carbon storage, and production. The effects of forest management are reflected also in the amount of harvested biomass that can ultimately be used as a substitute for fossil fuel. The objective of this research is to study alternative forest management regimes in climate change mitigation and biomass production in boreal conditions by means of ecosystem modeling and the integrated life cycle carbon assessment (LCA) tool. The outputs of varying management regimes for Norway spruce stands are compared with their impacts on biomass growth, timber and energy biomass recovery, and ecosystem carbon. Moreover, the holistic impacts of the regimes on the net CO_2 exchange and fossil fuel substitution potential are also assessed. The possibilities of increased biomass production and carbon storage are investigated by changing the basal area-based thinning thresholds, fertilization, use of cloned trees, and rotation periods. The results are also shown in terms of radiative forcing of biomass utilization compared to the use of fossil fuels.

Improving the resource efficiency of wood consumption—a life cycle assessment study on wood cascading. Richter, K., Weber-Blaschke, G., Höglmeier, K. (*Technical University of Munich; richter@hfm.tum.de; weber-blaschke@hfm.tum.de; hoeglmeier@hfm.tum.de*).

With increasing scarcity of resources, wood has been becoming increasingly attractive both for energy generation and for material use. Despite its renewability, available volumes are limited. Therefore, maximizing the efficiency of wood utilization is paramount. Cascading— the successive use of a material for several applications followed by a final use for energy production— is regarded as a suitable concept to achieve this goal, especially in the legislative and political context. However, the additional technological efforts to keep the wood fiber in service over several product lifetimes has not been taken into consideration thus far, and there is a risk that the environmental benefits associated with cascading will turn into disadvantages. The authors are conducting full life-cycle assessments of several wood cascade chains and respective products out of virgin wood, mainly focusing on the production of composite wood products such as oriented strand board and particle board. The authors aim to determine break-even points of technological investments and environmental benefits of wood cascading. Preliminary results confirm that cascading increases the efficiency in the use of wood as a resource by generating smaller amounts of greenhouse gases and consuming less primary energy compared to a one-time use of virgin wood. How these results change with the number and type of cascading cycles will be reported.

Lessons from consecutive life cycle assessments of plywood and oriented strand board in the United States. Taylor, A., Kaestner, D. (*University of Tennessee, USA; adamtaylor@utk.edu; dkaestne@utk.edu*).

A holistic assessment of the ecological impact of trees should include consideration of potential forest products. Life cycle assessment (LCA) is a standard and globally accepted tool for the holistic examination and comparison of products and processes, and LCA has been applied to forest products for the past two decades. LCA of forest products consistently shows that wood processing is efficient and that the environmental impacts of wood products are very low in comparison to non-wood alternatives. These findings are beginning to be documented and promoted in environmental product declarations (EPDs) for wood products, which are standardized summaries of LCA data. Life cycle inventories (LCIs) are the data basis for the LCA, and LCIs for U.S.-made structural plywood and oriented strand board (OSB) are being updated in 2013–2014 in order to produce up-to-date EPDs for these products. These data and two similar studies over the past 20 years show the consistently excellent environmental performance of these major wood building products yet also reveal how changes in technology and in the industry can have surprising impacts on eco-efficiency.

Environmental impact assessment of China's forest-to-pulp supply chain. Xu, W., Becker, G. (*Albert-Ludwigs-University Freiburg, Germany; wei.xu@fobawi.uni-freiburg.de; gero.becker@fobawi.uni-freiburg.de*).

Integration of wood pulp mills with eucalyptus plantations as a pulpwood source has become an important development pattern for the Chinese pulp industry. This study examined the environmental impacts of this "forest-to-pulp" supply chain by applying the methodology of life cycle assessment. System boundary was defined by a "cradle-to-gate"' perspective, including the forest and pulp mill subsystems, with the functional unit of 1 air-dried ton of market pulp at mill gate. Principle operations were investigated and site-specific inventory data were gathered in 2009 and 2010 through field trips to a leading eucalyptus plantation operator in Guangxi and a state-of-the-art kraft pulp mill in Hunan. System modeling and life-cycle inventory were carried out with Umberto®. Eight impact categories were taken into consideration for the environmental impact assessment. The forest subsystem showed significant contribution to the total environmental burdens mainly from fertilization in eucalyptus plantation management. The pulp mill was identified as the major emissions source mainly because of its onsite combined heat and power plant, chemical recovery unit, and water treatment plant. The upstream processes of raw materials and energy production greatly influenced the total environmental performance of the examined supply chain. These findings may help the Chinese forest and pulp industry achieve better performance toward sustainable development.

E-04a Forest biomass supply chains: Practice, economics, and carbon balance

Organizers: Nate Anderson (U.S. Forest Service), Gustaf Egnel (Swedish University of Agricultural Sciences) & Woodam Chung (Oregon State University, USA)

Forest biomass supply chains: practice, economics, and energy balance in Tochigi prefecture, Japan. Aruga, K. (*Utsunomiya University, Japan; aruga@cc.utsunomiya-u.ac.jp*).

Many biomass power generation plants have been planned as a measure against climate change and for energy security, especially since the disaster of 11 March 2011 in Japan. Resource requirements are being fulfilled by using unused materials such as small-sized logs and logging residue because power generation with unused materials was offered incentives in the Feed-in Tariff (FIT) effective in Japan as of July 1, 2012. This study first describes the current situation of biomass power generation in Japan. Then,

three scales of forest biomass supply chains in operation in Tochigi prefecture are described: (1) a large-scale practice with mechanized operations conducted by a forest owners' association or logging contractors, (2) a medium-scale operation with small forestry machinery operated by another forest owners' association, and (3) a small-scale one with manual operations or semi-manual operations by individual forest owners or private logging contractors. Finally, economic and energy balances of these forest biomass supply chains are discussed.

A review of wood fuel sourcing potentials and sustainability challenges in different regions of the world. Bentsen, N., Stupak, I. (*University of Copenhagen, Denmark; nb@ign.ku.dk; ism@ign.ku.dk*), Smith, C. (*University of Toronto, Canada; tat.smith@utoronto.ca*).

Several countries have policies for increased use of biomass for energy and biomaterials. It is likely that such policies will lead to increased international demand for wood and increased pressure on the world's forests. Concerns for forest sustainability have been expressed, especially in the EU and its biomass-importing countries. As countries and companies search worldwide for new biomass sourcing areas, there is a need to review and compare the biomass potentials in different regions and the associated forest sustainability challenges. The authors reviewed the literature to assess, evaluate, and compare forest biomass sourcing potentials and associated forest sustainability challenges in Europe, Russia, Africa, North America, and South America, under a scenario where international demand for energy wood continues to increase. The focus was on environmental sustainability criteria (greenhouse gas emissions reductions, ecosystem carbon, biodiversity, soil and water) and how well they are governed. The authors also addressed other issues of significant concern in a specific region, such as competition with food production. The authors propose and compare the most urgent short- and long-term forest sustainability and governance challenges in the different regions for consideration by institutions developing energy biomass sourcing policies and biomass sustainability criteria in the public and private sector.

Modeling the profitability of power production from short-rotation woody crops in Sub-Saharan Africa. Buchholz, T. (*University of Vermont & Spatial Informatics Group LLC, USA; tbuchholz@sig-gis.com*).

Increasing the electricity supply in Sub-Saharan Africa is a prerequisite to enable economic development and reduce poverty. Renewable sources such as wood-fueled power plants are being promoted for social, environmental, and economic reasons. This study analyzed an economic model of a vertically integrated system of short-rotation woody crop (SRWC) plantations coupled with a combined heat and power (CHP) plant under Sub-Saharan African conditions. A 5 MW (electric) base-case scenario was analyzed under Ugandan conditions with a 2 870-ha *Eucalyptus grandis* plantation and a productivity of 12 tonnes/ha/yr (oven-dry basis) under a 5-yr rotation. Plant construction and maintenance constituted 27 and 41% of total costs, respectively. Plantation productivity and carbon credit sales, as well as land, fuel, labor and transport costs, had a minor economic role. Highly influential variables included plant efficiency and construction costs, plantation design (spacing and rotation length), and harvest technologies. In conclusion, growing 12–24 tonnes/ha/yr at a 5-yr rotation can produce an internal rate of return (IRR) of 16 and 19% over 30 yr, respectively. The base-case scenario's 30-year IRR dropped from 16 to 9% when a heat market was absent. Implementation-related research needs for pilot activities should focus on SRWC productivity and energy life cycle analysis.

Influence of forest resource capacity, logistics, and public policy for co-combustion of woody biomass. Goerndt, M., Aguilar, F. (*University of Missouri, USA; goerndtm@missouri.edu; aguilarf@missouri.edu*), Skog, K. (*U.S. Forest Service, USA; kskog@fs.fed.us*).

Woody biomass co-combustion can be a viable option to increase renewable energy production and reduce criteria pollutant emissions. A multi-phase study determined influential factors of co-combustion of woody biomass in the northern United States. A regional woody biomass resource analysis focused on physical availability and sustainability criteria of commercial biomass removal, and estimated energy footprints based on current levels of electricity consumption. Econometric models were then developed to identify counties that have a high potential for co-combustion based on industry internal, external, and location-specific drivers encompassing a range of socioeconomic, resource, and policy-based variables. Fine-scale analyses of procurement areas, transportation distances, and operational costs of woody biomass co-combustion for individual plant locations within the region were conducted. Results indicate that marginal costs and limitations on transport distance would restrict most power plants to no more than 10% replacement of current coal usage. Attainment of renewable energy targets may necessitate caps on woody biomass energy to prevent potential degradation. Although woody biomass co-combustion has great potential for renewable energy, it has limited capacity to supplement current and future electricity demand.

Impact of EU Renewable Energy Sources policies on the use of wood for energy and international trade of wood biomass and pellets. Moiseyev, A., Solberg, B. (*Norwegian University of Life Sciences, Finland; moiseyev@efi.int; birger.solberg@umb.no*), Kallio, M. (*Finnish Forest Research Institute, Finland; maarit.kallio@metla.fi*).

This study examines the effects of different EU Renewable Energy Sources (RES) policies such as carbon emission prices and energy generation subsidies on the use of wood for electricity and heat production in the European Union. The analysis is carried out using the global forest sector model EFI-GTM expanded to cover electricity and heat production from wood, coal, and natural gas. Analysis shows that with a carbon price below 80 €/tonne CO_2 the use of wood for energy will be limited to low-cost logging residues. At a carbon price over 100 €/tonne CO_2, industrial wood starts to be increasingly used for energy. However, the amount of industrial wood used for energy may substantially increase with subsidies for using wood for electricity and heat. A subsidy of 30 €/MWh to the wood-based and coal with wood co-firing electricity production will have a significant impact on the European wood-based sector. Such a subsidy may cause a 10–15% reduction in forest products production, a 6–10% increase in harvest level, an increase of about 30–60% in pulpwood prices, and a sixfold to ninefold increase of wood imports in the EU, compared to the respective case without a subsidy in 2030.

A full supply chain optimization model for the location of forest biomass-based CHP production plants in Finland. Natarajan, K. (*University of Eastern Finland, Finland; karthiforester@gmail.com*), Leduc, S. (*International Institute for Applied Systems Analysis, Austria; leduc@iiasa.ac.at*), Pelkonen, P. (*EduSilva, Finland; paavo.pelkonen@uef.fi*), Dotzauer, E. (*Mälardalen University, Sweden; erik.dotzauer@fortum.com*), Tomppo, E. (*Finnish Forest Research Institute, Finland; erkki.tomppo@metla.fi*).

As a country rich in forest resources (73% of total land area) and a pioneer in forest technology, Finland has a longstanding tradition of utilizing forest biomass for bioenergy production. The National Renewable Action Plan 2010 strives to increase the present consumption of forest chips from 6 million m^3 to 13.5 million m^3 (97 PJ) by 2020, mainly for combined heat and power (CHP) production and separate heat production. Therefore, there is a need to build new biomass-based CHP plants at new locations and/or at the existing CHP plants where the coal boilers will be substituted with biomass. The aim of this study is to apply a mixed integer linear programming model (BEWHERE FINLAND) to optimize location, number, and production configurations of CHP plants by minimizing the entire costs and emissions of the supply chain with respect to biomass resource availability, energy demand, and existing industrial competition. The model results illustrate that most of the production plant locations are concentrated in the southern parts of the country because of higher heat demand in the region. The model results also present the sensitivity of different parameters used in the model. The results of this study would be of significance to the government, energy companies, and local communities in devising a suitable geographic energy planning strategy.

Evaluating the greenhouse gas mitigation potential and cost-competitiveness of forest bioenergy systems in northeastern Ontario (Canada). Smith, C., Ralevic, P. (*University of Toronto, Canada; tat.smith@utoronto.ca; peter.ralevic@utoronto.ca*), Cormier, D. (*FPInnovations, Canada; Denis.Cormier@fpinnovations.ca*), Kurz, W. (*Canadian Forest Service, Canada; wkurz@nrcan.gc.ca*).

The magnitude and temporal variation of ecosystem C stock changes resulting from harvest of roadside residues and unutilized whole trees for bioenergy in a boreal forest in northern Ontario (Canada) was estimated by using life cycle assessment (LCA). The Carbon Budget Model (CBM-CFS3) and Biomass Opportunity Supply Model (BiOS-Map) were used to estimate biogenic C emissions and cost analysis of different harvesting systems. Natural gas steam and electricity, grid electricity, and coal electricity reference systems were analyzed for pulp and paper mill energy. This forest was a net sink for carbon after the 20th year of roadside residue harvest; under whole-tree harvesting, the landscape remained a net source of carbon over the entire 100-yr rotation. The cost of delivering roadside residues was about $55/oven-dry ton, and $95/oven-dry ton for whole trees. LCA estimates showed break-even points of 25, 33, and 6 yr for roadside residues displacing NG steam, NG electricity, and coal, respectively. No greenhouse gas (GHG) reduction was achieved when forest biomass was used to displace grid electricity in Ontario. Whole-tree bioenergy resulted in no GHG reduction for NG displacement, and a break-even point of about 80 yr for coal. Utilization of roadside residues is recommended if the main goal is GHG mitigation.

Economics of forest biomass processing and transport from harvest residues in steep terrain. Zamora Cristales, R., Sessions, J. (*Oregon State University, USA; rene.zamora@oregonstate.edu; john.sessions@oregonstate.edu*).

The economics of forest biomass processing and transport from harvest residues is analyzed to estimate the most cost-effective combinations of processing machinery and transportation configurations for biomass recovery operations. The main goal of this research is improving operational economics to develop a cost-effective aviation-fuel supply chain from forest harvest residues. The focus of this paper is on mountainous areas, where road access is often difficult for large trucks and machinery. A decision support system, Residue Evaluation and Network Optimization (RENO), is presented to give operational support to forest managers, landowners, and contractors. RENO combines the use of mixed integer programming, simulation, GIS, and forest operation analysis in order to optimize in-field operations. RENO analyzes operations at the operational level and is able to estimate cost, based on the spatial location of the residue pile and its spatial relation with the forest road system. Additionally, in this study the authors discussed different technologies to increase bulk density of processed biomass in trucks to reduce transportation costs. Results indicate that RENO is capable of improving logistics when compared with actual operations. RENO can also be combined with different operational strategies to ensure the long-term success of this emerging industry in the United States.

E-04b Forest biomass supply chains: Domestic fuelwood and biomass heating

Organizers: Nate Anderson (U.S. Forest Service), Gustaf Egnel (Swedish University of Agricultural Sciences) & Woodam Chung (Oregon State University, USA)

Greenhouse gas emissions accounting in the production and utilization of woody biomass for heat energy. Bakhshi, M. (*Free University Berlin, Iran; mary_bakhshi@yahoo.com*).

The purpose of this research is an accounting and estimate of the greenhouse gas (GHG) balance in the supply chain of forest bioenergy production in Iran. Data will be collected and analyzed over a period of 6 months. The study will use a combination of the life cycle assessment (International Organization for Standardization (ISO) 14040) approach and IPCC guidelines and methods for land use change, forestry, and heat generation from biomass. The boundary of GHG accounting consists of all sectors of the bioenergy supply chain, and the estimated GHG balance will be based on modern combustion plants, which are assumed to be the main conversion technology used to produce heat from biomass. The biggest challenge is the baseline for GHG calculation of energy substitution; currently different types of fossil fuels are used, depending on region. This study will therefore address these challenges. The principle recommendations will highlight opportunities for Clean Development Mechanisms (CDM) and carbon credits, which can improve rural forest utilization in Iran and protect natural forests from inefficient utilization of wood fuel. This research is part of a research project titled "Bioenergy promotion strategies in Iran," which is being carried out at the Berlin Centre for Caspian Region Studies at the Free University of Berlin, sponsored by the Alexander von Humboldt Foundation.

Decision support for sustainable, community-based, wood biomass energy for heating. Danks, C. (*University of Vermont, USA; cdanks@uvm.edu*).

Many communities in forested regions are considering wood biomass as an alternative, local energy source. They are weighing complex issues of wood supply, economic feasibility, emissions, forest conservation, climate impacts, and appropriate scale. Here findings are presented from participatory research in the northeastern United States that studied local decision criteria and

decision-support needs for communities considering wood biomass heating options. One project in the state of Vermont examined local efforts to improve sustainability of wood heating in homes and schools. Another project spanning four Northern Forest states examined the environmental and economic factors that drive decisions about converting to wood pellet heating. These projects found that: (1) estimates of wood supply are important, but vary substantially by assumptions; (2) meeting sustainability safeguards could raise costs of biomass supply; (3) government incentives are important drivers of transition; (4) combustion technology can affect environmental impacts as well as where supply is sourced and the ability of local loggers to participate in the supply chain; and (5) service learning projects and non-governmental organizations are providing direct decision support to communities. Policy recommendations are offered to reduce environmental impacts and promote sustainable options for local wood biomass heating.

Wood energy in Cameroon: the overlooked contribution to the national economy. Eba'a Atyi, R. (*Center for International Forest Research; r.atyi@cgiar.org*).

A study was conducted in 2012–2013 to estimate the contribution of wood energy to the national economy of Cameroon as part of a broader study on the economic and social importance of the forest and wildlife sector to the country's economy. The study focused on firewood and charcoal. The study was based on the analysis of secondary data from recent studies conducted at subnational levels and was completed by data collection on firewood and charcoal consumption as well as market prices of these products in the remaining seven regions. Total consumption in urban areas of Cameroon was found to be 2.2 million metric tons and 356 530 metric tons of firewood and charcoal, respectively. The contribution of firewood and charcoal to Cameroon's GDP was an estimated US$304 million, representing 1.3% of GDP. In addition, the subsector provided about 90 000 equivalent full-time jobs and 16 million people out of 20 million depended entirely on wood energy for household energy supply. Unfortunately, no government agency has been assigned to monitor wood energy although there is a sense that the natural resource base from which the urban areas are supplied might be depleted soon in the northern region.

Evaluation of forest biomass as a substitute for firewood as an energy source in Costa Rican households. Morales Aymerich, J., Villalobos, R. (*CATIE, Costa Rica; moralesj@catie.ac.cr; rvillalo@catie.ac.cr*).

The use of firewood as an energy source is an important issue in Central America. Some authors (e.g., Chatterji, 1981 and Clawson, 1997) who have put the issue in the context of high rates of consumption in the region mention that use of firewood from forests causes several problems in the region, namely deforestation and degradation. According to the Latin America Energy Organization (OLADE) 2010 report, the consumption of traditional sources of energy is still relevant in Central America. To understand this issue, the authors of this presentation have evaluated the forest biomass chain from supply to demand and final use. Their study evaluated the potential of forest residues from harvest and other forest management activities as a substitute for unsustainable use of firewood in Costa Rican households.

Who gets what: analysis of wood fuel value chain in Ghana. Nunoo, I. (*Kwame Nkrumah University of Science and Technology, Ghana; nunooisaac85@yahoo.com*), Darko Obiri, B. (*Forestry Research Institute of Ghana, Ghana; bdobiri@yahoo.com*).

About 60% of the world's total wood removed from forests and outside forests is used for energy purposes, with wood fuels accounting for about 70% of the total primary energy supply. Ghana is likely to consume more than 25 million tons of wood fuel by the year 2020. The objective of the study was to investigate important marketing channels and actors involved in the wood fuel value chain and analyze how value added is distributed among the different actors. Three hundred eighteen actors in the value chain, comprising 204 producers, 32 transporters, and 82 marketers, were randomly selected and interviewed using semi-structured questionnaires as well as focus group discussions. A strong, active market is a motivating factor for participating in wood fuel production. Demand for wood fuel is inelastic as respondents are prepared to pay double the price. Producers enjoy 40% of the price spread, of which they receive only one-third (13%); the remaining two-thirds (27%) goes to production costs. Other participants in the chain enjoy the other 60%. Comparing percentage share from the price spread, the marketers and transporters have larger profits than the producers. Establishing woodlots is a comprehensive and straightforward approach to saving the forest in Ghana.

Profitability analysis of fuelwood marketing in Ibadan, Nigeria. Olugbire, O. (*Forestry Research Institute of Nigeria, Nigeria; olugbireolutoyin@gmail.com*), Aremu, F. (*Obafemi Awolowo University, Nigeria; fakunle2011@gmail.com*), Adeniran, O., Ayomide, A. (*Forestry Research Institute of Nigeria; chrisabel_t@yahoo.com; adedunmolalala@gmail.com.*

Fuelwood is an important domestic energy source for both rural and urban Nigerians; therefore the profitability and constraints to fuelwood marketing in Ibadan, Nigeria, were investigated. Data for the study were obtained from 50 randomly selected fuelwood marketers through interviews, structured questionnaires, and personal observation. Descriptive analysis was used to describe the respondents' socioeconomic characteristics. Gross margin analysis was used to examine the profitability of the enterprise. The results indicated that about half of the marketers (46%) were younger than 50 years; 86% were females, and 36% had less than 20 yr of business experience. The profitability analysis revealed that an average marketer incurred total variable costs of ₦31 731/month on average but earned average revenue of ₦38 290, implying that an average marketer earns ₦6 558 as gross margin per month. These results show that fuelwood marketing is a profitable enterprise. Transportation, season, and government policy are the major marketing constraints. It is recommended that government should provide good transportation incentives such as good road networks, and there is the need to review forest policy, taking into account current market conditions so that many people can benefit from the income-generating opportunities that fuelwood offers.

Biomass energy supply chains in Europe: Are we burning the house we live in? Ottitsch, A. (*University of Cumbria, UK; Andreas.Ottitsch@a1.net*).

Demand from the biomass energy production sector is increasingly perceived as a threat to the raw material supply base of forest industries. This paper analyses how this conflict is played out in different European countries. In several countries there exists a

longstanding prevalence of cooperative approaches in managing these conflicts using corporatist institutional arrangements. Biomass energy markets and related policy incentives have entered into this arena, offering new options for forest producers, who have welcomed these opportunities, especially during years of general economic recession. A qualitative approach analysing stakeholder positions and strategies is combined with content analysis of published campaign materials. This analysis is set against results of previous research on economic conflicts over use and prices of raw materials. The paper investigates whether actors on both sides are sticking to "tried and tested" approaches, framing the issue in traditional discourses and using traditional alliances, or whether this constitutes the development of an entirely new—yet to be established—balance of power, in which new discourses emerge and new alliances are formed, which could have wider impact on the shape of the forest sector in Europe.

Use and sources of domestic firewood in Wales, UK. Wong, J. (*Wild Resources Ltd, UK; Jenny.wong@wildresources.co.uk*), Atherton, S., Walmsley, J. (*Bangor University, UK; bsp408@bangor.ac.uk; j.walmsley@bangor.ac.uk*).

Rising energy prices in a time of economic downturn coupled with a desire for more sustainable forms of energy have resulted in a rapid and sustained growth in demand for firewood for domestic heating in Wales. However, there are few reliable statistics on domestic firewood production or consumption. Low-intensity omnibus public opinion surveys of forestry (2011) suggest that 14% of the population burn some firewood, but there were no available data on the volumes of wood consumed or its source. To fill this void, in 2012 a household survey was conducted and revealed that domestic firewood consumption could be as much as 40% of the official cut. Firewood is obtained from a number of sources: waste wood, arboricultural arisings, and sawmill offcuts. However, around half comes directly from householders' own land, neighbours' land, or family land. The importance of this source provides an additional incentive for woodland management. The authors' results indicate that domestic firewood use represents a significant contribution to renewable heat generation that is not captured in national energy statistics. This paper will present the results of the survey for Wales and set them against the context of emerging statistics for domestic firewood consumption in Europe.

E-05 Global and regional deployment of Biomass & CCS (BECCS): Reconciling top-down and bottom-up approaches and REDD+BECCS Nexus

Organizers: Florian Kraxner (International Institute for Applied Systems Analysis, Austria), Sabine Fuss (Mercator Research Institute on Global Commons and Climate Change, Germany), Ruben Lubowski (Environmental Defense Fund, USA); Nathalie Walker (National Wildlife Federation, USA)

BECCS+REDD: synergies between bioenergy-based climate change mitigation options and reducing emissions from deforestation. Fuss, S. (*Mercator Research Institute on Global Commons and Climate Change, Germany; fuss@mcc-berlin.net*), Kraxner, F. (*International Institute for Applied Systems Analysis (IIASA), Austria; kraxner@iiasa.ac.at*), Lubowski, R. (*Environmental Defense Fund, USA; rlubowski@edf.org*), Golub, A. (*American University, United States; Alexander.a.golub@gmail.com*).

The need for negative emissions in integrated assessment models is largely covered by combining bioenergy with carbon capture and storage (BECCS). But little research has focused on finding a business model for the implementation of BECCS on the ground and, in particular, in tropical forest countries, which typically display the largest potential in this respect. Why would countries prioritize climate change mitigation and, if they do, why would they concentrate their efforts on technologies with expensive components such as CCS when they have ample opportunity to meet ambitious mitigation targets by reducing their deforestation rates? In this article the authors argue that avoiding deforestation has many synergies with striving for the establishment of sustainable bioenergy—while keeping open the option to also capture the CO_2 emitted during the combustion process eventually (in the case of bioelectricity). Rather than fearing that BECCS could undermine REDD plans, the authors conclude from an analysis of the cost and benefits of measures under both concepts, that—if steered effectively and in tandem—BECCS and REDD could enhance each other in achieving their objective of reducing GHG emissions and stabilizing at low levels of ppm by 2100.

BECCS use and sustainability of the land use in mitigation pathways. Kato, E., Yamagata, Y. (*National Institute for Environmental Studies, Japan; kato.etsushi@nies.go.jp; yamagata@nies.go.jp*).

In the mitigation pathways to limit global mean temperature rise to <2 °C above preindustrial levels, net negative emissions would be required in a long-term target through the 21st century. To achieve net negative emissions globally, bioenergy with carbon capture and storage (BECCS) would be a cost-effective way of removing CO_2 from the atmosphere, and its large-scale use is a key component of mitigation strategies in future socioeconomic scenarios. This study evaluates the potential of bioenergy production for CCS in a mitigation pathway in terms of the bioenergy feedstock type, first-generation bioenergy crops, second-generation bioenergy crops, and woody biomass, by using a process-based terrestrial ecosystem model and a crop model. Analysis shows that first-generation bioenergy crop production would not be sufficient to achieve the required BECCS of the RCP2.6 scenario even when the cases of higher fertilizer and irrigation use are considered. It would require more than doubling the area for bioenergy crops around 2050 assumed in RCP2.6; however, such scenarios implicitly induce large-scale land use changes that emit significant amounts of carbon from deforestation. To reduce the potential land use change emissions, optimal use of second-generation bioenergy crops and woody biomass and its sustainability are discussed.

Principles of BECCS—regional and national case studies: assessing the potentials. Kraxner, F. (*International Institute for Applied Systems Analysis (IIASA), Austria; kraxner@iiasa.ac.at*), Fuss, S. (*Mercator Research Institute on Global Commons and Climate Change, Germany; fuss@mcc-berlin.net*), Leduc, S., Kindermann, G., Shchepashchenko, D. (*International Institute for Applied Systems Analysis (IIASA), Austria; kinder@iiasa.ac.at; schepd@iiasa.ac.at*), Shvidenko, A., Yowargana, P. Wicaksono, A., Forsell, N. Aoki, K. Best, D., Heidug, W.

The use of bioenergy in combination with carbon capture and storage (BECCS) could make a substantial contribution to achieving low atmospheric CO_2 concentration levels. Furthermore, this technology creates synergies and opportunities in the context of developing bioenergy potentials, thus creating a win-win strategy for energy security, economic development, and climate change mitigation. With the help of a techno-economic engineering model, the authors identify the BECCS potentials of Europe, Russia, Indonesia, Korea, and Japan under different scenarios and describe the complementary co-benefits. The engineering model helps optimize the locations and capacities of bioenergy plants while at the same time identifying the related in-situ potential for CCS. Sustainable production of biomass feedstock and energy demand and supply as well as competing industries and existing transport infrastructure are important input parameters in order to achieve an optimal BECCS solution for regional and national applications.

Balancing risks and regret from climate policy uncertainties: the role of REDD and other near-term opportunities. Lubowski, R. (*Environmental Defense Fund, USA; rlubowski@edf.org*), Golub, A. (*American University, USA; Alexander.a.golub@gmail.com*).

This paper develops a conceptual and simulation model to evaluate the role of REDD and other mitigation strategies, including bioenergy with carbon capture and storage (BECCS), in a context of climate policy uncertainties. The authors examine the choice of different abatement opportunities from the point of view of a central planner concerned about overall policy costs, including inevitable costs from policy corrections, and from the point of view of regulated entities that have to deliver abatement given evolving policies, costs, and technologies. Different abatement options are shown to have different degrees of irreversibility associated with sunk costs, and some approaches such as REDD are shown to be particularly appropriate for near-term action as they entail relatively low regrets. The authors also examine how emerging carbon market can create the right incentives for market players. This paper models a carbon market framework where buyers and sellers make decisions under uncertainty and have the opportunity for transactions in both spot and options markets. The authors derive optimal strategy for buyers and sellers and solve for equilibrium price and quantities of credits as well as (call) options on credits as distinct market instruments.

The potential of REDD+BECCS nexus for selected provinces in Indonesia. Yowargana, P. (*President's Delivery Unit for Development Monitoring and Oversight, Indonesia; ping.yowargana@ukp.go.id*), Wicaksono, A. (*Presidential Working Unit for Supervision and Management of Development* (*UKP4), Indonesia; agung.wicaksono@ukp.go.id*), Kraxner, F. (*International Institute for Applied Systems Analysis (IIASA), Austria; kraxner@iiasa.ac.at*), Fuss, S. (*Mercator Research Institute on Global Commons and Climate Change, Germany; fuss@mcc-berlin.net*), Saragih, M. (*Bandung Institute of Technology, Indonesia; manahan@sbm-itb.ac.id*).

This study analyzes the potential for bioenergy with carbon capture and storage (BECCS) in Indonesia within a broader land use context in order to support landscape-scale planning of two selected provinces. The potential for BECCS application was obtained from investigating biomass availability, generated from Global Forestry Model G4M, and geological suitability maps for carbon storage. This analysis is then expanded to impact analysis on the potential of deforestation in the region and also reforestation from sustainable forest management to support bioenergy production. Analysis is conducted on different types of bioenergy resources with optimum impact on constraints such as generated bioenergy resource, agricultural land use change, potential for future land use change from infrastructure development, biodiversity, and contribution to domestic and global energy systems. The result further enhances theoretical potential for in situ BECCS application with impact analysis on deforestation and with the technology and management options that need to be in place to take advantage of REDD financing mechanisms.

E-06 Emerging technologies for forest resource assessment and genetic improvement

Organizers: Xiping Wang (U.S. Forest Service), Jianxiong Lu (Chinese Academy of Forestry), Kyu-Suk Kang (Korea Forest Research Institute, Republic of Korea) & Marco Marchetti (Italian Academy of Forest Sciences)

Distinguishing eucalyptus clones by stem stiffness using ultrasound applied on standing trees. Gonçalves, R., Batista, F.F., Mansini Lorensani, R. (*University of Campinas, Brazil; raquel@agr.unicamp.br; fernandobatista_19@msn.com; rafaelmansini@hotmail.com*).

The production of eucalyptus for the cellulose and paper industry is based on the cultivation of clones, which are obtained by crossing species with desirable characteristics. However, clones that were considered to have great potential have presented serious problems due to permanent bending and breakage, which are caused mainly by wind forces during the early years of growth. Wave propagation methods have shown great potential in applications related to predicting the stiffness of logs and lumber. Based on the premise that the stiffness of the stem is a major contributor to a tree's resistance to the wind, the objective of the present study was to determine whether an ultrasound wave propagation test performed directly on trees would have the sensitivity within a sample group to differentiate between clones and whether this differentiation would be consistent with the differences in stiffness between them. A total of 189 trees were tested from 21 different clones. To differentiate the clones, the ultrasound wave propagation velocity was obtained directly from the trees. The velocity differences among the trees were consistent with the results obtained using the stem stiffness of the same trees.

Biomass production in the short rotation coppice of poplar treated with low-concentration liquid fertilizer. Kang, K., Kim, H., Bae, E. (*Seoul National University, Republic of Korea; kangks84@snu.ac.kr; reclimate@forest.go.kr; baeek@forest.go.kr*).

A short rotation coppice (SRC) refers to cultivation systems using fast-growing tree species with the ability to resprout from the stump after harvest. Harvest in SRC cultivation occurs in short intervals (2–5 yr), and management practices are more similar to

those of agricultural annual crops than to forestry. This study was conducted to analyze growth characteristics and biomass production of poplar clones in the SRC under the treatment of slurry composting and biofiltration liquid fertilizer (SCBLF). The average survival rate of poplar clones under the SCBLF treatment was 95.0% and that of the control was 92.5%. The average number of shoots per clone under the treatment was 11.8 and that of the control was 11.5. In terms of numbers of shoots, "72-31," "Bonghwa1," and "Clivus" from *Populus alba* × *P. glandulosa* were superior clones with 17.1ea/clone, 14.5 ea/clone, and 13.8 ea/clone, respectively, under SCBLF. For the average leaf area, the SCBLF treatment showed a 35% broader leaf (71.0 cm^2) than the control (52.3 cm^2). The annual average of aboveground biomass production was 51% higher under treatment (8.5 tons/ha) than the control (5.6 tons/ha). "Clivus," "72-31," and "Bonghwa1" clones from *P. alba* × *P. glandulosa* were superior for the annual average of aboveground biomass production with 15.2 tons/ha, 14.0 tons/ha, and 11.6 tons/ha, respectively, under the SCBLF treatment.

Fully automatic process to collect forest inventory data using terrestrial LiDAR. Kato, A. (*Chiba University, Japan; akiran@faculty.chiba-u.jp*), Moskal, L. (*University of Washington, USA; lmmoskal@uw.edu*).

Laser technology can provide high quality 3D structural data on trees, and many applications in forest monitoring, operations, and field inventories are being developed. In this study, two terrestrial LiDAR sensors (RIEGL VZ400 and SICK LMS511) were used to estimate forest biomass accurately and efficiently in tropical forest. The terrestrial laser is a portable and relatively cheap device that can estimate stem volume accurately without destructive sampling and without human error from manual measurement. Aboveground biomass was derived from stem volume. The technique developed in this study is a fully automated process to quantify the stem volume from terrestrial laser data and to obtain forest inventory data for any species. As a result, 98% of stems were automatically identified from the data, which were taken from multiple scanning locations without occlusion effect. The relative error of stem volume estimation was only 1.3 and 2.1% for coniferous and deciduous tree stems, respectively. In contrast, the conventional approach incurred errors of 6.8 and 12.1%. This result shows significant improvement over conventional methods in estimating stem volume and produces accurate forest inventory data. The techniques used for this research provide a direct, automatic, and non-destructive way to quantify stem volume for any shape of stems.

Rapid, cost-effective, and non-destructive phenotypic determination of meaningful end use properties in tree breeding programmes. Meder, A., Brawner, J. (*Commonwealth Scientific and Industrial Research Organisation, Australia; roger.meder@csiro.au; jeremy.brawner@csiro.au*), Downes, G. (*Forest Quality, Australia; geoff.downes@forestquality.com*), Japarudin, Y. (*Sabah Softwood Bhd, Malaysia; yanijaparudin@yahoo.com*), Nazri, W. (*Universiti Teknologi MARA, Indonesia; wmdnazri@gmail.com*).

Utilisation of the forest resource is undergoing considerable change as traditional old-growth forests decline or are increasingly protected under government conservation agreements. Greater reliance on planted forests for both softwood and hardwood supply has led to a significant change in the quality of the available logs and to variability in supply. Processors are therefore increasingly turning to non-destructive testing (NDT) technologies to gain improved knowledge of feedstock at all points along the value chain. Tree breeders have traditionally used growth and form for selection but are increasingly demanding meaningful phenotypic data on every individual in their breeding programme. Data collection often involves more than 2 000 individual trees. Traditional phenotypic measurements for properties such as density, stiffness, pulp yield, and calorific value, are often destructive, expensive, and time-consuming, which limits their utility. Rapid, non-destructive technologies are being used on standing trees to classify hybridization, or provide multiple phenotypic properties, in breeding trials in Australia and Southeast Asia in order to select next-generation germplasm.

Automated wood species identification by CT technology. Sauter, U., Laudon, N., Brüchert, F. (*Forest Research Institute of Baden-Wuerttemberg, Germany; udo.sauter@forst.bwl.de; norvin.laudon@forst.bwl.de; franka.bruechert@forst.bwl.de*).

X-ray computed tomography (CT) is increasingly introduced in industrial practice to optimise the value yield in the sawmilling and wood material industry. For many softwood species algorithms for automated detection and detailed assessment of value-determining features have been described; many of them work in real-time during industrial roundwood processing at speeds up to 120 m/min. Examples of assessed features are dimension and position of knots, resin pockets and cracks, the distinction of sound and dead knots, and the amount of rot. Sawmills depend on reliable detection algorithms for wood species to correctly assign logs from mixed lots to species-specific product lines. In modern sawmills wood species identification is no longer guaranteed due to fully mechanised harvesting in the forest and the high-speed feed-in of logs. This paper presents an approach to combine established algorithms for the detection of species-specific features and thus to clearly identify wood species. Initially, the focus is on softwood species common in Central Europe: Norway spruce (*Picea abies* (L.) Karst), Sitka spruce (*Picea sitchensis* (Bong.) Carr), silver fir (*Abies alba* (Mill.)), grand fir (*A. grandis* (Dougl.) Lindl), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), Scots pine (*Pinus sylvestris* (L.)), and black pine (*Pinus nigra* (Arn.)).

Genetic improvement and advanced generation breeding of *Larix* spp. in China. Sun, X. (*Chinese Academy of Forestry, China; xmsun@caf.ac.cn*).

Larches are a common plantation species in northern China and the sub-tropical alpine region, and genetic improvement of larch has been conducted since 1964 in China. This study focuses on larch genetic improvement strategies using a combination of sexual and asexual reproduction technologies, including hybridization, recurrent selection, multiple traits selection, and molecular marker assisted breeding. Four ecological breeding zones were identified based on climate and larch species resources in the primary plantation areas. Strategies for breeding and species improvement were formulated for each zone. Independent breeding populations and superior varieties appropriate for each particular zone were selected, including 237 superior families and 96 clones. Oriented cultivation matching technology was conducted on 1 513 second generation plus trees. Second-generation breeding gardens and seed orchards were established based on the different zones. Properties related to pulp performance and timber properties as a function of genetic origin were evaluated at the level of species, family, and clone. Twenty varieties for

pulpwood purposes and four varieties for structural timber end use were selected by using multiple-trait evaluation and BLUP breeding value. Three seedling silviculture technologies, namely large-scale cutting propagation, greenhouse container seedlings, and industrialized propagation of somatic embryogenesis, were developed.

Near infrared reflectance spectroscopy: dialing stem chemistry for optimal root disease resistance and forest products. Via, B., Eckhardt, L. (*Auburn University, USA; bkv0003@auburn.edu; eckhalg@auburn.edu*).

The objective was to first partition 14 genetic *Pinus taeda* families based on near infrared reflectance (NIR) spectroscopy modeled for wood chemistry. Then the goal was to identify chemical loadings, or functional groups, or a combination of the two, that may correspond with lower lesion severity and determine if this relationship played a role in genetic separation for improved forest health. It was found that the NIR modeled extractives loading (independent variable) followed a two-parameter single exponential decay function with lesion area/root collar diameter (dependent variable) across two different sites ($R^2 = 0.52$ for Florida and $R^2 = 0.32$ for Georgia (USA)). The non-linear trend equated to a decrease in lesion severity with increased extractives content and was an indication of better forest health. A strong site by family interaction effect was found for extractives content, suggesting that most families will not perform equally across multiple sites. However, there was one family that yielded consistently lower lesion severity at both sites while maintaining a high extractives loading and an overall chemistry distribution necessary for pulp and paper or other forest product outlets. More work is underway to further test the hypothesis that lesion severity can be reduced through increased extractives loading across different sites and genetic sources.

Evaluating thinning and bio-solid fertilization effects on wood quality in a 70-year-old Douglas-fir stand with time-of-flight acoustic wave measurement. Wang, X. (*U.S. Forest Service, USA; xiping_wang@hotmail.com*).

This study examined the potential of using a time-of-flight (TOF) acoustic wave technique to evaluate thinning and bio-solid fertilization effects on modulus of elasticity (MOE) and grade yields of structural lumber at a 70-yr-old Douglas-fir (*Pseudotsuga menziesii*, (Mirb., Franco)) stand. The stand consisted of four treatments: control, thinned, bio-solid fertilization, and thinned and bio-solid fertilization, each with three replicates on 0.08-ha plots. Four trees were selected in each plot by using a stratified random sample based on the plot quadratic mean diameter, resulting in a total sample of 48 trees ranging in DBH from 14.2 to 53.3 cm. The trees were first non-destructively tested using a TOF-based acoustic tool to obtain acoustic wave velocities for the standing trees. The sampled trees were then harvested, bucked into mill-length logs, and sawn into dimension lumber. Acoustic velocities of the logs and MOE of the dimension lumber were subsequently obtained. Statistical analysis was conducted to determine: (1) the relationships between standing tree and log acoustic velocities, (2) the relationships between tree acoustic velocity and MOE and grade yield of the structural lumber produced, and (3) the effects of thinning and bio-solid fertilization on both tree acoustic velocity and lumber MOE.

E-07 Genomics and biotechnology for improvement of woody energy crops

Organizer: Carl Douglas (University of British Columbia, Canada)

Target enrichment and exome sequencing for marker discovery in eucalypt species. Dasgupta, M. (*Institute of Forest Genetics and Tree Breeding, India; modhumitaghosh@hotmail.com*), Krutovsky, K. (*University of Goettingen, Germany; kkrutov@gwdg.de*).

The rapidly evolving sequencing technologies provide tools for efficient large-scale discovery of markers for high density genotyping in plants. The present study was undertaken to identify gene-based markers for wood property traits in two Eucalypt species (*Eucalyptus tereticornis* and *E. grandis*) used as parents in mapping population. Ninety-three genes from 12 major pathways governing xylogenesis were selected for target enrichment and exome sequencing. Probes were designed with 1bp tilling and approximately 169 700 probes were designed for capture. Genomic DNA was isolated from the leaf tissues and on-array hybridization was done followed by sequencing using the Illumina platform. The raw sequence data were trimmed and HQ reads were aligned to the *E. grandis* reference sequence. The average read depth was 216X. SNP calling and InDel detection were conducted and a total of 4 130 heterozygous SNPs and 555 heterozygous InDels were detected. The most SNPs were documented in *CesA5* (220); the fewest, in *F5H* (1). *HB1 class III* harbored the most InDels (20) across the two species. This study has provided an array of genetic markers for conducting QTL and Association analysis tagging wood property traits in Eucalypt species.

Variation in resistance of *Populus nigra* within and among provenances to *Septoria musiva*. Dunnell, K., LeBoldus, J. (*North Dakota State University, USA; Kelsey.Dunnell@ndsu.edu; Jared.LeBoldus@ndsu.edu*).

Septoria musiva causes stem cankers on hybrid poplar, affecting the sustainability of commercial poplar plantations across North America. To characterize the variability in *Septoria* canker resistance, 50 genotypes of *Populus nigra*, a common parent in hybrid poplar breeding programs, were inoculated with six isolates of *S. musiva*. Three weeks following inoculation the number of cankers/cm and a disease severity rating (1 resistant – 5 susceptible) were recorded. The full range of variation from resistant to susceptible was observed and significant differences among provenances for both the number of cankers/cm ($P < 0.001$) and disease severity rating ($P = 0.006$) were detected. A second experiment was conducted to determine the relationship between disease severity and mortality. Thirteen genotypes representing the full range of disease severity ratings were inoculated with a bulk spore suspension of six isolates of *S. musiva*. Disease severity and cankers/cm were evaluated at 3 weeks, as described above, and mortality was evaluated on a weekly basis for the remainder of the experiment. Between the two experiments the mean disease severities of each genotype were correlated ($R^2 = 0.880$) and trees assigned a disease severity of 4 and 5 had a high incidence of mortality.

Understanding the social context of strategies to develop biofuels from optimized *Populus* feedstocks in British Columbia. Harshaw, H. (*University of Alberta, Canada; harshaw@ualberta.ca*).

This study examined British Columbians' attitudes about the development of biofuel from poplar (n=916). Although deriving bioethanol from trees is a novel approach, British Columbians' knowledge about forests and forestry may provide a foundation upon which to begin this discussion. There is little support for high technology genetic modification of trees, but the development of optimized poplar feedstocks through traditional selective breeding may not be a source of conflict. The controversial issue appears to be the development of large-scale plantations and the use of trees as feedstock. Respondents indicate a desire for more transparency in management approaches and outcomes. Although there was general agreement that all technologies for tree improvement should be considered for managing forests, there was disagreement with the idea that trees are crops and should be managed in plantations. Trees were ranked as the least acceptable of the six potential sources of biofuel. Preferences for policy options to implement biofuel plantations appear to be linked to concern about climate change. There is some acceptance of the risks from the development of biofuel, such as uncertain ecological or economic outcomes, if it decreases reliance on fossil fuels. Results of this study show that the benefits and risks associated with the development of biofuel (from any source) need to be clearly articulated to the public.

Insect feeding on genetically modified aspen is more affected by intentional (Bt induction) than unintentional changes or clone differences in plant defense. Hjälten, J., Axelsson, E. (*Swedish University of Agricultural Sciences, Sweden; joakim.hjalten@slu.se; petter.axelsson@slu.se*).

In synchrony with intended beneficial changes in plant expressions, plant genetic engineering may cause unintended effects on plant physiology, such as effects on traits involved in plant-herbivore interactions. The relative importance of these unintentional changes of plant defense for herbivore resistance in relation to differences between, for example, different clones or tree species used in forestry has not been evaluated. The authors investigated if insect feeding on genetically modified aspens is more affected by intentional (Bt induction) than unintentional changes or clone differences in plant defence. The authors used two aspen hybrids wildtype clones (*Populus tremula x P. tremuloides* and *Populus tremula x P. alba*) which have been genetically modified for insect resistance (Bt two lines) and altered lignin properties (COMT and CAD), respectively. Measurements of biochemical properties suggest that unintended changes by GM modifications in phytochemistry were generally smaller than differences seen among different aspen hybrids wildtype clones. However, neither clone differences nor unintended changes in leaf phenolics influenced consumption by the leaf beetle *Phratora vitellinae*. In contrast, Bt induction had a strong direct as well as post-experiment effect on leaf beetle consumption. The latter result suggests lasting, if not permanent, reduction of fitness following Bt exposure.

Fungal pretreatment of lignocellulosic biomass by wood rot transformants. Kim, M., Ryu, S., Cho, M. (*Korea Forest Research Institute, Republic of Korea; mkkim@forest.go.kr; shryu@forest.go.kr; michael0421@naver.com*).

Polyporus brumalis was genetically transformed using a laccase overexpression vector to generate strains with increased laccase production. Stable genomic integration of the expression vector was confirmed by PCR using vector-specific primers. The transformants exhibited increased laccase activity and more effective decolorization of the dye Remazol Brilliant Blue R than the wild type. When the transformants were grown with wood chips from a red pine (softwood) and a tulip tree (hardwood), these lines showed higher lignin-degradation activity as well as higher wood-chip weight loss than the wild type. When the wood chips treated with transformant were enzymatically saccarified, the highest sugar yields were found to be 33% for the red pine wood and 40% for the tulip tree wood, on the basis of the dried wood weights, which were 1.6- and 2.2-fold higher than those for the wild type. These results suggest that the laccase gene and its overexpression may prove useful for developing a highly effective lignin-degrading fungal strain that might contribute to the pretreatment of lignobiocellulose for increasing sugar yield.

Silver birch (*Betula pendula*): a novel model tree for molecular genetics. Nieminen, K. (*Finnish Forest Research Institute, Finland; kaisa.nieminen@metla.fi*).

The aim of this research is to understand molecular mechanisms controlling forest tree development; natural variation in tree development will be explored in order to identify novel genetic regulators. Our model is silver birch (*Betula pendula*), a tree important in forestry. The small diploid genome of this species is currently being sequenced. This tree is monoecious, and young seedlings can be induced to flower. Birch brings the power of inbreeding and short generation times to tree genetics, enabling exploitation of advanced crossing schemes for genetic analyses. Our current focus is a collection of naturally occurring tree mutants with atypical cambial activity, architecture, or secondary metabolite content. The research has advanced furthest in characterizing a "swirly birch" mutant, which has a striking growth pattern. Its stem initially grows upright, but starts to bend downwards when it gets older. Intriguingly, inside the stem tension wood formation is mutated into a rotating pattern. Our aim is to map the causative gene behind this phenotype, and study its function in transgenic trees. With birch as our model, our project represents a novel approach with potential for ground-breaking insights into tree development. Besides its fascinating basic science aspect (what makes a tree a tree?), this knowledge has immense applied value for forest tree domestication.

Resistance breeding against two major forest diseases— conifer root rot and rust in willows. Stenlid, J., Elfstrand, M., Lind, M., Samils, B. (*Swedish University of Agricultural Sciences, Sweden; jan.stenlid@slu.se; Malin.Elfstrand@slu.se; Marten.Lind@slu.se; Berit.Samils@slu.se*); Karlsson, B. (*Forestry Research Institute of Sweden; Bo.Karlsson@skogforsk.se*).

Tree diseases are threatening the health of forests and are causing major economic losses to forest owners worldwide. An environmentally friendly approach to the problem is to increase disease resistance in host trees. This presentation reports on research programs that are aimed at generating knowledge on the genetic basis for disease resistance in Norway spruce against Heterobasidion root rot and in *Salix* spp. against leaf rust. Quantitative trait loci (QTL) and association mapping have been carried out to help identify genetic markers that can be used for marker assisted breeding. Certain key processes in the host response to fungal attacks have also been identified, including involvement of R-genes and onset of phenylpropanoid pathways. The work has been facilitated by genomic information for both the host and the pathogen species. Short-term benefits of the work include the identification of Norway spruce genotypes that are highly susceptible to root rot and that should be excluded from future breeding programs and seed orchards.

E-08 Biobased products and bioenergy

Organizers: Jianchun Jiang, Fuxiang Chu (Chinese Academy of Forestry), Dominique Lachenal (Grenoble INP-Pagora, France) & Jingxin Wang (West Virgina University, USA)

Nondestructive estimation of the chemical and thermal properties of forest biomass using vibrational spectroscopy and thermogravimetric analysis. Acquah, G., Via, B., Fasina, O., Eckhardt, L. (*Auburn University, USA; gea0002@auburn.edu; bkv0002@auburn.edu; fasinoo@auburn.edu; eckhalg@auburn.edu*).

The use of biomass as alternative sources of energy, fuels, and chemicals derived from fossil fuel will reduce our dependence on the non-renewable resource and also minimize net greenhouse gas emissions. Forest-derived biomass will play a big role in this necessary shift to a sustainable low carbon economy. In order to utilize this resource, its properties must be well understood. In this study, NIR and FTIR spectra, and TGA thermographs will be used to develop partial least squares regression (PLSR) models for the rapid prediction of the chemical composition (i.e., monomeric sugars, cellulose, hemicellulsoses, extractives, and lignin) of forest biomass from whole trees, slash, wood, and bark of loblolly pine. In addition, thermal properties including calorific value, ash, volatile matter, and fixed carbon will be estimated. Data collected via conventional methods will be used for calibration and model validation. It is expected that the three analytical tools will give different but complementary results to enable us to have a better understanding of the chemical composition of forest biomass. In addition, models from this study should be able to rapidly predict the studied properties of similar biomass types. This capability will be useful in allocating feedstocks that optimize biomass conversion technologies.

Determination and quantification of fatty and resin acid composition in boreal lodgepole pine and Scots pine for biorefinery applications. Arshadi, M., Mörling, T., Geladi, P., Backlund, I., Bergsten, U. (*Swedish University of Agricultural Sciences, Sweden; mehrdad.arshadi@slu.se; tommy.morling@slu.se; paul.geladi@slu.se; ingegerd.backlund@slu.se; urban.bergsten@slu.se*).

The potential for Scots pine and lodgepole pine for biorefinery applications was investigated. Wood samples from mature trees from five different sites in northern Sweden were compared. Twenty-one fatty and 10 resin acids were detected by extraction and GC-MS analysis. Total fatty- and resin-acid concentration varied between 2.4 and 41.4 mg/g (Scots pine) and between 2.3 and 26.0 mg/g (lodgepole pine) of dry material. Multivariate models were made with principal component analysis. Heartwood showed about five times the extractive concentration of sapwood. Resin acids were mainly associated with heartwood, whereas fatty acids were associated with sapwood. The concentration of extractives was 0.2–4% of dry weight of stem wood, which corresponds to a significant amount of wood chemical production per ha. Around 150 kg of fatty acids and 1 ton of resins can be harvested per ha from mature boreal lodgepole pine stands. By using wood type models for sapwood and heartwood combined with concentrations of the investigated chemical compounds, potential production and harvest can be predicted at tree and hectare levels. This information together with a systematic fractionation and selection of heartwood and sapwood would greatly improve the industrial biorefinery applications of wood raw material.

Oil content and fatty acid profile of *Calophyllum brasiliense* Cambes: a new resource for biodiesel feedstock in Mexico. Bernabe-Antonio, A., Alvarez Berber, L. (*Universidad Autonoma Del Estado De Morelos, Mexico; bernabe_aa@hotmail.com; lalvarez@uaem.mx*), Cruz-Sosa, F. (*Universidad Autonoma Metropolitana-Iztapalapa, Mexico; cuhp@xanum.uam.mx*), Salcedo-Perez, E. (*Universidad De Guadalajara, Mexico; esalcedoperez@yahoo.com*).

High global demand for energy makes it necessary to search for feedstock for biodiesel production, and non-edible oil remains a viable alternative. For purposes of biodiesel feedstock, the authors evaluated the oil content, fatty acids (FA) profile, and oil physicochemical parameters (OPP) from two seed sources from *C. brasiliense* : San Andres Tuxtla (SSAT) and Pajapan (SPAJ). Significant differences ($P \leq 0.05$) were found between the two oil seed sources. Oil content of SSAT and SPAJ were 58.2 and 47.6%, respectively. Oil from SPAJ contained a higher percentage of unsaturated FA (73.4%), consisting mainly of oleic (39.3%) and linoleic acid (31.4%). However, higher amounts of linoleic acid (41.3%) and palmitic acid (17.2%) were obtained in the oil from SSAT. Additionally, the FA profile of the leaves was determined. High palmitic (32.4–34.3%), linolenic (21.8–25.7%), and linoleic acid (15.6–21.4%) were obtained. FA profile, density, viscosity, iodine, acidity, and saponification values of the oil tested were found to comply with industrial standards for use as biodiesel feedstock. This is the first report on the FA composition and OPP from *C. brasiliense* seed. Furthermore, a 62.5% biodiesel yield was achieved in the first initial attempts.

Phenolation of kraft lignin catalyzed by boron trifluoride. Chang, H., Hu, Z., Jameel, H. (*North Carolina State University, USA; hchang@ncsu.edu; zhu2@ncsu.edu; jameel@ncsu.edu*).

A kraft lignin produced using LignoBoost Process is called BioChoice Lignin (BCL). The authors have fully characterized BCL using wet chemistry, oxidative degradation, and spectral analyses. Several potential applications of this lignin have been identified and are being studied. In this presentation, the authors report the detailed chemical structure of BCL and the results of phenolation of BCL as a potential replacement for phenol formaldehyde resin, using boron trifluoride (BF_3) as a catalyst. BCL is dissolved in 10 times excess of phenol and reacted in the presence of BF_3 at 60 °C for 2 hours. Even under these mild conditions, BCL was phenolated, as indicated by the increase in phenolic hydroxyl content and decrease in α-carbonyl and stilbene structures. About 80% of lignin was recovered as phenolated lignin in two fractions, an ether-soluble and an ether-insoluble fraction in about 1:3 ratio. Both fractions have lower molecular weight and lower poly-dispersity than BCL, indicating some acid-catalyzed degradation during phenolation reaction. The ether-soluble fraction has higher phenolic hydroxyl content and lower molecular weight than the ether-insoluble fraction. More than 95% of the phenol is recovered. Guaiacol is produced in a yield of about 8–10% of BCL via nucleus exchange reaction.

Two-stage autohydrolysis pretreatment combined with refining for improved enzymatic hydrolysis of hardwood. Chang, H., Jameel, H., Wang, Z., Han, Q., Phillips, R. (*North Carolina State University, USA; hchang@ncsu.edu; jameel@ncsu.edu; zwang8@ncsu.edu; qhan@ncsu.edu*), He, L.

Autohydrolysis followed by refining has shown great promise for pretreatment of biomass because of high sugar recovery due to its simple process features. To further improve enzymatic hydrolysis efficiency and sugar recovery, two-stage autohydrolysis of mixed hardwood followed by refining was evaluated. At the best autohydrolysis conditions (two-stage process of 140–180 °C and 1 hour), the total sugar recovery including sugars from both the prehydrolysate and enzymatic hydrolysate was approximately 79% for an enzyme loading of 5 FPU/g. The amount of byproducts (organic acids, furfural, and 5-hydroxyfuranmethal) was significantly lower for the two-stage autohydrolysis process. The sugar recovery from the single-stage process at an enzyme loading of 5 FPU/g was 75%. Two-stage autohydrolysis cannot be justified based only on sugar recovery. However the inhibitors produced during pretreatment are significantly lower for the two-stage process. Economic analysis of autohydrolysis of hardwood shows that ethanol could be produced at a minimum ethanol revenue (MER) of about $0.40–0.60/liter, which is significantly lower than that calculated for the dilute acid process due to both lower capital expenditure and operating costs.

Overcoming barriers to cogeneration from biomass in the U.S. wood products industry. Espinoza, O., Laguarda Mallo, M., Weitzenkamp, M. (*University of Minnesota, USA; espinoza@umn.edu; lagua006@umn.edu; weitz072@umn.edu*), Buehlmann, U. (*Virginia Polytechnic Institute and State University, USA; buehlmann@gmail.com*).

Cogeneration can be defined as the simultaneous generation of thermal and electrical energy from the same energy source. Cogeneration typically doubles the efficiency of power plants, because it uses rejected heat to produce thermal energy. Woody biomass-fed cogeneration systems have the potential for significant savings in electric and thermal energy and represent an opportunity to improve environmental conditions, since power generated with wood biomass is carbon-neutral. However, the level of adoption of cogeneration among wood products manufacturers is low. Possible reasons for wood products manufacturers' lack of interest are high initial investment, low steam pressure generated onsite, complexity of operating cogeneration installations, existence of more profitable outlets for wood biomass, environmental regulations, low fossil fuel cost, or too high investment costs, among others. Most often, in fact, a combination of reasons prevents pursuit of cogeneration projects. The goal of this research project is to evaluate wood biomass-based cogeneration technologies for U.S. wood products manufacturers and the potential for cost savings. Barriers to adoption of cogeneration by the industry will also be described. A combination of surveys and case studies of wood products manufacturers will be used to meet the objectives.

Effect of woody biomass feedstock on gasification synthesis gas. Groom, L., Elder, T., Bragg, D. (*U.S. Forest Service, USA; lang811023@163.com; telder@fs.fed.us; dbragg@fs.fed.us*).

Woody biomass is a broadly defined term that encompasses a wide variety of feedstocks ranging from clear bolewood to logging residues. However, the physical, chemical, and thermochemical properties can vary greatly depending on the origin and type of woody biomass feedstock. Furthermore, the majority of woody biomass to liquid transportation fuels plants under construction or being developed use a thermochemical conversion platform with a synthesis gas serving as an intermediate. This paper will focus on the physical and chemical composition of commercially available woody feedstock sources in the southern United States and the relationship between feedstock characteristics and the production of synthesis gas. This paper presents the findings from laboratory analysis of physical, chemical, and thermochemical characterization of 10 loblolly pine samples from various silvicultural regimes and from various locations within the tree. Results will also be shown for subsequent conversion of these samples to synthesis gas in a pilot-scale gasification unit. Efficacious conversion of the various woody biomass feedstocks into commercial liquid transportation fuels will be discussed based on the analyses presented.

Upgrading wood pyrolysis oil by hydrogenation using nanocatalysts to green transportation fuels. Han, Y., McDonald, Kengne, B., McIlroy, D. (*University of Idaho, USA; han4115@vandals.uidaho.edu; armandm@uidaho.edu; foue3398@vandals.uidaho.edu; dmcilroy@uidaho.edu*).

In order to reduce greenhouse gas (GHG) emissions, biomass-derived fuels have become an alternative to fossil fuels. Wood and agricultural biomass are a readily available renewable resource. Fast pyrolysis is a process that can convert the woody biomass to a crude bio-oil (pyrolysis oil), which contains anhydro-sugars, alcohols, ketones, aldehydes, carboxylic acids, phenols, and water. Nevertheless, some of these compounds contribute to bio-oil shelf life instability and difficulty in refining. Catalytic hydrodeoxygenation (and hydrogenation) of the bio-oil can upgrade the bio-oil into stable hydrocarbons, which can be refined into various fuel grades (gasoline, jet fuel, and diesel). Therefore, developing new catalysts with enhanced performance and lowering costs for upgrading bio-oils are required. This study aims at developing and evaluating nickel-decorated SiO_2 nanosprings (Ni-SiO_2-NS) hydrodeoxygenation/hydrogenation catalysts for upgrading pyrolysis bio-oil. The Ni-SiO_2-NS and conventional catalysts were characterized by H_2-temperature programmed reduction (H_2-TPR), scanning electron microscopy (SEM), and X-ray photoelectron spectroscopy (XPS). The reactions were performed in a stirred reactor at 200–250 °C at 250 psi H_2 pressure. The bio-oil and reaction products were characterized by GC-MS for volatile products, HPLC for sugars and acids, and ESI-MS for pyrolytic lignin oligomers. The results from this study will be discussed.

The research and development status of Chinese biomass gasification and pyrolysis. Jiang, J. (*Chinese Academy of Forestry, China; lexu1023@163.com*).

Researchers at the Institute of Chemical Industry of Forest Products (ICIFP) have developed a grinding mill for tree branches and grain straw. This mill is capable of meeting the crushing requirements for forest and agricultural residues with fiber length ≤20 mm. ICIFP also developed a new tapered fluidized bed biomass gasifier with multiphase flow amplification. Researchers prepared a porous metal element modified particulate dolomite catalyst, and designed a fixed bed tar autothermal cracking furnace. The tar content dropped to 10 mg/Nm^3, while the calorific value of the gas remained at 5.5 MJ/Nm^3, which could meet the gas requirements of power generation and heating supply. Researchers proposed air box pulse and pulse-jet injection pipe combined filter new technology. With the development of sub-room blowback pulsed operation high-temperature filtration equipment for dust removal, continuous segment off-line cleaning was achieved. The filtration equipment reached a purification efficiency of 99.75%. The institute built a 5 MW biomass pyrolysis and gasification demonstration unit and 500 ton/yr activated

carbon engineering test equipment. This unit could produce high quality bio-gas, biomass briquette charcoal, and activated carbon. With such efficient and high-value utilization of forest and agricultural biomass, the economic benefits of biomass energy conversion projects increase significantly.

Storage of torrefied wood—investigating the sorption properties and susceptibility to fungal degradation. Kymäläinen, M. (*University of Helsinki, Finland; maija.kymalainen@helsinki.fi*).

Torrefaction is a thermochemical degradation process used to turn heterogeneous, hydrophilic, and tenacious biomass into a homogeneous, hydrophobic, and friable material with increased heating value and properties comparable to coal. Storage of the material was expected to be easy because of its hydrophobic nature, which would minimize mass losses and hence economic losses from moisture-induced chemical degradation and fungal activity. The decrease in the ability of torrefied and charred wood (*Picea abies* (L.) Karst. and *Betula pubescens* Ehrh. pyrolysed at 220–450 °C) to take up water, both chemically and physically, under storage conditions was evaluated. Samples were also exposed to different fungi to assess susceptibility to biological degradation. An inoculation experiment showed that selected fungi were able to utilize torrefied wood and charcoal under optimal conditions, leading to a loss in carbon content and increase in moisture content. The investigation of hydrophobicity showed that the adsorption of water vapor decreases but the capillary absorption potential of liquid water increases, leading to a conclusion that torrefied material is not as hydrophobic as thought. Expectations of the high potential for storage of torrefied wood need to be revised.

Extraction of hemicelluloses from *Eucalyptus globulus* woodchips for their valorisation into surface-active agents. Lachenal, D., Chirat, C. (*Grenoble INP-Pagora, France; dominique.lachenal@grenoble-inp.fr; christine.chirat@grenoble-inp.fr*), Sanglard, M. (*Scion, New Zealand; marion.sanglard@cpe.fr*).

This research project aims at converting a kraft pulp mill into a biorefinery, by extracting hemicelluloses from *Eucalyptus globulus* wood chips and valorising them into surface active agents, in parallel with the production of cellulose fibers. Autohydrolysis of the woodchips was carried out under different conditions of temperature and time. Contents of monosaccharides and oligosaccharides (mainly xylose and xylose oligomers) and the other substances present in the hydrolysates, were determined. The hydrolysates obtained were used to synthesise "bio"-based surface active agents, namely alkylpolyxylosides (APX), through the reaction between the saccharides of the hydrolysates and a fatty alcohol. The saccharides were the hydrophilic part of the molecule, and the alcohol was its hydrophobic group. The impact of each of the species found in the hydrolysates (such as furfural, HMF, methylglucuronic acid, acetic acid, lignin, xylan oligomers) on the production of APX was studied. In particular, it was shown that the presence of lignin can significantly decrease the yield of APX formation and should preferentially be removed, at least in part. Reasons for this problem were sought, and solutions to overcome it are given.

Effect of chemical pretreatments on bamboo for bioethanol production. Li, Z., Fei, B., Jiang, Z. (*International Center for Bamboo and Rattan, China; lizq@icbr.ac.cn; feibenhua@icbr.ac.cn; jiangzehui@icbr.ac.cn*).

Bamboo, with cellulose and hemicellulose as its main components, is a fast-growing and inexpensive renewable resource for bioethanol production. The objective of this study was to evaluate the promotion effect of chemical pretreatments on enzymatic hydrolyability of bamboo. Several pretreatment methods were designed to evaluate the feasibility of bamboo bioethanol production. The chemical pretreatments of moso bamboo, along with the chemical composition of the substrates and spent liquors, and the enzymatic hydrolyability were analyzed. The fermentation of the enzymatic hydrolysates of selected pretreatment substrates was also conducted. The study revealed that ethanol can be successfully produced from bamboo after pretreatment, enzymatic hydrolysis, and ethanol fermentation. The crucial step was pretreatment. Bamboo was much more difficult to pretreat efficiently than other biomass. The cellulose-to-glucose conversion yield (CGCY) of untreated bamboo was only 2.4% after enzymatic hydrolysis with generic cellulase donation. The CGCY of sulfite pretreatment ranged between 11 and 62%. The CGCY of organosolv pretreatment was between 77 and 83%, but recovery of components was low. After lignin was removed from raw bamboo by acetic acid-sodium chlorite method, the CGCY of solid residue was more than 93%, and reducing sugar yield was more than 98%.

Catalytic upgrading of biomass pyrolysis vapors. Nimlos, M. (*National Renewable Energy Laboratory, USA; mark.nimlos@nrel.gov*).

Catalytic upgrading of the vapors from fast pyrolysis is a promising approach for producing carbonaceous oils that are compatible with existing hydrocarbon fuel infrastructure. High yields of oils (>70%) can be obtained by fast pyrolysis of biomass, but unsuitable properties (such as instability, immiscibility with hydrocarbons, viscosity, and corrosivity) make its direct use improbable. These physical properties are due to the high oxygen content of the oil, and catalytic upgrading may serve as a tool to remove oxygen. However, many technical challenges are associated with vapor phase upgrading and there is a great need for a better understanding of the chemical and physical processes involved. This presentation will discuss our efforts to explore catalytic upgrading at a laboratory scale to investigate important processes such as catalyst deactivation and regeneration, deoxygenation of biomass vapors, and hydrogenation mechanisms and kinetics. Laboratory experiments and computational modeling are used to help build this understanding and to explore processing strategies.

Progress in dissolving pulp manufacture. Roselli, A., Sixta, H. (*Aalto University, Finland; annariikka.roselli@aalto.fi; herbert.sixta@aalto.fi*).

Both existing and novel dissolving pulp processes provide a highly suitable basis for an advanced biorefinery. The SO_2-ethanol-water (SEW) process can be viewed as a further development of the conventional acid sulphite process for the production of rayon-grade pulps, showing a higher flexibility in the selection of the raw material source, substantially lower cooking times, and the near absence of sugar degradation products. In our research special attention is paid to developments that target the selective and quantitative fractionation of paper-grade pulps into hemicelluloses and cellulose of highest purity. This target has been

accomplished best by the newly developed IONCELL process, where the entire hemicellulose fraction is selectively dissolved in an ionic liquid, the solvent properties of which are adequately adjusted by the addition of a cosolvent. At the same time, pure hemicellulose can be recovered by further addition of the cosolvent, which then acts as a non-solvent. The residual pure cellulose fraction may then enter a Lyocell process for the production of regenerated cellulose products. The potential of the new IONCELL process has been demonstrated by converting commercial paper pulp into high purity acetate-grade dissolving pulp.

Woody biomass utilization for bioenergy: opportunities and challenges in biomass harvest and logistics in the northeastern United States. Wang, J., Hartley, D. (*West Virginia University, USA; Jingxin.Wang@mail.wvu.edu; Damon.Hartley@mail.wvu.edu*).

The utilization of biomass as an energy feedstock in the northeastern United States can potentially provide a means toward energy security and independence, while simultaneously creating environmental and economic benefits for the region. Most of the energy used in this region and throughout the United States is based on fossil fuels. The burning of fossil fuels has been shown to have negative environmental impacts. Biomass, on the other hand, has been shown to have less environmental impact and can be produced domestically, reducing security concerns and enhancing local rural economies. However, the current methods and logistics used to harvest and transport renewable energy feedstocks are unable to deliver these feedstocks at a price at which they can compete with traditional fossil fuels for energy production. If the large-scale adoption of biomass as an energy feedstock is to occur in the region, methods of harvest and logistics must be used that minimize costs while maintaining the environmental benefits. This study specifically examines the challenges and opportunities of biomass harvest and logistics. The results would be useful in bioenergy development in any region.

Theme F: Forests and Forest Products for a Greener Future

F-01 Innovation in the forest sector: maximizing the sector's competitiveness

Organizers: Eric Hansen (Oregon State University, USA), Erlend Nybakk (Norwegian Forest and Landscape Institute), Lyndall Bull (Australian National University) & Gehard Weiss (University of Natural Resources and Life Sciences, Austria)

Factors influencing architects in specifying eco-labeled wood products in the U.S. residential construction industry. Bowers, C., Ganguly, I., Eastin, I. (*University of Washington, USA; taitb@uw.edu; indro@nararenewables.org; eastin@uw.edu*).

Innovations in building materials and construction designs continue to evolve as fuel costs rise and the demand for energy-efficient structures increases. The development of green building programs (GBPs) in the late 1990s marked the beginning of the effort to adopt energy-efficient design guidelines and eco-friendly renewable materials in residential and commercial structures. These programs were targeted at reducing environmental impacts by integrating eco-friendly materials into the design and construction of buildings, including promoting the use of environmentally certified wood products (ECWPs) derived from sustainably managed forests. This research was developed to assess which attributes might influence architects' decisions to use environmentally certified wood products in residential construction projects and how they might influence their participation in green building programs. For this study, 509 architects who are involved in residential construction responded to an online survey. Energy efficiency and long life were the most important attributes on which architects made their material selection decisions. Architects who had participated in GBPs were more likely to have specified ECWPs in their homes. Architects who work directly for either homeowners or small homebuilders were more inclined to use ECWPs than those working for large homebuilders.

Environmentally conscious forest landowners as forerunners for multiple uses of forests? Häyrinen, L., Mattila, O., Berghäll, S., Toppinen, A. (*University of Helsinki, Finland; liina.hayrinen@helsinki.fi; osmo.mattila@helsinki.fi; sami.berghall@helsinki.fi; anne.toppinen@helsinki.fi*).

In the face of a society's strong emphasis on sustainable development, the development of environmentally conscious consumers is becoming increasingly important. Non-industrial private forest (NIPF) owners constitute a large share of the population in Finland and their values have become more diverse, strongly emphasizing timber production as well as other aspects such as the recreational and conservation values of forests. Therefore, understanding consumer behavior of this high-involvement group can provide useful knowledge on future consumer value creation in Finnish society. The aim of the study was to identify consumer segments among NIPF owners by classifying owners based on level of environmental consciousness and to study how these groups value the various uses of forests. The data set of 400 forest owners was collected in Finland in 2013 via telephone interviews and was analyzed using multivariate methods. Findings indicate that the most environmentally conscious owners emphasize multiple benefits of forests more than owners who are less environmentally concerned. Results also suggest that environmentally conscious landowners are likely to be female and from older age groups.

Renewing wood product value chains and timber procurement solutions. Heräjärvi, H., Sirén, M., Verkasalo, E. (*Finnish Forest Research Institute, Finland; henrik.herajarvi@metla.fi; matti.siren@metla.fi; erkki.verkasalo@metla.fi*).

The Finnish Forest Research Institute carried out an extensive research and development (R&D) program, "Renewing wood product value chains and timber procurement solutions in 2009–2013." With an overall budget of approximately 10 million € and staff of 20–30 persons per year, the program consisted of more than 30 R&D projects of different sizes and kinds. The aim of the program was to improve the competitiveness of wood product value chains in Finland by producing information on the current and prospective wood raw materials, timber procurement solutions, conventional and improved wood products, their markets, and business concepts in the wood products sector. Much attention was paid to industry collaboration as well as knowledge and technology transfer from researchers to customers. Compared with single R&D projects with small groups of researchers, the program was organized in a way that provided an innovative, flexible, and multidisciplinary platform for project planning, allocating human resources, and disseminating the research results. This presentation highlights the results of selected R&D projects, and draws relevant conclusions regarding the achievements of the program in relation to its objectives.

Production planning at a sawmill comparing optimization models with simple heuristics for a short-term multiperiod production problem. Huka, M., Gronalt, M. (*University of Natural Resources and Life Sciences (BOKU), Austria; maria.huka@boku.ac.at; manfred.gronalt@boku.ac.at*).

As a result of the competition for wood as raw material, it is essential to optimize timber production to maximize the output and gain an advantage over competitors. In this work different methods to optimize the sawmill production planning problem are investigated, while optimally using the allocated resources. The authors compare different modeling approaches and investigate the effects of one-period planning vs. multiperiod planning or a rolling planning horizon. In doing so, decision-making models are formulated as mixed integer programs where not only the net revenue but also the variable costs of production, inventory costs for raw material and products, purchasing price for raw material, storage costs for products, and the stock value at the end of the planning horizon are considered. In addition some special assumptions (e.g., minimum production values, useful cutting patterns, appropriate raw material) have to be made to make the model applicable in practice. The results are again compared to the solutions of simple heuristics applied by plant managers. For computational reasons and convenience of handling, heuristics are important for the optimization in real life. The authors develop new heuristics and show their performance compared to an optimization-based approach.

Awareness, perceptions, and willingness to adopt cross-laminated timber in the United States. Laguarda Mallo, M., Espinoza, O. (*University of Minnesota, USA; lagua006@umn.edu; espinoza@umn.edu*).

One of the most recent innovations in engineered wood products is the development of cross-laminated timber (CLT) panels. CLT is a new construction technology that has been very successful in Europe. The system is based on the use of a massive multilayered panel made from solid wood components that are glued together in successive layers placed at right angles (similar to plywood), which improves rigidity, stability, and mechanical properties. The purpose of this project is to assess the market potential and barriers for the adoption of CLT in the United States. For this purpose, this study will assess the awareness and perceptions about CLT, and willingness to adopt it in the American architecture community. The study includes in-depth interviews with CLT experts and potential adopters and a survey of architecture firms in the United States. In the last phase of the study a prototype design will be developed to demonstrate the capabilities of the system. This study will provide important market information for potential adopters, entrepreneurs, government agencies, and other stakeholders.

Innovation in forest management for new forest owner types: a literature review. Nybakk, E. (*Norwegian Forest and Landscape Institute, Norway; nye@skogoglandskap.no*), Lawrence, A. (*Forest Research UK, UK; anna.lawrence@forestry.gsi.gov.uk*), Dobšinskă, Z. (*Technical University in Zvolen, Slovakia; dobsinska@tuzvo.sk*), Feliciano, D. (*James Hutton Institute, UK; dianafeliciano80@gmail.com*), Ficko, A. (*University of Ljubljana, Slovenia; andrej.ficko@bf.uni-lj.si*), Weiss, G.

Forest ownership is changing across the world, and this change requires more innovative forest management. However, this issue is rarely directly addressed among scholars. This paper addresses this gap by focusing particularly on innovative forest management approaches for the properties of new forest owner types. This paper builds on innovation theory and a literature review based on existing literature in international scientific forest journals. In addition, the paper is based on a review of gray literature conducted through the European Cooperation in Science and Technology (COST) Action FP1201 Forest Land Ownership Changes in Europe: Significance for Management and Policy (FACESMAP) with 28 participating countries. The following questions are addressed: (1) How adequate are existing forest management approaches and concepts for different ownership types? (2) What are the consequences of the changing pattern for forest management and for the provision of forest ecosystem functions and services? (3) Which new and innovative forest management approaches, concepts, and techniques are needed for the different ownership types? (4) What are the levels of new owners' awareness of and access to information, advice, and support, and how could they be improved?

Analysing multiproduct economic efficiency relative to forest ownership types in Spain: implications for management and policy. Quiroga, S., Suarez, C., Galindo, E. (*Univerisdad de Alcala, Spain; sonia.quiroga@uah.es*; *cristina.suarez@uah.es; esther.galindo@uah.es*).

The authors explore the extent to which forest products efficiency in Spain is responding to change as a function of forest ownership structure and innovative management frameworks. The country offers a great opportunity to analyze the vast challenges that will affect the Mediterranean forest community in the near future. Climate change is increasing water scarcity in the Mediterranean regions and has exacerbated related problems, such as frequency of forest fires, land use changes, deforestation, and degradation. Attention has now turned to socioeconomic conditions as the financial crisis has forced governments to focus their efforts on economic development. Because of all of these factors, forest policy in Spain is being re-oriented towards ways to increase productivity, and new ownership types and private management concessions for public forests are examples of the means proposed. Therefore, traditional structures are facing substantial change. This paper uses a multiproduct frontier analysis of the mentioned potential drivers affecting forest products efficiency in Spain. Results show that innovative management is a more important factor for efficiency than is forest land ownership under changing conditions. Implications for management and policy are also discussed.

Innovation in diffusion of biorefinery materials and chemicals. Roos, A., Woxblom, A., Stendahl, M. (*Swedish University of Agricultural Sciences, Sweden; anders.roos@slu.se; lotta.woxblom@slu.se; matti.stendahl@slu.se*).

The purpose of this study was to develop a framework for the diffusion process of wood-based biorefinery products. This study is practice oriented and synthesizes different studies, by the authors and others, on business strategy, innovation, and customer analysis. Special attention is paid to resources and capacities, industrial networks, success factors, and the role of stakeholders, including the customer. The empirical basis for the study consists of case studies, market intelligence studies, and customer and sensory analysis. Products include wood-based materials, fabrics, and nanomaterials. Considering that the diffusion process can take 10 years, the study suggests where there is potential for improvement of the innovation process. It presents and classifies methodological tools and approaches in the stages of opportunity identification, screening, development, and market launch for business markets and for consumer goods. A provisional agenda for quicker material, fabric, and chemical innovation is presented.

F-02 The interface between quantitative forest sector modeling and policy analysis: What can be improved?

Organizers: Birger Solberg (Norwegian University of Life Sciences), Daniela Kleinschmit (Swedish University of Agriculture Sciences) & Clark C. Binkley (International Forestry Investment Advisors, USA)

A long-term analysis of the potential of Swedish forests to satisfy sector demand. Eriksson, O., Athanassiadis, D., Nordfjell, T., Öhman, M. (*Swedish University of Agricultural Sciences, Sweden; ola.eriksson@slu.se; dimitris.athanassiadis@slu.se; Tomas.Nordfjell@slu.se; mikael.ohman@slu.se*).

The need for fuel from forest biomass is expected to increase. The aim of this study is to investigate the capacity of the forest to satisfy Swedish product markets under assumptions about the demand for different products. The products are saw logs (for sawmills), pulpwood (for pulp mills), and forest fuel (for the energy sector). The sectors are highly interdependent: harvest on

one site could supply material for all three sectors simultaneously. Three scenarios are analyzed: (1) Current market conditions continue, (2) the energy sector increases by 50% over the next 10 years, and (3) pulp industry demand goes down by 25% over the next 10 yr. The analyses are conducted with the Heureka planning system with some 6 000 National Forest Inventory plots as input and a time horizon of 100 yr. The analyses indicate that there is potential for increased supply of fuel from the Swedish forests without significantly impeding the other sectors. Pulpwood is a more important feedstock to the energy sector than is slash. If the traditional pulp industry reduces its demand, an expanding energy sector will help keep prices up. The long-term supply tends to decrease for the sawmill industry. The sawmill industry will benefit from increased demand in other sectors and thus also from an expansion of the energy sector.

Future of the European forest-based sector: combining forest sector models with foresight analysis. Hetemaki, L., Hurmekoski, A. (*European Forest Institute, Finland; lauri.hetemaki@efi.int; elias.hurmekoski@efi.int*).

The global forest sector is facing major structural changes in the operating environment, and it has become even more complex and interlinked with other sectors, such as the energy sector. This dynamic environment creates a need to anticipate and prepare for these changes. At the same time, however, this task grows ever more challenging due to the structural changes and complexities that induce such needs. For example, there are important emerging issues, such as challenges and opportunities related to new forest products and services, as well as forthcoming policies, that are missing in the existing studies. These issues will have major implications to policy-makers and stakeholders in the coming years, but are not yet on their agenda. This study provides an outlook and synthesis for the European forest-based sector by combining the existing forest sector models and outlook studies, with a foresight panel that analyses the new emerging issues. The foresight panel analysis is similar to that used by, for example, the United Nations Environmental Programme (UNEP) 2012. The results provide a synthesis of the long-run outlook for the European forest-based sector, as well as introducing new emerging issues and related research gaps that are not captured by the forest sector models.

The linkage between environmental policies and international trade in the pulp and paper industry. Korhonen, J. (*University of Helsinki, Finland; jaana.e.korhonen@helsinki.fi*), Prestemon, J. (*U.S. Forest Service, USA; jprestemon@fs.fed.us*), Toppinen, A. (*University of Helsinki, Finland; anne.toppinen@helsinki.fi*), Cubbage, F. (*North Carolina State University, USA; fred_cubbage@ncsu.edu*).

National and international input and output markets for the pulp and paper sector have undergone radical changes during the past few decades. This shift has diminished the importance of Scandinavian and North American resource- and knowledge-based pulp and paper industry clusters. In addition, there has been heated debate on how environmental policies are affecting competitiveness and how they are linked to developments in production and international trade. The authors concentrate on evaluating how certification (which can be seen as a market-driven environmental governance) and recovered paper collection (as a proxy for environmental policy driving competitive advantage) have affected the volume of exports, imports, and production in the main pulp- and paper-producing countries. The empirical analysis is performed by using longitudinal data and panel regression in six countries, 1990–2010. In addition, the authors model the impact of local purchasing power, exchange rate variation, and distance to the main markets for imports, exports, and production. In the preliminary results, a positive relationship between international trade and environmental policies exists in the pulp and paper industry. Similarly, relations between trade and the environment are observed in the wood products industry.

A model of timber supply in Finland. Lintunen, J., Laturi, J., Uusivuori, J. (*Finnish Forest Research Institute, Finland; jussi.lintunen@metla.fi; jani.laturi@metla.fi; jussi.uusivuori@metla.fi*).

The authors develop a new kind of timber supply model usable both in surplus-maximizing and competitive equilibrium-based forest sector models. The model combines growth and inventory data with economic modeling of individual forest owners' harvest behavior and results in logically consistent timber supply functions. The modeling proceeds in several steps. First, a stand-level growth data simulator is used in generating growth data for pine, spruce, and birch stands in various regions and site classes. Second, a simplified three variable stand-level description is estimated from the simulated data for each age-class. Third, the forest owners' thinning and clearcut decisions are optimized using discrete time stochastic dynamic programming. The authors allow for AR(1)-type persistence in the stochastic price process. Three different forest owner types are specified encompassing different amenity valuations in a standard Hartman setting. Fourth, the optimal harvest policies are econometrically estimated, resulting in a smooth function approximation of the harvest policies. In the final step, forest areas from inventory data are allocated to the forest owner types. The initial endowments and amenity valuations are used in calibrating the model to the observed harvest levels. The joint area and volume data and the estimated harvest rules jointly define dynamically evolving supply functions. Properties of the supply model are illustrated with case study projections.

Improving forest sector model inputs on wood supply through the European Forestry Dynamics Model. Packalen, T. (*Finnish Forest Research Institute, Finland; tuula.packalen@metla.fi*), Sallnäs, O. (*Swedish University of Agriculture Sciences, Sweden; ola.sallnas@slu.se*), Sirkiä, S. (*Finnish Forest Research Institute, Finland; seija.sirkia@metla.fi*).

In many countries decisions on forest management are regulated by policy measures but driven by market demand. Unintended impacts may result if market actors' response is not foreseen when designing policy targets and measures. Forest sector models are used to study effects of policy measures on forest product markets, and consequently on the demand of forest resources. Most of them require estimates for wood supply and supply elasticity as initial data and produce estimates for supply (both amount and price) matching given demand scenarios as outputs. In order to track the impacts of policies on forest management and, further, on potential wood supply, a quantitative forestry dynamics model is required. In collaboration with the Joint Research Centre (JRC) and the European National Forest Inventory Network (ENFIN), the European Forestry Dynamics Model (EFDM) was developed. EFDM is a matrix model based on the multiplication of forest initial state (X), transition probability (P), and activity probability (A) matrices. Compared to other existing large-area forestry models, EFDM has an improved ability to model policy impacts by differentiating activity probabilities (A) from (basic) transition probabilities of activities (P). Consequently, the EFDM model supports modeling responses of forest owners to policy measures.

Support to forest policy analysis in the European Union through the Forest Information System for Europe. San-Miguel-Ayanz, J., Schmuck, G. (*European Commission Joint Research Centre, Italy; jesus.san-miguel@jrc.ec.europa.eu; guido.schmuck@jrc.ec.europa.eu*), Schulte, E. (*European Commission, Belgium; ernst.schulte@ec.europa.eu*), Vogt, P. (*European Commission Joint Research Centre, Italy; peter.vogt@jrc.ec.europa.eu*).

This article analyzes new initiatives supporting policy decision-making in the EU forest sector. These followed from the recent adoption of the new EU Forest Strategy in September 2013. Despite efforts on harmonization in the forest sector, the EU, which currently comprises 28 countries, is characterized by fragmentation of knowledge, data, and models among its member states. After adoption of the EU Forest Strategy, the legislative body of the EU, the European Commission, decided on the establishment of the European Forest Information System for Europe (FISE) by its Joint Research Centre (JRC) in collaboration with its member states. The JRC is the EC's technical body, which provides scientific support for policy-making in the EU. As in many other government organizations, one of the JRC's main challenges is to bridge the gap between quantitative forest research analysis and policy decision-making. The new FISE intends to bring together knowledge, data, and models that can provide advice to European policy-makers in the forest sector as a whole. This article presents the current structure and functions of FISE, which is organized into four modules dealing with (1) forest disturbances, (2) forest ecosystem services, (3) forest and climate change, and (4) forest and the EU bioeconomy.

Modeling for adaptive forest management under climate change in Europe. Yousefpour, R. (*Max Planck Institute for Meteorology, Germany; rasoul.yousefpour@mpimet.mpg.de*).

A modeling concept is developed to handle the complexity in adaptive forest management (AFM) and the multidimensional context of risks and uncertainties inherent in climate change. The complexity arises from (1) hazardous risk alongside (2) the gradual changes by climate change, and (3) risks endogenous to management. Uncertain gradual change calls for adaptive measures over long time spans, whereas hazards risk may call for both preventive and adaptive management. Moreover, the behavior of the decision-maker facing risk may differ, ranging from a determinist "no-change" manager not ready to change decisions—that is, business as usual—to an actively adaptive manager observing any changes and optimizing decisions accordingly. The latter makes use of novel information about climate conditions and combines various evidence to define his or her perception about the realization of climate change projections. In this study a process-based forest growth model, Bayesian updating, and Dempster combination rules were used in a forest decision-making process subject to multiple objectives, such as maximizing carbon storage in biomass, or substituting low-energy wood for energy-intensive materials, or a mixture thereof. Results were different at the stand and landscape levels and show sensitivity to climate change realization and ownership. AFM decisions were mostly superior to business-as-usual in the long term and may need multiple revisions over time.

Scenario generation for future development of forested landscapes—linking practice and policy through foresight and modeling. Wallin, I., Trubins, R., Brukas, V., Carlsson, J., Sallnäs, O. (*Swedish University of Agricultural Sciences, Sweden; ida.wallin@slu.se*; *renats.trubins@slu.se; Vilis.Brukas@slu.se; julia.carlsson@slu.se; ola.sallnas@slu.se*).

Forested landscapes are increasingly subjected to a diversity of interests regarding the utilization and extraction of forest resources. Decision-makers and new and old forest stakeholders require novel tools and instruments to face the challenges presented to them. Aiming to create integrated forest management and to provide a holistic landscape perspective, the incorporation of foresight studies into forest planning is a promising and acknowledged opportunity. But it is still a challenge that necessitates novel approaches and testing of ideas. An advanced decision support system (DSS) and good infrastructure for forest research are available in Sweden, yet their use for improving public policy-making has been negligible. In-depth empirical information about key socioeconomic, ecological, and technical factors is gathered from two case study landscapes representing the South and the North, respectively: Helgeå and Vilhelmina. Combined with participatory scenario development and modeling in the Heureka decision support system, scenarios are generated as the basis for stakeholder discussions regarding future forested landscapes. The processes for scenario generation in the Swedish case study landscapes are here presented and evaluated according to their ability to create interesting, plausible, and internally coherent scenarios as well as to respond to needs expressed by policy analysts and decision-makers.

F-03 Contributions of business and marketing to a greener future

Organizers: Eric Hansen (Oregon State University, USA), Tom Hammett (Virginia Tech, USA) & Birger Solberg (Norwegian University of Life Sciences)

Media consumption, environmental values, and the sustainability of forestry: exploring perceptions of paper and digital media. Bull, J., Kozak, R. (*University of British Columbia, Canada; jgbull@gmail.com; rob.kozak@ubc.ca*).

The notion that digital media are a preferable to paper alternatives is widely held. Peer-reviewed life cycle assessments (LCAs) consistently come to this conclusion, helping propagate phrases like, "Please consider the environment before printing this email." The authors' research explores environmental values and media consumption patterns in North American consumers. Consumers' beliefs are described by using the New Ecological Paradigm, a set of questions designed to gauge environmental values. Media consumption patterns—of both digital and paper media—are measured in the same group of consumers, as are views on the effectiveness and credibility of different media types. The authors find that marginal decisions, like printing an email, influence consumers' environmental values. In contrast, the sustainability of an industrial system, perhaps the most important environmental attribute of forestry, is lost on consumers. The authors suggest that the tangibility of a marginal decision compared to the abstraction of an industrial system makes it difficult to influence consumers' environmental values. The authors conclude with potential marketing approaches for the forest products sector, highlighting the inherent sustainability of forest products.

Fundamentals of viable inclusive or pro-poor business models in community forestry. Greijmans, M., Gritten, D., Cheung, A. (*Center for People and Forests (RECOFTC), Thailand; martin.greijmans@recoftc.org; david.gritten@recoftc.org; alyssa.cheung@recoftc.org*).

The literature suggests that community forestry has not delivered on its promise to effectively manage forests and conserve biodiversity while contributing to poverty alleviation. However, a diverse range of community forestry business models practiced in the Asia-Pacific region show that in particular contexts poverty reduction is a feasible solution. These business models are driven either by entrepreneurial communities engaged in production and small-scale processing and trade, with or without outside support, or through the private sector's innovative approaches following an "inclusive business approach" that reaches downstream into the value chain. This paper describes the fundamentals of viable pro-poor business models from both perspectives, based on 10 case studies located in Lao PDR, Thailand, Nepal, Indonesia, and Cambodia. Preliminary results indicate that community forestry models can significantly enhance local people's livelihoods when regulatory opportunities suit smallholder engagement in business operations, both "soft" and "hard" skills of community forestry stakeholders are strengthened, and appropriate investments in the sector are attracted to develop "win-win" business models with communities. These insights provide a framework to guide effective pro-poor forestry programs.

Producer- vs. customer-oriented mix within the forest biomass market. Halaj, D., Brodrechtova, Y. (*Technical University in Zvolen, Slovakia; halaj@tuzvo.sk; brodrechtova@tuzvo.sk*).

The EU's new environmental and energy policy encourages green energy from forest biomass and thus supports the emergent forest biomass market. Among these tools is also promotion of the use of a marketing mix in the forest biomass business. The aim of the research study is to compare the tools of the producer- and customer-oriented mix used by forest companies and biomass-consuming companies within the forest biomass market. An exploratory case study approach with qualitative methods was applied within the theoretical framework of the 7P and 7C concepts of the marketing mix. The study focused on Austria, Finland, and Slovakia because of their high potential in forest biomass resources. One case study from each country was presented, within which five producers and purchasers of forest biomass were purposely selected. The semi-structured interviews with open questions were to be conducted in November 2013 in the case of Austria, and 2014 for Finland and Slovakia. Respondents would be asked to identify producers' and purchasers' marketing mix. Interviews will be analysed with content analysis by using MAXqda software. The goal will be to compare and respectively match the producer- and customer-oriented mix in the dynamically developing European market of forest biomass.

Designers' wooden furniture ecodesign implementation in Scandinavian country-of-origin branding. Lähtinen, K. (*University of Helsinki, Finland; katja.lahtinen@helsinki.fi*), Samaniego Vivanco, D. (*Independent, Peru; dora.alina@gmail.com*), Toppinen, A. (*University of Helsinki, Finland; anne.toppinen@helsinki.fi*).

The potential value of brands is affected by the branding system's capability to satisfy customers' functional (e.g., product quality) and representational (e.g., individual values) needs, for example, by industrial design and country-of-origin (COO) branding. In global markets, Scandinavian COO represents symbolic associations with, for example, high design related to democratic values and product alignment with the natural environment. For Scandinavian wooden furniture industries, the good ecological and social reputation of the Scandinavian COO brand is an opportunity for increasing their value added, especially in affluent, socially conscious, and ecologically conscious customer groups. The aim of this study was to identify links between components of ecodesign orientations (EDOs) and integration of ecological criteria into wooden furniture of different Scandinavian design styles (SDSs). Data were gathered from Nordic wood furniture designers and analysed with factor analysis and logistic regression analysis. According to the results, ecological criteria were integrated into components of EDOs, whereas links between SDSs and integration of ecological criteria were not confirmed. In the future, information on the ecological value expectations of customers both in the volume and premium brand markets of Scandinavian COO wooden furniture could provide opportunities for strategic integration of ecological aspects into SDSs and new value creation in the markets.

Role of the private sector in forest ecosystem services: markets, drivers, constraints, and strategies towards market development. Li, N., Toppinen, A. (*University of Helsinki, Finland; ning.li@helsinki.fi; anne.toppinen@helsinki.fi*), Wen, Z. (*Nanjing Forestry University, China; zmwen@njfu.edu.cn*).

The purpose of this research is to provide a conceptual review of forest ecosystem services (FES) and assess the private sector's engagement in FES. A qualitative literature review will serve as the basis for this project. Data will be collected from published studies and reports. Costs and benefits of four types of FES—biodiversity conservation, carbon offsets, watershed protection, and landscape beauty—will be discussed in economic, environmental, and social terms. Themes specific to market evolution, market form (i.e., commodity offered), driving factors from the perspective of demand, supply, and regulation, market maturity, competitiveness, and payment mechanisms will be discussed to describe the market characteristics of FES. The potential of and key constraints to market development will also be considered. The three broad strategies of fostering private markets, managing public lands, and raising awareness, will be discussed, along with their relevance to forest products.

Global forest management certification: future development potential. Kraxner, F., Shchepashchenko, D. (*International Institute for Applied Systems Analysis (IIASA), Austria; kraxner@iiasa.ac.at; schepd@iiasa.ac.at*), Fuss, S. (*Mercator Research Institute on Global Commons and Climate Change, Germany; fuss@mcc-berlin.net*), Lunnan, A. (*Norwegian University of Life Sciences, Norway; anders.lunnan@umb.no*), Aoki, K. (*United Nations Industrial Development Organisation, (UNIDO), Austria; k.aoki@unido.org*), Shvidenko, A. (*International Institute for Applied Systems Analysis (IIASA), Austria; shvidenk@iiasa.ac.at*).

As of 2013 about 10% of the global forest area has been certified by one of the major programs. During the past two decades, forest management certification (FMC) developed as a tool supporting a transition to sustainable forest management (SFM). It also serves as a template for other certification efforts for different commodities. However, the increase in certification slowed from exponential to linear growth during the past decade and there is an uneven split of the total certified area. The majority of certified forest area did not develop in the Tropics or in the Southern Hemisphere. This article aims at providing a detailed

spatiotemporal overview of the development of FMC globally. It tries to assess the different circumstances under which FMC could succeed in different world regions. Systems analysis and GIS methodology are used to analyze and visualize available information on FMC over the past two decades in order to identify the drivers and derive an outlook on future developments, including the potential contribution of forest certification to the transition to SFM, providing adaptation and mitigation mechanisms, and preventing deforestation and illegal logging.

Ongoing corporate responsibility initiatives amidst an economic downturn. Panwar, R. (*Northland College, USA; rpanwar@northland.edu*), Nybakk, E. (*Norwegian Forest and Landscape Institute, Norway; nye@skogoglandskap.no*), Hansen, E. (*Oregon State University, USA; eric.hansen@oregonstate.edu*), Pinkse, J. (*Grenoble École De Management, France; Jonatan.PINKSE@grenoble-em.com*).

A long stream of research in the corporate responsibility (CR) area has examined the relationship between a firm's financial and social performance. This rich repository, however, has overlooked one fundamental question: how the changes in a firm's financial situation affect its ongoing CR initiatives. The present study addresses this gap by examining the changes in community and environmental initiatives of small manufacturing firms in the forest sector during the recent economic downturn. The authors first develop a study framework drawing on strategic lock-in and cost behavior perspectives and then empirically test it by using data gathered from 441 small firms representing wood products (Standard Industrial Classification (SIC) 24), furniture (SIC 25), and paper (SIC 26) sectors. Results suggest that a decline in a firm's financial performance causes a higher decline in its ongoing community initiatives relative to environmental initiatives. The declining effect of financial performance on community initiatives is more pronounced for firms whose top management views their business context as highly dynamic. The effect on environmental initiatives remains unaltered regardless of top management's views of the dynamism of the business context.

"First I would go to IKEA": A consumer cultural approach to young people's choice of wooden household furniture in Germany and Finland. Toppinen, A., Hakala, I., Autio, M. (*University of Helsinki, Finland; anne.toppinen@helsinki.fi; inkeri.hakala@helsinki.fi; minna.autio@helsinki.fi*).

Previous studies on wooden furniture in the United States have examined the effect of tangible and intangible product attributes on consumer choice. Similar studies in Europe, however, are scarce; there is a substantial research gap in studying consumer choices in furniture from either the cultural perspective or the viewpoint of young consumers. This paper examines young people's experiences with wooden furniture in Germany and Finland. Qualitative material was gathered with ethnographic field work and by conducting 22 thematic interviews with 23- to 34-yr-old consumers in 2013. Results show that IKEA as a global brand and the leading retail store in both countries is culturally represented as an anti-hero of the furniture market with a dual role. First, it is a key classifier for shared meaning in interior decoration discourse; that is, "IKEA quality" refers to ecologically unsound furniture with low durability bought on a limited budget. Second, IKEA is nevertheless mentioned as a major option for upcoming furniture purchases. The results underline young consumers' high respect for handicraft skills associated with traditional wooden furniture and the value of embedded heritage, and a degree of cynicism towards eco-labels in use. From the marketing point of view, domestic origin and safety aspects are emphasized as key attributes among young consumers.

F-04 Greening society and non-wood forest product commercialisation: assessing the environmental, economic and social trade-offs

Organizers: Luis Fontes (Technical University of Lisbon, Portugal), Jenny Wong (Wild Resources Ltd, UK), Robert Mavsar (European Forest Institute, Finland) & Marla Emery (US Forest Service)

Forest conservation and utilization of non-timber forest products in southwest Ethiopia: an overview of actors and their interactions. Endalamaw, T. (*Dresden University of Technology, Germany; tefera10@yahoo.com*), Habte, Y. (*NTFP Development and Research, Ethiopia; yidne_habte@yahoo.com*).

This study provides an overview of how forest conservation actors (native and settlers) interact and how incentives based on non-timber forest products (NTFPs) serve or provide a disservice to forest conservation ideals. Data were collected through semi-structured questionnaires and analyzed using qualitative and descriptive statistics and multiple regressions. The study showed that the interaction of natives, settlers, and private investors, rather than the dichotomy between native and settler, determines whether forest land undergoes conservation or conversion. Land use decisions are mainly dependent on economic incentives rather than settlement history with the exception of the Majingirs (native community), who have still strong association with the forest. The study confirmed that NTFPs contribute substantially to local livelihood. However, there are micro-differences among regions in the type of NTFPs and utilization intensity. Moreover, NTFPs are generally undergoing changes from a product from the forest to an agroforestry product as a result of the conversion of the forest to agroforestry systems. Thus, incentives from NTFPs alone have done little to mitigate the trend of forest conversion. The paper concludes by providing an inclusive conservation model that encompasses the involvement of major actors and a range of incentive measures, embracing cultural interactions and the evolution of institutions.

Balancing subsistence and commercialization: perspectives from North American indigenous peoples' experience. Emery, M. (*U.S. Forest Service, USA; marla.r.emery@gmail.com*).

Some 20 years ago, Dove (1994) and Homma (1996) cautioned that non-wood forest product (NWFP) development was not a social or ecological panacea. They noted that history and theory suggest commercialization of NWFPs has adverse effects on access to land and resources by less powerful users, diminishes market values over time, and, ultimately, reduces biodiversity. These cautions are echoed in later meta-analyses of global case studies (Belcher and Schreckenberg 2007, Kusters et al. 2006). Nevertheless, NWFP commercialization continues to be proposed as a sustainable development strategy. NWFP commercialization

can be especially consequential for indigenous peoples. Wild plants and fungi are central to their material and cultural survival through diverse uses, including subsistence practices. Market development that compromises access to subsistence resources compromises the welfare of indigenous people who depend on them. However, decisions by indigenous communities to market subsistence resources begs the question of whether NWFP commercialization must always and everywhere have adverse impacts. This talk explores the nature of contemporary subsistence practices in North America and their interplay with NWFP commercialization. Examples show the cautions raised by Dove, Homma, and other scholars are well placed, while highlighting measures that indigenous communities use to mitigate their negative consequences for subsistence.

European non-wood forest products network. Fontes, L. (*University of Lisbon, Portugal; luisfontes@isa.ulisboa.pt*).

Non-wood forest products (NWFPs) have important commercial, environmental, social, and recreational roles in many European forests. They also have a relevant place in the multifunctional sustainable forest management (MSFM) paradigm, being the main source of income from forests in several regions. Although the importance of NWFPs is recognised and accepted, forest research remains mainly focused on timber production. Consequently knowledge about European NWFPs is comparatively scarce. There is also little research on their ecology, management, and economics, required to optimize sustainable simultaneous production of different products from forests. It is proposed that a multidisciplinary European network on NWFPs will help to bridge these gaps. In this context, the main goal of the action is to build a broad multidisciplinary network of researchers and managers of European NWFPs, to review the current state of the art, highlight existing innovation, share information and experience, identify research topics, seek research synergies, and by increasing the European-wide theoretical and practical understanding of NWFPs, promote their sustainable management.

Economic contribution of gum and resin resources to household livelihoods and the national economy of Ethiopia. Gebretsadik, Z. (*Ethiopian Institute of Agricultural Research, Ethiopia; zenebemg2014@gmail.com*), Worku Gizaw, A., Yohannes, T., Bahru, T. (*Forestry Research Center of Ethiopia, Ethiopia; adefires@yahoo.com; teme89el@yahoo.com; batinsae@gmail.com*), Mebratu, T. (*Melkasa Agricultural Research Center, Ethiopia; tremeb1@yahoo.com*), Teketay, D.

A study to explore the value chain of gums and resins and their contribution to rural livelihood and the national economy was conducted in five regions within the major gum- and resin-bearing tree belts in Ethiopia. A questionnaire survey was carried out at 135 households, and market assessments were made. Results showed that about 93% of the interviewed households engaged in activities involving gums and resins. Gums and resins contributed up to 14% of the households' average annual cash income. Despite the observed inefficiency of the value chain, gum and resin resources make a considerable contribution to the national economy. The survey showed that between 2002 and 2010, about 2 306 tonnes of different gum and resin products were supplied and an average revenue of US$3 220 542 was obtained in one district of the Tigray region. At the national level, between 1997 and 2010 about 6 174 tonnes of gum arabic and about 33 865 tonnes of other gums and resins were exported, and more than US$72 million was generated. Recommendations are made for key policy and development interventions that could enhance the socioeconomic importance of the gum and resin value chain at the local and national levels, while also increasing responsibility and commitment towards long-term management of the resource bases.

Development of the global trade of non-wood forest products. Mavsar, R. (*European Forest Institute (EFI), Finland; robert.mavsar@efi.int*), Vidale, E. (*University of Padua, Italy; enrico.vidale@unipd.it*), Lovrić, M. (*European Forest Institute, Finland; marko.lovric@efi.int*), Da Re, R. (*University of Padua, Italy; riccardo.dare@unipd.it*).

There is a growing interest around the globe to develop more sustainable economies. For example, the European Union initiated an ambitious plan to make its economy more innovative, resource efficient, and bio based. This concept foresees the sustainable production and conversion of renewable biomass, for a range of food, health, fibre, and industrial products and energy. Renewable biomass encompasses any biological material to be used as raw material. Certainly forests could play an important role as providers of ecoproducts and ecoservices. However, in the past the focus was mainly on wooden products. However, it is expected that also non-wood forest products could have a significant role. To explore the current significance of these products at the global level, this paper analyses the current global trade of non-wood forest products (NWFPs) and its development over the past two decades. Data were collected from the ComTrade database, and include the exports and imports for the main groups of NWFPs (e.g., mushrooms, nuts, honey, foliage, medicinal and aromatic plants). Furthermore, it also compares the development of the global trade of NWFPs with the trade of wood products in terms of extent and quantities.

Towards a new paradigm: valuation of the impacts of reforestation and non-timber value-chain projects on fundamental human needs. Métro, N., Faré (*Kinomé, France; nicolas.metro@kinome.fr; yohann.fare@kinome.fr*).

Deforestation is generally considered to be an environmental issue. Policies to mitigate deforestation usually arise from sources exogenous to local populations, who are often perceived as responsible for deforestation. During implementation of these policies, local populations might be invited to take part in predetermined participatory actions or simply kicked out of protected areas. The work of Kinomé and Forest&Life is founded on the tenet that the success of reforestation projects relies on serving the fundamental human needs of the local population: health, security, well-being, integration into society, respect, access to knowledge, self-realization. Inspired by ethical leadership, we deploy this global approach to enable rural development actors to identify the real causes of deforestation and to make trees and forests a local development solution. The case study to be presented concerns production of *Acacia seyal* gum arabic (Chad, Cameroon) from 2009 to 2012. We surveyed women gum pickers, local middlemen, merchants, and international actors (dairy industry and traders) involved in an innovative value chain reorganization aimed at improving local livelihood and at giving more value to standing trees (gum production) than to cut trees (firewood). An innovative Web-based tool that we developed to follow the ensemble of our projects will be presented.

Non-timber forest products as a sustainable development path full of obstacles: a case study in Costa Rica. Villalobos, R. (*CATIE, Costa Rica; rvillalo@catie.ac.cr*), Ocampo, R. (*Bougainvillea S.A., Costa Rica; bougainvillea@ice.co.cr*).

The use of non-timber forest products (NTFPs), along with timber and environmental services, represents an opportunity to provide value to tropical forests as productive systems that can contribute to local development and consequently should be saved

from deforestation. However, a number of conditions of the commercial, political, and legal environment do not always make it possible to develop an NTFP value chain, and these barriers are especially present in small countries where there is little extensive forest area, as is the case of Costa Rica. This paper reviews the case of the species *Quassia amara*, based on more than 10 years of research at CATIE and on the efforts by the company Bougainvillea at a similar time to develop industrial production. The analysis shows that traditional practices of NTFP international markets, as well as local policies, regulations, and institutions, appear to be designed to prevent the development of local enterprises and to avoid changing the traditional paradigm. In this paradigm, tropical countries are limited to the role of raw material suppliers, to the detriment of the forest and its owners, typically indigenous peoples.

Posters

Socioeconomic importance of indigenous fruit trees, *Strychnos cocculoides* and *Schinziophyton rautanenii*, in Rundu Rural West constituency, Kavango Region, Namibia. Elago, S. (*Ministry of Agriculture, Water and Forestry, Namibia; selmaelago06@gmail.com*).

The purpose of this research was to assess the socioeconomic importance of two indigenous fruit trees, *Strychnos cocculoides* and *Schinziophyton rautanenii*, in Mile 20 village, Rundu Rural West constituency, Kavango region, Namibia. Specifically, the study assesses the contributions of indigenous fruits to households' cash income and reduction of food insecurity. It determined which of the two species contributes more to households' cash income and to food. It further assessed the traditional and other uses of the two indigenous fruit trees at the household level. A semi-structured questionnaire was administered to collect data at the household level. Results of the study indicate that most of the rural households in Mile 20 village benefit from the consumption and sale of indigenous fruit. More than one benefit is obtained from the sale of indigenous fruits as cash income generated is essential for purchasing needed household goods. The findings indicate that *Strychnos cocculoides* contributes to households' cash income only; *Schinziophyton rautanenii* contributes both to cash income and to food. The study further revealed that a wide range of products are obtained from these two fruit tree species.

The characteristics of global trade of truffles. Lovrić, M. (*European Forest Institute, Finland; marko.lovric@efi.int*), Vidale, E., Da Re, R. (*University of Padua, Italy; enrico.vidale@unipd.it; riccardo.dare@unipd.it*), Mavsar, R. (*European Forest Institute (EFI), Finland; robert.mavsar@efi.int*).

Truffles are among the most expensive globally traded non-wood forest products (NWFP). Despite the relatively high price of truffles, the sector has sought new markets to increase the customer base and suppliers at the international scale; consequently the global truffle market expanded dramatically between 1988 and 2007 in sales and structure. However, the trade flows in this market have not yet been analyzed systematically. This paper analyzes ComTrade data on export of truffles in terms of values and quantity for the last decades. Cross-sectional analysis of data from the two decades reveals changes in the cohesive section of the market, whereas roles in the trade flow channels have remained relatively constant. Dynamic network analysis was applied for the entire period, where key macroeconomic data and production capacities were included in the calculations. Hence, a trade network model and a co-evolution model of export values and of production capacities were constructed. The results of longitudinal analysis confirm the results of cross-sectional analysis, where the dominant trends are the rapid increases in the rate of change in the density and in the strength of trade flows.

Analysis of non-timber forest products activities and income among rural households in Nigeria. Olugbire, O., Ayomide, A. (*Forestry Research Institute of Nigeria; olugbireolutoyin@gmail.com; adedunmolalala@gmail.com*).

In this paper, the availability and economic importance of some selected non-timber forest products (NTFPs) among rural households in Nigeria were investigated. The National Living Standard Survey (NLSS) data collected by Nigeria's National Bureau of Statistics were used for the study. A number of forest products activities were found to be of importance to the livelihood of households in the study area. These include hunting, honey processing, palm wine tapping, fruit processing, hides, and mushroom gathering. About 17% of the respondents were engaged in hunting, 17% in honey processing, 17% in palm wine tapping, and 16% in mushroom gathering. With respect to income generation, the most important of these activities is palm wine tapping with income share of 88%. The results also show that the poor were found to be more dependent on the forest than the non-poor, and households from the Southern zones were more forest dependent than households from the Northern zones. It is recommended that research should be conducted into breeding of early maturing species of these valuable trees, which are being cut down at an alarming rate, in order to guarantee future availability for food, medicinal, and livelihood purposes.

Decision-making along a tropical forest product commodity chain: implications for ecological sustainability. Sierra Huelsz, J. (*University of Florida, USA; jasierra@ufl.edu*), Kainer, K., Keys, E.*; kkainer@ufl.edu; ekeys@ufl.edu*), Colli Balam, S. (*Ejido X-pichil, Mexico; salvador_colli_@hotmail.com*).

Tree harvests and other forest management decisions are driven by factors and actors at multiple scales. A diverse tropical forest product from the Yucatan Peninsula was used to explore the role of individuals, culture, markets, and institutions in shaping tree harvests and forest management. Tropical polewood, consisting of small trees (5–35 cm DBH) of >40 tree species, has a long history of subsistence use as a construction material. In the last decade, polewood also has been harvested commercially by local communities to supply a booming Mexican tourism industry and the construction of rustic beach huts and other structures. Polewood harvest is legally regulated by forest management plans; however, forest management decisions often do not follow a formal structure and vary widely among communities. The authors analyzed how players in the polewood commodity chain made decisions that influence what, where, and how trees are harvested. Locally the authors monitored polewood harvests, and regionally they interviewed polewood commodity chain players (harvesters, middlemen, forest technicians, contractors, and tourism industry representatives). Qualitative comparative analysis was used to identify harvesters' age, community land-tenure arrangements, forest structure, and market segment as key elements that determine within-community harvest area and polewood species selection and regional production centers.

Wild mushrooms in Italy: from a commodity to a recreational service. Vidale, E., Corradini, G., Pettenella, D., Gatto, P. (*University of Padua, Italy; enrico.vidale@unipd.it; giulia.corradini83@gmail.com; davide.pettenella@unipd.it; paola.gatto@unipd.it*).

Italy has a long history of collection and consumption of wild mushrooms. Production data have been officially recorded since the 1930s. National professional pickers provided data on the amount until the late 1970s. Production collapses after 1975 because of economic factors and a change of policies and legislative framework. Years later, the amount of wild mushrooms traded began to return to previous levels, due to a massive increase in imports from Eastern European countries and Asia. By contrast, internal production remained quite limited. Analysing the economic trends and legislative framework, this research aimed at defining the changes in Italians' attitudes toward wild mushrooms. In addition to globalization of the wild mushroom trade, the results revealed a shift from collection performed by professional pickers and focused on production, to gathering as a recreational activity. Through multiple case studies in the Veneto region, the study also tried to understand whether recreational picking of wild mushrooms has led to income generation in areas where wild mushroom provisions in forest management have been included. The authors highlight the positive income generation in forests where management systems consider wild mushroom-picking activity.

Contribution of income from non-timber forest products to households' economy in Xing'an Mountains forest area. Zhu, H., Bai, X., Li, H., Cao, Y. (*Northeast Forestry University, China; honggebill@163.com; 674436263@qq.com; 1589767180@qq.com; cyklk@163.com*).

The forests of the Great Xing'an Mountains are the most important forests in China with respect to ecological function and timber resource reserves and contain the largest area of national forests. China is implementing a plan for ecological protection and economic transformation in the Xing'an Mountains forest area (2010–2020). This plan requires timber production to be greatly reduced and transformation and upgrading of the forest industry to be accelerated in the forest area. Developing non-timber forest products (NTFPs) is one of the most important approaches to meet these requirements and achieve economic transformation. This paper used the method of stratified random sampling in 7 county forestry bureaus and administered a questionnaire survey to 301 households living in the forest. Results show that 114 households, or 38%, own forest land with 50 ha per capita available for NTFPs. Although occupying the larger area of forest land, only 11% of the households develop NTFPs and the money invested is small. Household income from NTFPs is RMB 1 373.50 per capita, accounting for only 10% of the total income, which indicates a low contribution of NTFP income to households. A socialized service system for developing NTFPs in forest areas is not in place, and households' demand for socialized service is difficult to satisfy because of lack of supply.

F-05 Gender and forestry value chains

Organizers: Herry Purnomo, Bimbika Sijapati Basnett (CIFOR, Indonesia), Sola Phosiso, (CIFOR, Kenya) & Pablo Pacheco (CIFOR, Indonesia)

Gender, value-added chains, and certification in the furniture industry. Purnomo, H. (*Center for International Forestry Research & Bogor Agricultural University, Indonesia; h.purnomo@cgiar.org*), Shantiko, B. (*Center for International Forestry Research, Indonesia; b.shantiko@cgiar.org*).

Global annual value of furniture trade is US$135 billion. Indonesia's share of the furniture market is 1.5%, and it is among the four biggest non-oil and gas sectors, along with oil palm, rubber, and footwear. In Central Java's Jepara District—the center of teak furniture production in Indonesia—annual furniture exports are valued at US$120 million. Although women play an important role in furniture value chains from teak growing, furniture processing, and marketing, their involvement in decision-making is weak. This paper describes women's participation in the creation of value added and potential impacts of green certification. Research was conducted by implementing value chain analysis, semi-structured interviews, and focus group discussions. The authors found that generally men dominated value chain nodes, but in some nodes women do have roles and indeed play significant roles, such as in the warehouse, in showrooms, and as tree growers. Women perceived green certification as an essential step to comply with certain markets, such as the European Union, United States, and Australia. Certification potentially could improve occupational safety and health for women, income, and sustainability of forest resources. To improve women's participation, the authors recommend carrying out training specifically for housewives, for example, in accounting, marketing, investment in Internet-based marketing infrastructure, and furniture tourism, and in value-added skills such as woodcarving.

Opportunities for enhancing poor women's socioeconomic empowerment in the value chains of three African non-timber forest products. Shackleton, S. (*Rhodes University & Center for International Forestry Research, South Africa; s.shackleton@ru.ac.za*), Paumgarten, F. (*University of the Witwatersrand, South Africa; fi.paumgarten@gmail.com*), Kassa, H. (*Center for International Forestry Research, Ethiopia; habtekassa@yahoo.com*), Husselman, M. (*Innovations for Poverty Action, Ghana; madeleenhusselman@yahoo.com*), Zida, M. (*Center for International Forestry Research, Burkina Faso; m.zida@cgiar.org*).

Gum arabic from Burkina Faso, gum olibanum from Ethiopia, and honey from Zambia are three non-timber forest products (NTFPs) from Africa's dry forests with international value chains. These respective chains were assessed in terms of the roles of women and the benefits they acquire from their involvement. Although women are involved in various stages of the chains, their roles are often poorly recognised. Reasons include the predominance of their involvement in the informal sector, their role as part-time employees, and their tendency to carry out NTFP-based activities at home in conjunction with household responsibilities. Some of the constraints to empowering these women and increasing their presence in the respective value chains are easier to overcome than others. Particularly challenging is addressing gender-based social-cultural barriers. Possible measures to enhance

women's benefits include: greater appreciation of informal markets, the opportunities and constraints associated with them, and their position relative to export markets; improved support for collective action, thereby amplifying women's negotiating power and establishing economies of scale; more targeted training that addresses areas identified by women as specific challenges to engaging more actively in the value chains; time-saving technologies and support systems such as child care; and creating greater gender awareness across the value chain.

Women and charcoal value chains in eastern and southern Africa. Sola, P. (*Center for International Forestry Research, Kenya; p.sola@cgiar.org*), Gumbo, D. (*Center for International Forestry Research, Zambia; d.gumbo@cgiar.org*).

Wood fuel is the main energy source for most people in sub-Saharan Africa. A substantial amount is supplied as charcoal, which forms the primary cooking and heating fuel for many low-income households in peri-urban and urban areas where a high proportion cannot afford the more costly sources of energy and where other sources are not reliable or available. Thus the charcoal industry, though informal and deemed illegal most of the time, remains efficient in meeting urban and local demand. This happens through a network of producers, transporters, traders, wholesalers, and retailers moving charcoal from the rural areas to cities and urban centres. The objective of the study is to compare the charcoal trade in eastern and southern Africa by using gender and value chain tools and methods. The purpose of this research is to improve the understanding of how different gender groups participate in, benefit from, and are affected throughout the value chain in different countries. The authors will review and synthesize literature as well as present primary data from questionnaire surveys targeted at a sample of all stakeholder groups within the value chain. Preliminary assessments have shown that the players in the middle of the chain benefit more than those at the two ends. These stages are mostly dominated by men.

The role of women in the management of forest resources on Afadjato Mountain Ecosystem in Ghana. Wiafe, E., Arku, F. (*Presbyterian University College, Ghana; edward.wiafe@presbyuniversity.edu.gh; fsarku@gmail.com*).

This study provides information on the role of and challenges faced by women who are involved in management and utilization of natural resources in mountain areas. The study used semi-structured guided interviews to obtain information from 100 women at Mount Afadjato in the Volta region of Ghana. The results revealed that most of the women interviewed contributed to the development of the resources to ensure their sustainable utilization. They harvested many resources, ranging from food and materials to amenities, from the mountain ecosystem. Though men generally did not prevent the women from harvesting the resources from the mountain, some of the men competed with the women by harvesting resources that were meant traditionally for women or assisted other women. The women mentioned some constraints in the course of utilizing the resources such as difficulty in climbing, lack of environmental management personnel, and lack of public education. Extensive environmental resource management education is recommended for the communities living in the mountainous area.

F-06 Impact of forest certification on sustainable forest management

Organizers: Wenming Lu (Chinese Academy of Forestry, China), Robert L. Deal (U.S. Forest Service) and John Innes (University of British Columbia, Canada)

FSC-Chain of Custody analysis of companies in Spain and Brazil. Aviles, C., Zelaya, L. (*Polytechnic University of Madrid, Spain; cavilesp@gmail.com; leirezelaya@gmail.com*), Camargo Correa, C. (*Federal University of Paraná, Brazil; cmcamargocorrea@gmail.com*).

Several different certification systems are in place today, but the most widespread worldwide are the Programme for the Endorsement of Forest Certification (PEFC) and the Forest Sustainability Council (FSC). These two are the only two systems in force in Spain. The present study is focused on the FSC system and its Chain of Custody (CoC) certificate, which is a way to guarantee product traceability. The perception of forest sector companies from Spain and Brazil regarding CoC certification was analyzed. A questionnaire was sent to these companies and thereafter a statistical analysis was performed using SPSS Statistics 19 software. Conclusions from the results follow. (1) The main barrier preventing further development of certification is its high cost. (2) Medium and large companies are more satisfied with their CoC certification than smaller firms are. (3) For small enterprises certification may be prohibitively expensive. (4) In Spain, certification means only slight modification in management for the company. However, in Brazil this change is significant. (5) The existence of various certification systems represents a trade barrier. (6) Being certified improves the image of the enterprise, and environmental organizations' campaigns against the use of forest products are countered. (7) Since it is not required by law, certification is simply a marketing tool. (8) Certification is not a real need for Spanish forests. However, in developing countries it is a guarantee of good forest management.

Logging concessions and local governance: social legitimacy and effectiveness of forest certification in the Congo Basin. Cerutti, P. (*Center for International Forestry Research, Kenya; p.cerutti@cgiar.org*), Nasi, R. (*Center for International Forestry Research, Indonesia; r.nasi@cgiar.org*), Lescuyer, G. (*Center for International Forestry Research/CIRAD, Cameroon; g.lescuyer@cgiar.org*), Tsanga, R., Essiane, E. (*Center for International Forestry Research, Cameroon; r.tsanga@cgiar.org; e.essiane@cgiar.org*), Tabi, P. Wardell, A.

Forest management certification is a voluntary, market-driven governance system. Positive outcomes for certification have been documented for setting international standards, for the increased legitimacy of third-party audited products, and for public policies. There is still, however, little evidence that forest management certification has had global significant environmental or social impacts on the ground. This is particularly true in the Congo Basin, which holds the largest surface of certified tropical natural forests, and where several institutions created to satisfy the very demanding social criteria of the Forest Stewardship Council (FSC) have yet to be assessed. The authors provide such an assessment through the analysis of the legitimacy and effectiveness of local governance structures, set up around certified and non-certified logging concessions with the aim of creating

a "social space" for the resolution of conflicts between concessionaires and the local population. Preliminary results indicate that around FSC concessions both the legitimacy and the effectiveness of such "social spaces" are increased because of improved dialogue, financial investment, and regular follow-up. Conversely, notably in rural areas where the State's presence is weak, certified concessions may undermine the legitimacy of State institutions. The authors discuss such findings and suggest options to improve the outcomes of forest certification.

Analysis on creation of a domestic forest certification program in Korea's forestry and forest products industries. Chong, S., Lee, S. (*Korea Forest Research Institute, Korea, Republic of; skchong@korea.kr); leeferas@forest.go.kr*).

This study was carried out to analyze the impact of a national certification programme on forestry as a tool for sustainable forest management (SFM). A key reason for implementing SFM, as expressed in both the Forest Principles (8d) and Chapter 11 of Agenda 21(Section 11.23b), is the formulation of internationally agreed-upon methodologies and criteria for SFM. In compliance with this commitment, the initiatives for SFM such as Montreal Process, Forest Europe, Forest Stewardship Council (FSC), and the Programme for the Endorsement of Forest Certification (PEFC) have been intensified regionally and internationally in the form of criteria and indicators or performance standards. First, this study conducted a comparative analysis of some of the international and national certification programs. Second, 11 FSC FM certified bodies and 194 FSC Chain of Custody (CoC) certified companies in Korea were surveyed to examine the effects of certification in terms of supply and demand of certified timber products and prospects for introduction of domestic certification programme. Forty-two non-certified Korean timber companies were also asked for their opinions on certification. The results showed positive responses on the need for a national certification programme. Last, links between forest management certification and criteria and indicators for SFM were examined to determine the potential for development of standards.

Context matters: implementation of sustainable forest management under different governance and socioeconomic conditions. Elbakidze, M., Angelstam, P. (*Swedish University of Agricultural Sciences, Sweden; marine.elbakidze@slu.se; per.angelstam@slu.se*).

Although sustainable forest management (SFM) policies at global and national levels are similar, the local context for policy implementation is very diverse. The objective of this study is to examine the roles of commonly advocated tools to implement SFM policy. The authors present the results of three comparative case studies done in Sweden and Russia on: (1) multistakeholder approaches used in four Model Forests (MF), (2) outcomes of Forest Stewardship Council (FSC) implementation for boreal biodiversity conservation, and (3) implementation of the sustained yield (SY) forestry concept. While a MF in Sweden is understood as a process with largely bottom-up decision-making, in Russia it is a project with clearly top-down distribution of power among stakeholders. In Sweden set-aside areas for biodiversity conservation according to national FSC standards were two orders of magnitude smaller and had much lower connectivity than in Russia. In Sweden SY forestry was defined as maximum yield forestry based on high-input forest management; in Russia SY forestry was based on mining of old-growth forest followed by natural regeneration with minimal investments in silviculture. To understand the contribution of different policy tools to implementation of SFM, evidence-based collaborative learning based on integrative research and a multiple case study approach should be encouraged and promoted.

Evaluating conservation impacts of forest management certification: testing causality through the use of counterfactual study design. Loucks, C., Mo, K. (*World Wildlife Fund (WWF) – United States; colby.loucks@wwfus.org; karen.mo@wwfus.org*), Shapiro, A. (*World Wildlife Fund (WWF) – Germany; aurelie.shapiro@wwf.de*), Renstrom, M. (*World Wildlife Fund (WWF) – Sweden; margareta.renstrom@wwf.se*).

Established as a market-based instrument to drive responsible forest management, the certification program of the Forest Stewardship Council (FSC) has had significant growth in market uptake over the last two decades. However, there is little causal evidence linking sustainable forest management with the on-the-ground impact on biodiversity and ecosystem. The World Wildlife Fund (WWF) has worked with the scientific and conservation communities, as well as FSC, to develop a scientifically rigorous approach based on counterfactual study design to evaluate the contributions of forest management certification to responsible forest management and associated biodiversity conservation values. The authors will discuss the research challenges, current methodological approaches and applications, and preliminary findings from WWF's work on evaluating FSC certification in Chile, Cameroon, Peru, and Indonesia. This work will serve as a catalyst and a learning platform to bring together experts and key stakeholders involved in forest certification to develop and use standardized frameworks for FSC impact evaluation.

Challenges of forest certification in China. Lu, W. (*Chinese Academy of Forestry, China; luwenmingcaf@126.com*).

The demand for forest certification in China is increasing rapidly. There are three different forest certification systems—the Forest Stewardship Council (FSC), the Programme for the Endorsement of Forest Certification (PEFC), and the China Forest Certification Scheme—and although competition among them is a positive aspect, challenges remain. This presentation analyzed two categories of challenges of forest certification in China. One deals with challenges for companies experiencing strong demand for certification. These companies may have to apply two or even three times for certification because their products have different market destinations and are thus subject to different certification programs. This process is very expensive and requires different management systems to be put into place to comply with the different programmes. The other category concerns challenges about the legal status of some certification programmes in relation to China's relevant laws and regulations. Such challenges are not only for the programmes themselves but also for the companies certified under the programmes. Questions about legal status may lead to government actions over issuance of certification, and this line of inquiry might lead to invalidation of the certifying bodies, the process itself, and even the certificates granted. This presentation makes suggestions to forest certification programmes, certification bodies, and companies that would like to apply for certification, about how to deal with such challenges.

Evaluation of tropical forest management certification. Putz, F., Romero, C. (*University of Florida, USA; fep@ufl.edu; romero@ufl.edu*), Sills, E. (*North Carolina State University, USA; sills@ncsu.edu*), Guariguata, M. (*Center for International Forestry Research, Peru; m.guariguata@cgiar.org*), Cerutti, P. (*Center for International Forestry Research, Kenya; p.cerutti@cgiar.org*).

Forest management certification is a prominent market-based incentive for ecosystem conservation and social welfare enhancement. The authors are conducting a field-based evaluation of the impacts of certification of responsible forest management by the Forest Stewardship Council (FSC). Although the benefits of FSC certification are assumed, the authors address the scarcity of independent evaluations of its on-the-ground impacts. The authors are conducted this evaluation in ways that avoid problems associated with positive selection bias into this voluntary program, that capture the dynamics along the "certification continuum," and that recognize the importance of contextual factors (e.g., markets and policy changes). With a growing network of collaborators, this framework for evaluation of the biophysical, social, economic, and policy impacts of forest management certification is being applied to natural forest management in the Tropics. The authors' interdisciplinary approach uses formulation of a theory-of-change that accounts for how certification is meant to achieve its goals and that promotes assessment of the intervention's direct and indirect impacts. Their participatory design and mixed-methods approach allow capture of the intervention's intended and unintended consequences for different social actors. The authors hope this research improves forest management while it builds a forum in which issues related to forest management sustainability, in all its complexity, can be considered.

Assessment of new methods for sustainable management practices in remote areas. Trishkin, M., Lopatin, E. (*University of Eastern Finland, Finland; maxim.trishkin@uef.fi; eugene.lopatin@uef.fi*).

Sustainable management practices are based on compliance with ecological, economic, and social principles of forest management which are applied in multi-level conditions. Forest certification is one of the major tools to assess sustainable forest management practices in many parts of the world. At the same time the traditional verification procedure is based on field sampling and has limitations in relation to quality of assessment. With the use of remote sensing, particularly Landsat images, which are free of charge with spatial resolution of 15–90 m, it has become possible to analyze time series of satellite images on any area of the forest during the period from 1974 to 2013. The aim of this study was assessment and testing of sustainable forest management practices based on analysis of generic Forest Stewardship Council (FSC) standard requirements. Sustainability criteria were retrieved from the indicators of FSC standards, and tested with the use of the remote sensing tool box. As a result about 15% of indicators can be assessed remotely. Moreover, due to overlapping and interrelation between indicators in the standards, about one-third of them can be verified through remote sensing techniques.

Posters

Sustainable development in an international framework: overview and analysis in the context of forestry and forest products. Hyytiä, K. (*University of Helsinki, Finland; annika.hyytia@helsinki.fi*).

In international markets for forest products, certification provides a way to verify that the products have come from forests that meet certain standards of forestry practices. The certification process is designed to promote sustainable forest management, and products from sustainably managed forests will play an even greater role in global markets. Markets already exist for products from forests certified under the various certification systems, and standards are being developed to address specific market segments. Forest certification requires compliance with relevant regulations. In the value chain from forests, forest certification is an environmental performance tool. Certification systems also provide a framework for standardization and quality management. For this study, the research method is a literature analysis to explore sustainable development in relation to forestry in an international framework, including the role of private forest land owners in Finland. There is considerable discussion worldwide about the potential economic, ecological, and social benefits to be realized from forest certification. Taking into account the primary forces affecting forest industry development, many features of sustainable development and of a green economy can be found to support forestry and forest products markets.

Is certification contributing to sustainable forest management in British Columbia? A Forest Practices Board perspective. Oman, D., Mosher, C., Leitch, C. (*British Columbia Forest Practices Board, Canada; Darlene.Oman@gov.bc.ca; Chris.Mosher@gov.bc.ca; Cameron.Leitch@gov.bc.ca*).

British Columbia has one of the largest and most important forest economies in the world. British Columbia is a leader in the amount of forested land that is certified under the leading certification standards, International Organization for Standardization (ISO), Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), and the Canadian Standards Association (CSA). British Columbia's Forest Practices Board provides independent oversight of forestry activities by auditing forest companies operating on public land (94% of the province) for compliance with provincial forest practices legislation. Much of the area audited by the board is also certified under the various certification standards. One of the primary requirements for certification is compliance with provincial forestry legislation. Being certified by one of these standards is generally assumed to show that a company's forest operations are sustainable and generally well managed. This poster illustrates the scope of certification in British Columbia and summarizes the board's audit findings relative to certification status. The board has found that certified operations are more likely to pass a Forest Practices Board audit. However, the Board has also found non-compliance with provincial legislation in certified areas, and that finding is related to the type of forest licence. This poster uses the results of those findings to provide insights about the impact of certification on sustainable forest management in British Columbia.

Growing stock, community forest management, and deforestation rates in Brazilian biomes. Pieruzzi, F. (*Brazilian Forest Service, Brazil; fernanda.pieruzzi@florestal.gov.br*).

The aim of this work was to establish a relationship between growing stock, community forest management, and deforestation rates recorded in the Brazilian biomes between 1990 and 2010. Amazonia and Atlantic Forest were intensively deforested during

the 20th century. Today, Atlantic Forest has a deforestation rate of 0.11% and just 2 900 million m^3 of growing stock. The Amazonia Forest has a larger growing stock (74 400 million m^3) and one of the lowest deforestation rates in Brazil (0.19%). The other Brazilian biomes, Cerrado, Caatinga, Pantanal, and Pampa were deforested more recently. They have a lower growing stock (3 000, 1 900, 481, and 187 million m^3, respectively) and higher deforestation rates (0.44%, 0.64%, 0.15%, and 0.57%, respectively). One of the reasons for the differences between deforestation rates is the stimulus for community forest management applied in the Amazon Forest in the early 2000s. This practice allowed the increase in timber production and a continuous decline in deforestation. Furthermore, under some programs, part of the profit obtained is designated for forest conservation programs. Thus, despite the recognized ecological importance in these other biomes, community forest management in Brazil is shown to be a good option for biome conservation without reduction in timber production.

Assessment of motivation and attitudes of forest industry companies towards forest certification in north-western Russia. Trishkin, M., Lopatin, E (*University of Eastern Finland, Finland; maxim.trishkin@uef.fi; eugene.lopatin@uef.fi*).

This study explores for the first time the attitudes and motivation associated with forest certification among forest industry companies in north-western Russia. A structured questionnaire was used to carry out interviews with 35 forest industry companies operating in north-western Russia. Although certification in individual companies was initiated by general market demand, representatives of certified companies also emphasized the importance of internal corporate policy. Representatives of certified and non-certified companies identified market demand as a main driving force influencing development of forest certification. Insuring the legality of wood origin, company's image, and competitiveness of wood products were recognized as the most important benefits associated with forest certification. Absence of mandatory requirements from authorities and customers appeared to be the largest obstacle among both groups of respondents. Representatives of non-certified companies identified two points of high importance: economic inaccessibility and low level of preparedness of management, which is mainly associated with absence of a quality management system. The results of the study indicated a general positive attitude towards forest certification. It was noticed that respondents have gaps in understanding the principles and limited awareness of forest certification, especially among non-certified forest industry companies.

F-07 Forest governance and legality of timber: Challenges of legality in practice

Organizers: Margaret Shannon (University of Freiburg, Germany), Wenming Lu (Chinese Academy of Forestry), Mersudin Avdibegovic (University of Sarajevo, Bosnia-Herzegovina) & Qiang Li (International Tropical Timber Organization, Japan)

Legality and "the three Gs." Arts, B. (*Wageningen University, Netherlands; bas.arts@wur.nl*).

Legality of timber is an important aspect of sustainable forest management. It could be seen as a public good for all. However, different perspectives on legality are possible, and they are needed to put things in perspective. This presentation takes the so-called three-G framework (Arts, forthcoming) as a starting point to assess the meaning and consequences of timber legality. From the perspective of the government (the 1st G), legality refers to the rule of law: forest laws should be obeyed and enforced. In many cases, this means strengthening the state and its capabilities. From a governance (the 2nd G) perspective, legality also includes the social aspects and consequences of law. This implies taking relevant stakeholders and their ideas and interests into account when designing and enforcing law. From a "governmentality" (the 3rd G) perspective, legality refers to the production of law-abiding subjects (people who respect and follow the law), excluding those who do not or cannot respect and follow the law (e.g., encroachers, informal traders). Legality may appear to be a logical and uncontested concept from a governmental perspective, but it is not from the other two perspectives.

Governance, legality of timber, and corruption: the case of the Federation of Bosnia-Herzegovina. Avdibegović, M. (*University of Sarajevo, Bosnia and Herzegovina; mavdibegovic@gmail.com*), Pezdevšek Malovrh, Ã. (University of Ljubljana, *Slovenia; spela.pezdevsek.malovrh@bf.uni-lj.si*), Bećirović, D., Marić, B., Mutabdzija, S. (*University of Sarajevo, Faculty of Forestry, Bosnia and Herzegovina; becirovic.dzenan@gmail.com; bruno.m.maric@gmail.com; senka.mutabdzija@gmail.com*).

International reports and recent national studies refer to illegal activities as the most serious problem in the forest sector of Bosnia-Herzegovina. In order to combat corruption in forestry, several efforts have been launched by responsible institutions and governmental bodies within the last few years. This paper presents some findings related to corruption in the forest sector of the Federation of Bosnia-Herzegovina in terms of amount, types, drivers, actors, and impacts of illegal activities. The role of emerging actors in forest policy (e.g., local municipalities) in developing a new legal framework for forestry will be examined. This paper also explores the potentials of several activities associated with forest governance in the wider context (e.g., forest certification, improving transparency, developing programs for prevention of illegal activities at the company level) to combat illegal activities in the forestry and wood-processing industry. By analyzing the impacts of an international legal framework (e.g., EU Timber Regulation) at the national level, the authors discuss whether and how general principles of legality—lack of corruption—can be integrated into forest governance practices at the national level but also how national forest policy can be improved by strengthening institutional and legal requirements for assurance of timber legality.

Legal challenges for the EU Forest Law Enforcement, Governance and Trade/Timber Regulation (FLEGT/EUTR). Lu, W. (*Chinese Academy of Forestry, China; luwenmingcaf@126.com*).

Illegal logging and associated trade have become a global concern, and the international communities have been working together to tackle it. Studies show that there are many challenges for timber producing, processing, and trading companies to meet the requirements of EU Timber Regulation (EUTR). However, there are very few studies that have been conducted on the challenges of EUTR itself, such as legal and logic challenges. This presentation will focus on a dozen challenges of the Forest Law Enforcement, Governance and Trade (FLEGT), mainly Voluntary Partnership Agreements (VPAs), and EUTR from aspects of

legal and logic sciences, such as challenges on legal grounds for the design of a legality verification mechanism, for burden of proof over illegal timber, for selective citation of legal requirements, for fundamental difference between being illegal and just a minor violation of legislative requirements. By analyzing these legal and logic challenges, the presentation will put forward many suggestions for the implementation of FLEGT and EUTR, including a legally sound definition of legality and a due diligence mechanism such as chain-of-custody tracing. These suggestions could help to improve the implementation of FLEGT and EUTR both for the EU and its timber trade partners, whether producers, processors, or traders.

Are timber legality requirements giving rise to an international forest law? Meidinger, E. (*State University of New York, USA; eemeid@buffalo.edu*).

This paper examines the hypothesis that the recently adopted EU and U.S. timber legality requirements may be catalyzing a new, increasingly harmonized and integrated global forest law. While ostensibly focusing solely on the law of the jurisdiction where the timber was produced, the timber legality requirements require decisions on which laws count for purposes of legality (for example, timber rights do and truck licensing probably does not). Implementation by actors based in different countries also creates pressures for mutual understandability and relative simplicity, because complex and variable laws are more difficult and expensive to enforce than simple, consistent ones. Yet legality in many cases is much more contested than the "positivist" model of state law acknowledges: Legal rights in forests may be defined in one way by a state bureaucracy and in quite another by a traditional forest community. The position of the forest community may be more in accord with emerging international standards than that of the state. This paper proposes that a "legal pluralist" framework can significantly improve on the traditional "legal positivist" one in understanding and implementing timber legality requirements. It then provides an analysis of the EU's Forest Law Enforcement, Governance and Trade/Timber Regulation (FLEGT/EUTR) program based on the legal pluralist framework.

Feminist perspectives on legality of timber and governance. Shannon, M. (*State University of New York, USA; mshannon@buffalo.edu*).

As one branch of critical social theory, feminist theory focuses specifically on gender inequality. While the UN Millennium Goal 3 is "to promote gender equality and empower women," this goal is often linked directly with poverty rather than political power. Because poverty and inequality are the product of a political and economic system, feminist research aims to identify, understand, and correct the lack of political and economic power among women that leads to and tolerates a system of inequality. While governance theory and analysis may include diagnostics related to poverty and gender inequality in political and economic life, it is seldom a central focus of governance theory and analysis. This paper analyzes timber legality programs from a feminist perspective. To what extent do the emerging transnational legal frameworks for governance and legality promote gender equality? Governance is a network of relationships and partnerships aiming to organize political and economic activity at all levels of society. To what extent are the relationships promoting gender equity and reducing poverty and political exclusion of women?

Posters

Evaluation of the management of two community forests in the eastern region of Cameroon under FLEGT. Fomou Nyamsi, G., Mala, W., Annie-Claude, N. (*University of Yaoundé I, Cameroon; ghislainfomou@yahoo.fr; williammala@yahoo.fr; annieclaude_pial@hotmail.com*).

In order to address illegal logging, Cameroon in 2010 ratified the EU's Forest Law Enforcement, Governance and Trade (FLEGT) Voluntary Partnership Agreement (VPA), and the initiative has been in force since March 2013. This agreement is expected to be implemented by all foresters, including community forest managers. Research was carried out via the triangulation method to check the legality of logging activities in two community forests located in the Boumba-and-Ngoko (East Cameroon) with regard to the VPA. After field work, the authors performed an appraisal of logging activities, identified regulatory and legal shortcomings with regard to the VPA FLEGT number 6 grid, and suggested improvements to the plan. In conclusion, it appears that neither forest fulfills all the requirements of the VPA FLEGT number 6 legality grid. Therefore, the Asdebym and Codebom community forests are not entitled to FLEGT certification. The major irregularities are those relating to compliance with logging and forest development, as well as requirements concerning biodiversity and environmental protection. The lack of logging equipment and communities' inability to comply with various technical documents are the main causes of such shortcomings. In order to fill the identified gaps, all stakeholders in forest management should be involved and should undertake high-priority actions, including supporting communities in acquiring logging equipment, ensuring their capacity building in mechanized logging, and increasing awareness of the FLEGT process.

The potential of legal timber trade policies to expand demand for U.S. wood products in the Chinese re-exports sector. Lu, Z., Ganguly, I., Eastin, I., Perez-Garcia, J. (*University of Washington, USA; luz8@uw.edu; indro@uw.edu; eastin@uw.edu; perjohm@u.washington.edu*).

The recent adoption of timber legality legislation in the United States (Lacey Act 2008 Amendment) requiring timber imports be sourced from legally harvested wood provides an opportunity to expand exports of sustainably managed U.S. value-added wood products to Asia for re-export. This study focuses on the interactions between Chinese furniture/flooring manufacturers and exporters and the U.S. Lacey Act. The overall goal of the study is to demonstrate: (1) how perceptions associated with the Lacey Act have affected the export/raw material sourcing behavior of Chinese furniture and flooring manufacturers/exporters; (2) how the change in Chinese wood products exports to the United States over the past 5 years can be explained by the respondents' demographic and psychographic characteristics; and (3) how the Lacey Act has affected Chinese companies' manufacturing and export costs. The results were obtained from a series of structured interviews administered during DOMOTEX Asia/ CHINAFLOOR Show in March 2013 and the Furniture Manufacturing & Supply China Show in September 2013. Quantitative statistical techniques were used to analyze the survey data. Results obtained provide us with a better understanding of the strategies that furniture and flooring companies in China are adopting in order to ensure that illegally harvested wood is excluded from their supply chain.

Impact of timber legality policies on U.S. wood importers and their business practices. Roe, B., Ganguly, I., Eastin, I. (*University of Washington, USA; Benjamin.e.roe@gmail.com; indro@uw.edu; eastin@u.washington.edu*).

Until recently, little regulatory action was taken in developed countries to address the problem of illegal logging or to stem the trade in wood products manufactured from illegally sourced wood products. In 2008, the U.S. Congress passed landmark legislation expanding the scope of the Lacey Act to include wood and non-wood materials. Since that time, both the EU and Australia have adopted legislation of their own designed to make it a crime to import illegally harvested wood into their respective region or country. This study looks at the effects of timber legality policies on U.S. imports with a focus on the attitudes and perceptions of U.S. wood importers. Exploratory interviews and targeted Web-based surveys of key managers will identify market trends, segmented by company demographics and compared across industry sectors. This study explores the impact of legality legislation on business practices, material sourcing decisions, and the use of Chain of Custody certified products. These results will be compared with parallel questions from surveys of tropical hardwood exporters in China, Vietnam, and Thailand which are being administered by the Center for International Trade in Forest Products (CINTRAFOR). Results will be assessed to identify global trends and market opportunities.

How can forest governance approaches under Forest Law Enforcement, Governance and Trade Voluntary Partnership Agreements and REDD+ be helpful for each other? Tegegne, Y. (*European Forest Institute, Finland; yitagesu.tekle@efi.int*).

Several tropical countries are involved in two international programs: the EU's Forest Law Enforcement, Governance and Trade (FLEGT) initiative and its Voluntary Partnership Agreements (VPAs), and the program of the UN Framework Convention on Climate Change (UNFCCC) to reduce deforestation and forest degradation in developing countries (REDD+). Since the aims of these initiatives are related, and they are simultaneously being implemented in several tropical countries, questions have emerged on how these two policies influence each other at the national level, and how synergies between them can be enhanced. This study will examine and compare observed and anticipated institutional interactions between FLEGT-VPAs and REDD+ in four Congo Basin countries, Cameroon, Republic of Congo, Central African Republic, and Democratic Republic of Congo, by applying an institutional interaction and interaction management approach. The objective is to determine the nature of the interactions (whether disruptive, neutral, or synergistic) and develop ways of mitigating existing and potential disruptive interactions while enhancing synergies. This paper is based on review of official documents and in-depth interviews with experts involved in VPAs and the REDD+ process in the targeted Congo Basin countries.

Residual DNA extracted from timber and its effectiveness for identification of wood species. Watanabe, U. (*Chiba Institute of Technology, Japan; ugai.watanabe@it-chiba.ac.jp*), Abe, H. (*Forestry and Forest Products Research Institute, Japan; abeq@affrc.go.jp*).

Accurate identification of wood species can contribute to the abatement of illegal logging and the maintenance of a sound timber market. Accurate identification requires a variety of methods. To apply molecular biological methods to the identification of wood species, the polymerase chain reaction amplification of residual DNA extracted from old timbers of *Cryptomeria japonica* was quantitatively analyzed and the effectiveness of residual DNA in wood identification was discussed. No clear correlation between concentration of residual DNA extracted and copy numbers was observed for either sapwood or heartwood, indicating that the concentration of residual DNA extracted from timber is not an important requirement for the DNA identification of wood species. Fragmentation of plastid DNA would have proceeded for 40–50 yr after cutting but would not have continued much after this period. By fragmentation over a long period, the residual DNA in wood would have been shortened to the length of 200–300 bp. For both sapwood and heartwood that have been elapsed for more than 400 yr, 93-bp amplifications of plastid DNA were detected, indicating that the species of old wood products can be identified by extracting and amplifying their residual DNA.

F-08 Forest resources assessment for non-wood forest products

Organizers: Marco Marchetti (University of Molise, Italy), James Chamberlain (U.S. Forest Service), Pawel Staniszewski (Warsaw University of Life Sciences, Poland) & David Pettenella (University of Padua, Italy)

Uses and preferences of non-timber forest products among urban households in Ado-Ekiti metropolis, Ekiti State, Nigeria. Adedayo, G. (*Federal University of Technology Akure, Nigeria; gideonadedayo@yahoo.com*).

This study investigates the uses and preferences of non-timber forest products (NTFPs) among urban households in Ado-Ekiti metropolis, Ekiti State, Nigeria. Systematic random sampling technique was used to select 20 households from each of the 12 wards in the metropolis. A structured questionnaire was used to obtain information from the head of each household. Results of the study showed that the various uses of NTFPs among urban households in the study area include food, medicinal use, fuel, and trading. The preferred NTFPs among urban households in the study area include *Chrysophyllum albidum*, *Parkia biglobosa*, bushmeat, snail, *Irvingia gabonensis*, and *Garcinia cola*. Chi-square test ($p < 0.05$) shows that respondents' level of income and level of education have a significant association with the use of NTFPs. Thirty-four percent of the respondents use NTFPs because of their high nutrition value and 33% uses NTFPs because of their unique taste. The study also showed that the problems faced by urban households in the use of NTFPs in the study area include poor roads and seasonality of NTFPs. It is essential that government help to repair many of the bad roads and encourage more research about NTFPs.

Underground value: assessing non-timber forest products in Appalachia (USA). Kruger, S., Munsell, J. (*Virginia Polytechnic Institute and State University, USA; skruger@vt.edu; jfmunsel@vt.edu*), Chamberlain, J. (*U.S. Forest Service, USA; jchamberlain@fs.fed.us*).

Harvesting wild medicinal forest plants has long provided a source of income and cultural identity in Appalachian communities in the eastern United States. In recent years global demand for native woodland medicinals from the region has grown significantly,

presenting new opportunities for landowners, harvesters, and buyers. Assessing the value of non-timber forest products (NTFPs) and size of their markets is difficult due to the often informal, unregulated nature of supply chains. This study, modeled after the U.S. Forest Service Timber Product Output program, seeks to create a voluntary, replicable mechanism for monitoring the variety and volume of NTFP species that enter the global marketplace, beginning at the first point of sale. In a partnership between the U.S. Forest Service and Virginia Tech, surveys were distributed to Appalachian ginseng dealers, who are required under the 1973 CITES treaty to be registered and to record ginseng transactions. Dealers were asked about the variety and quantity of other untracked species they purchased from harvesters. Quantitative data provided from the surveys were integrated with qualitative interviews with buyers to estimate the size, structure, and direction of the Appalachian medicinals market. The authors discuss their findings and possibilities of using these methods to assess NTFPs in other regions.

Potential gum Hagar production from *Commiphora holtziana* in Kenya. Mbiru, S., Muga, M., Oriwo, V., Kiama, S. (*Kenya Forestry Research Institute, Kenya; sheilambiru@gmail.com; meshackmuga@hotmail.com; voriwo@yahoo.com; mastakim500@yahoo.com*), Waithera, R. (*FAO, Kenya; rispha@gmail.com*), Gachathi, F., Chikamai, B., Jaldesa, A.

Isiolo and Garissa Counties has abundant *Commiphora holtziana* with potential for commercial gum resin (Hagar) production. However, there is limited information on its inventory, distribution, and gum production potential. This study carried out a resource assessment and mapping exercise to estimate Hagar production potential in the country. Landsat images (medium resolution) were acquired, processed, and used to generate and identify relevant land cover classes; areas covered by the gum resources were mapped. Sixty-three sample plots (20 m × 20 m) in key Hagar producing areas were used. Stocking density, tree height and DBH, and crown were determined for all the *C. holtziana tree*s in each plot. Potential Hagar production was estimated based on number of stems, crown cover, and gum yield per tree. Results show that *C. holtziana*, has a mean DBH of 21.5 cm, stocking density of 134 stems/ha, height of 6.6 m, and crown diameter of 7.9 m but has poor natural regeneration. It is concluded that Kenya has a potential annual Hagar yield of 5 596 MT, which needs to be utilized as an alternative source of livelihood. It is recommended that the *C. holtziana* trees be protected and sustainable tapping methods introduced and promoted.

Resource assessment and mapping of *Acacia senegal* var. kerensis in Samburu and Isiolo Counties, Kenya. Muga, M. (*Kenya Forestry Research Institute, Kenya; meshackmuga@hotmail.com*), Mutunga, C. (*World Agroforestry Centre, Kenya; mutunga.christopher@gmail.com*), Elizah, P. (*Centre for Training and Integrated Research in ASAL Development, Kenya; peterelizah@yahoo.com*), Chikamai, B., Oriwo, V. (*Kenya Forestry Research Institute, Kenya; director@kefri.org; voriwo@yahoo.com*).

Acacia senegal var. kerensis, is the main source of commercial gum arabic production in Kenya, yet information on its inventory, distribution, and potential gum production is scanty. A resource assessment and mapping study was therefore carried out in Isiolo and Samburu Counties in order to establish gum production potential. Landsat images (medium resolution) were used to generate and identify relevant land cover classes, and areas covered by these resources were mapped. Stocking density, tree height, DBH, and crown were determined in 24 plots (20 m × 20 m). Results indicate mean stocking density of 356 stems/ha, height of 4.7 m, DBH of 7.8 cm, and crown diameter of 5.6 m with no significant differences between counties. The potential gum yield based on number of stems, crown cover, and gum yield per tree was 17.8 kg/ha. It is also reported that the species is found mainly in the Central, East, and Oldonyiro Divisions of Isiolo County and the Baragoi, Nyiro, and Waso Divisions of Samburu County. In conclusion, the stocking density is low, and protection of sites is critical in promoting natural regeneration and ensuring sustainable gum production.

Combined impact of exploitation and habitat degradation on the abundance and structure of *Mimusops andongensis* Hiern in Benin. Sinasson Sanni, K. (*University of Abomey-Calavi, Benin; sinasson.gisele@gmail.com*), Shackleton, C. (*Rhodes University, South Africa; c.shackleton@ru.ac.za*), Sinsin, B. (*University of Abomey-Calavi, Benin; bsinsin@gmail.com*).

Mimusops andongensis is a multipurpose species, of which the bark, roots, and leaves are used for rural healthcare needs. This use, together with habitat destruction, limits its availability and conservation. The effect of use and habitat degradation with different human pressure levels on its population in Lama Forest in Benin was examined by using structural characterization. Dendrometric characteristics and diameter size distributions were assessed through forest inventory. Adult trees were found in 92% of plots in non-degraded forest, in 71% in degraded forest, and in 7% in preforest fallow land. Tree density (in stems/ha) in non-degraded forest (43 ± 35) is 2–23 times higher ($p < 0.001$) than in degraded forest (23 ± 39) and preforest fallow land (2 ± 8). A similar trend was obtained for regeneration density (106 ± 117, 84 ± 140, and 17 ± 74 stems/ha, respectively). Diameter size distributions were positively asymmetric, showing relative dominance of young or small-diameter individuals in non-degraded and degraded forests. Similarly, in preforest fallow land, it was declining exponentially, indicating a population facing extinction. Furthermore, sexually mature trees were scarce in degraded forest and fallow land. Establishing a management plan for this species will help to sustain its use by local communities and its conservation.

Assessment of non-wood forest product resources—trends in Poland. Staniszewski, P. (*Warsaw University of Life Sciences (SGGW), Poland; pawel.staniszewski@wl.sggw.pl*).

One of the primary prerequisites for sustainable use of forest resources is the identification of the product base. However, this amounts to a particularly complex problem in the case of non-wood forest products. These products continue to be widely perceived as "goods of minor economic value"; most of them are not covered by any management plans and are not subjected to any silvicultural treatments. Poland is one of the few countries where regular research on quantitative and qualitative identification of ground vegetation resources has been carried out. Detailed inventory was taken of major useful plants, predominantly fruit-bearing and medicinal plants. However, there are no quantitative data on specific products available for harvesting. The only, as yet incomplete, figures on hand concern forest goods offered on the market. Detailed inventory is considered for exceptional cases only, and covers predominantly endangered or partially protected species. This paper presents the objectives, scope, and methods of general and detailed inventorying of ground vegetation resources applied in Poland. It analyses currently available information relating to the identification of non-wood forest product resources. The paper also discusses prospects of resource estimation and use, with consideration given to natural as well as socioeconomic conditions.

Estimation of the value of non-timber forest products and services in Austria. Vacik, H. (*University of Natural Resources and Life Sciences (BOKU), Austria; harald.vacik@boku.ac.at*), Wolfslehner, B. (*European Forest Institute, Austria; bernhard.wolfslehner@efi.int*), Huber, P., Ruprecht, H. (*University of Natural Resources and Life Sciences (BOKU), Austria; patrick.huber@boku.ac.at; herwig.ruprecht@boku.ac.at*).

The Austrian national report to Forests in Europe on sustainability indicators of non-wood goods and services proposed a higher degree of information. Knowledge currently available about non-timber forest products (NTFPs) and services appears poorly structured and assessed. In addition, data sources tend to be heterogeneous, making estimation of quantities and values a complex task. The core of this project was the analysis of existing data and application of new approaches to data collection (e.g., telephone surveys among producers and purchasers, systematic online questionnaires) in the absence of any statistics. On this basis, quantity and values balances for the provision of NTFPs and services in 2000, 2005, and 2010 were compiled. The value of NTFPs and services for 2005 was estimated at 220 million €, 43% of which came from NTFPs and 57% of which came from forest services. Payments for hunting licences contribute the largest share with 22% of total value, followed by production of Christmas trees (17%) and forest-related tourism (11%). Generally, the value of marketed NTPFs is stagnating or slightly decreasing as many of the traditional uses are prone to losing competitiveness. On the other side, a dynamic, innovative market for forest services is emerging.

F-09 Sustaining bamboo and rattan resources

Organizers: Jinhe Fu (International Network for Bamboo and Rattan, China), (International Center for Bamboo and Rattan, State Forestry Administration of China) & Jinzhong Xie (Chinese Academy of Forestry, China)

Bamboo as a new alternative to wood in the Philippines. Aggangan, R., Cabangon, R. (*Forest Products Research and Development Institute, Philippines; rtaggangan@gmail.com; rjcabangon@hotmail.com*).

Bamboo products from the Philippines such as furniture and handicraft and construction materials are sold in both domestic and export markets. In the domestic market, high quality bamboo products are sold in high-end markets while lower quality products are generally sold to medium- and low-income consumers. The global market in 2006 stood at about US$7 billion and was projected to increase to US$17 billion between 2015 and 2020. At present, the most promising extensive utilization of bamboo in the country is for the manufacture of engineered bamboo for school desks for all Philippine public schools as mandated by Executive Order 879, which created the Philippine Bamboo Industry Development Council (PBIDC). The number of bamboo desks required by the Department of Education averages 139 000 per year. Engineered product using the bamboo-flattening machine developed by the Forest Products Research and Development Institute (FPRDI) has already been found comparable to premium hardwood lumber. However, in order to reduce the price and make engineered bamboo products mainstream, the following strategies must be developed: (1) inexpensive adhesives, preservatives, and finishing chemicals; (2) economical methods of drying and preservation; (3) product development and processing of lesser-used species of bamboo; and (4) processing tools, equipment, and machinery. Furthermore, processing wastes from bamboo can be recycled into fuel products such as charcoal and its distillate.

***Guadua angustifolia* Kunth in Costa Rica: guidelines for sustainable management and use.** Briceño-Elizondo, E., Arias, D. (*Instituto Tecnologico de Costa Rica, Costa Rica; ebriceno@itcr.ac.cr; darias@itcr.ac.cr*), Alegria, A (*Ecoindustrias Tecnologicas, Costa Rica; alejandra@ecoindustrias.com*), Esquivel, E. (*Instituto Tecnologico de Costa Rica, Costa Rica; eesquivel@itcr.ac.cr*).

The Guadua bamboo (*Guadua angustifolia* Kunth) is the third tallest bamboo in the world, reaching 35 m in height and 25 cm in diameter under good soil conditions. In the Atlantic region of Costa Rica, the species has been established and put to certain uses, but it is not in high demand because of inadequate management. The experimental Station Diamantes of the Agricultural Innovation and Transfer Institute of the Ministry of Agriculture of Costa Rica, contains 177 ha of *G. angustifolia*, which has fallen under sporadic and inadequate management. It is the objective of this research to establish a sustainable management plan for the species. The plan will focus on multiple uses, such as construction use, an alternative for bioenergy production from biomass, and the possibilities of incorporating bamboo into climate change mitigation programs under the rules and regulations of Clean Development Mechanisms and Payment for Environmental Services. Results have shown that it is possible to supply these uses and simultaneously meet goals for carbon sequestration. Culm stocking and management can be varied to around 4 500 culms/ha to promote sprouting and to supply different uses, while capturing from 3 to 9 tons of carbon/ha/yr and adding between 1 and 24 tons C/ha/yr to the soil.

Edible bamboo shoot utilization: problems and prospects in India. Chandramouli, S., Viswanath, S. (*Institute of Wood Science and Technology, India; sowmya.chandramouli@gmail.com; syam.viswanath@gmail.com*), Chongtham, N. (*Panjab University; cnirmala10@gmail.com*).

Bamboo shoots are used as a vegetable in many South Asian nations. Shoots are high in protein, fiber, essential amino acids, bioactive compounds, and minerals, and they are also low in fat. This combination makes bamboo an excellent food for direct consumption and in nutraceuticals. However, in India, which is the second largest producer of bamboo shoots after China, the food potential seems grossly underutilized. In north-east India, which is home to a rich diversity of bamboo, shoots are a part of the traditional cuisine. In other parts, especially surrounding forest areas, shoots of species like *Bambusa bambos* and *Dendrocalamus strictus*, which generally occur in the wild, are consumed. Although multipurpose species like *D. stocksii*, *B. balcooa*, *D. asper*, *D. brandisii,* and *D. hamiltonii* are widely cultivated, the potential of bamboo as food is poorly recognized. Presence of cyanogenic glucosides that render bitterness to fresh shoots appears to be partly responsible. Therefore, it is essential to devise acceptable and cost-effective processing schedules for eliminating bitterness while retaining nutritional qualities. A suite of

practices that match species with site and with pest management schedules is currently lacking because annual production of edible shoots and volume of the edible portion are dependent on site and management practices. Additionally, preservation techniques, upscaling of shoot industry initiatives, and innovative and clear marketing strategies are needed to promote the bamboo shoot industry in India.

Micro-differences in bamboo commercialization in Ethiopia: analysis of commercial income and value chain relationships. Endalamaw, T., Pretzsch, J. (*Dresden University of Technology, Germany; tefera10@yahoo.com; pretzsch@forst.tu-dresden.de*).

This study examined extent of bamboo commercialization and livelihood income in Ethiopia. Data were collected from actors in the value chain. Semi-structured interviews, group discussion, and secondary information were used to obtain relevant data to address the research objective. Data were analyzed by using qualitative analysis, descriptive statistics, ANOVA, and multiple regressions. Results revealed that commercialization is highest in Awi followed by Sidama and Sheka with a commercialization of 60, 40, and 9%, respectively. Differences were significant among Sheka and the other regions at P = 0.05. Differences between Awi and Sidama were not significant. The value chain structure showed that in Awi and Sidama a large number of actors are involved. The major factors explaining differences in commercialization among regions were distance to market centers and presence of alternative products. Education, family size, and access to training were significantly different among Sheka households at the P = 0.05 level. Households with larger family size, higher education attainment, and access to training reportedly engaged in commercial extraction. Thus, development of infrastructure for linking resource and consumer centers and expansion of extension education may enhance commercial engagement of producers and improves accessibility of bamboo resources for commercial production.

Bamboo as a sustainable biomass energy. Fu, J. (*International Network for Bamboo and Rattan (INBAR), China; jfu@inbar.int*), Tesfaye, H. (*International Network for Bamboo and Rattan (INBAR), Ethiopia; thunde@inbar.int*), Michael, K. (*International Network for Bamboo and Rattan (INBAR), Ghana; mkwaku@inbar.int*).

In view of the magnitude of poverty and environmental problems caused by overdependence on traditional biofuel, it is urgent to search for sustainable sources of biofuel in Africa. An assessment of alternatives to the production and marketing of firewood and wood charcoal is also needed. Bamboo and bamboo charcoal heating values are very high, so bamboo and bamboo charcoal are a very good energy alternative to fuel and charcoal from wood. To address household energy need in Africa, the International Network for Bamboo and Rattan (INBAR) has implemented an EU-funded project, "Bamboo as sustainable biomass energy: A suitable alternative for firewood and charcoal production in Africa." In this project INBAR has trained more than 6 000 beneficiaries on how to manage their existing bamboo plantations sustainably and has also introduced 13 important bamboo species and propagated more than 200 000 bamboo seedlings to increase bamboo range and varieties for biomass production. INBAR also promotes bamboo for fuel, and transfers technology on how to produce high quality bamboo charcoal bamboo and charcoal briquettes. To increase heating efficiency INBAR promotes energy-efficient stoves for bamboo fuel and charcoal, which has saved a half million tonnes of firewood. INBAR also encourages micro small enterprise (MSE) development and makes policy recommendations on biomass energy to the governments. This project has greatly increased the use of bamboo as a sustainable source of energy for Africa.

Harnessing the diversity of rattan and its benefits for a green economy and environment. Lapis, A. (*Ecosystems Research and Development Bureau, Philippines; acbl2002@yahoo.com*).

Rattans belong to the family Arecaceae and is one of the largest groups of palms, with more than 600 taxa. It thrives in tropical and sub-tropical countries of Asia. The center of its diversity lies in Southeast Asia. Rattan is considered a major economic resource providing subsistence and livelihood to a long chain of stakeholders, in particular to the dwellers of most Asian countries. Although there is a notion that the rattan industry is in the sunset stage, this paper will present otherwise. In addition to being the source of raw material for the furniture and handicraft industries, rattan has the potential for medical, pharmaceutical, and other natural products in the green economy. This paper will deal with the traditional and emerging rattan-based industries in ASEAN countries. It will provide recommendations on harnessing rattans' diversity in production and utilization for the benefit of people and the green environment.

Effectiveness assessment of forest tenure reform on the resource cultivation and institutional innovation on livelihood development in bamboo areas: case studies in China and India. Li, Z. (*International Network for Bamboo and Rattan (INBAR), China; zyli@inbar.int*), Rao, R. (*International Network for Bamboo and Rattan (INBAR), India; rrao@inbar.int*), Li, L. (*Zhejiang Agro-Forestry University, China; junqi77@hotmail.com*), Wu, J. (*International Network for Bamboo and Rattan (INBAR), China; jqwu@inbar.int*).

World bamboo resources are mainly distributed in the less developed areas. Policy and institutional innovation is closely related to the cultivation of bamboo resources and its processing, resulting in poverty alleviation in bamboo-producing areas. In Anji County, Zhejiang Province of China, the implementation of forest tenure reform that distributes bamboo forest to households has greatly stimulated farmers' enthusiasm for cultivating bamboo resources, which results in a 40–50% increase in the annual average income for bamboo farmers. Moreover, because farmers work through bamboo economic cooperatives, it reduces the risk that farmers will use decentralized, extensive, and unsustainable resource management. In the Konkan region, in the state of Maharashtra in India, inclusive social enterprises have been set up as public-private partnership (PPPs) by the Konkan Bamboo and Cane Development Centre (KONBAC). PPPs connect bamboo farmers with enterprises as shareholders so that farmers have access to venture and other commercial capital. Practices in China and India show that policy and institutional innovation which respects and protects the interests of different stakeholders effectively promotes the cultivation of bamboo resources and its processing, eco-environment protection, and livelihood development in less developed areas.

Field performance of bamboo propagules produced through micropropagation. Ramasamy, Y., Vijaykumar, B. (*Institute of Forest Genetics and Tree Breeding, India; yasodharaja@yahoo.com; vkwbachpai@icfre.org*).

Micropropagation is the most popular approach for mass propagation of bamboos. Field demonstration trials for the micropropagated bamboos are highly essential to verify the growth performance and to motivate farmers to use micropropagation-derived plants for plantations. Evaluation of micropropagated plants of *Bambusa bambos*, *Psudoxytenanthera stocksii*, and *Dendrocalamus strictus* for spacing and fertilizer application was carried out. Initial data up to1 yr did not show any significant differences. After 2 yr, *B. bambos* height growth varied from 4.1 m (control) to 4.9 m (farmyard manure) and mean number of shoots produced varied from 8.9 to 12.0. In *D. strictus* the treatment with NPK (50 g: 50 g: 25 g) promoted greater height (5.3 m), number of shoots (13.6), collar diameter (43.4 mm), number of internodes (32.5), and average internodal length (16.4 cm). In *P.stocksii* spacing and fertilizer trials, the control showed poor growth compared to NPK treatments, where the height of the tallest shoot recorded was 4.4 m in 1.5 yr of growth. Other growth parameters like number of shoots and average internodal length did not show any significant differences. The strategies to be adopted for promoting bamboo cultivation among the farmers were discussed.

Bamboo resources for a greener future: assessment of species characteristics for furniture manufacturing and green building in Ghana. Tekpetey, S., Essien, C., Appiah-Kubi, E., Wilson Owusu, F. (*Forestry Research Institute of Ghana, Ghana; nii9larte y@gmail.com; caessien@ymail.com; appiahkemma@yahoo.com; fwowusu3@yahoo.com*).

The sustainable harvesting and utilization of non-timber forest products (NTFPs), especially bamboo, have been identified as a strategy towards a greener future as these resources have relatively shorter time to maturity and are readily available in many regions of the world. It is believed that the development and sustainable utilization of bamboo resources will help minimize the pressure on dwindling commercial timber species and will also help balance the need for wood-based construction materials around the world with environmental sustainability. In this study, the potential of indigenous and exotic bamboo species in Ghana for green building and furniture manufacturing were explored and the technical properties of these species for various end uses towards a greener future assessed. Results revealed the establishment of about 18 exotic species with varied physical, mechanical, and morphological characteristics that will influence their uses. *Bambusa vulgaris* and *B. bambos* were identified for use in housing and the construction industry in Ghana, if environmentally friendly preservatives are applied to enhance durability. The abundant bamboo species that are underutilized in many countries can be taken advantage of for use towards a greener future.

A competitive analysis of bamboo products in the global market. Wu, J., Li, Z. (*International Network for Bamboo and Rattan (INBAR), China; jqwu@inbar.int; zyli@inbar.int*).

Due to serious forest degradation and eco-environment issues, bamboo as an important non-timber forest resource, is attracting greater attention because of such characteristics as its fast growth and regeneration. As the world's largest exporter of bamboo products in the world, China plays the dominant role in global supply and demand and consequently has a great influence on the structure, features, and trends of global trade of bamboo products. Meanwhile, with the rapid development of the global bamboo industry as well as the green economy becoming hot issues around the world, Chinese bamboo products are faced with increasingly fierce competition and challenges, especially from those countries with an emerging bamboo industry and industrialized countries. This paper describes China's bamboo trade and analyzes the country's strengths and weaknesses in the sector, based on the global bamboo market. A few recommendations are made to improve the market competitiveness of bamboo products and to facilitate the bamboo products trade.

Preparation and properties of microfibrillated cellulose (MFC) from bamboo processing residues. Yu, Y., Wang, H. (*International Center for Bamboo and Rattan, China; yuyan1975830@gmail.com; wanghankun@icbr.ac.cn*).

The utilization rate of bamboo is about 40% and only 20–50% of the residues can be reused in China. By utilizing the processing residues in an appropriate way, bio-based products with high added value could be created to increase the utilization ratio of the bamboo resource and its economic benefits. Microfibrillated cellulose (MFC) is one possible approach to high value-added utilization of bamboo. In this research, MFC was obtained by disintegrating bleached bamboo (*Phyllostachys pubescens*) particles with a procedure of chemical pretreatment and ultrasonic treatment. The influences of ultrasonic treatment times were evaluated by optical properties and dynamic viscosity of MFC dispersions, and mechanical properties of films, which were characterized by using a rheometer, UV-vis spectrophotometer, and commercial mechanical microtester, respectively. Morphology of MFC was also characterized by using a field emission environmental scanning electron microscope.

Posters

Profiling of aroma compounds released from four major bamboo shoots of high economic value in China-Taipei. Chung, M., Cheng, S., Lin, S., Wang, Y., Chang, S. (*National Taiwan University, China-Taipei; jasonchung@ntu.edu.tw; d89625006@ntu.edu.tw; aisiteru555@hotmail.com; m627@ntu.edu.tw; peter@ntu.edu.tw*).

This study examined the aroma compounds of four major bamboo shoots: shoots of *Dendrocalamus latiflorus* and *Phyllostachys makinoi,* and spring shoots and buried winter shoots of *P. pubescens*. Volatile compounds of fresh and boiled bamboo shoots were extracted using solid-phase microextraction. Results obtained from GC-MS analyses revealed that the three main constituents in *P. pubescens* shoots were methoxy-phenyl oxime, *n*-hexanol, and 3*Z*-hexenal, which gave a fresh aroma. Limonene, with the fragrance of citrus fruits, and 2-pentyl furan, which gave off the scent of flowers and fruits, were the major volatile components in *D. latiflorus* shoots. The main constituent of *P. makinoi* shoots at ambient temperature was methyl salicylate, which had a sweet, spicy, and minty fragrance and offered protection against insect attack. After heating at 100 °C for 30 min, the major compounds in spring and winter *P. pubescens* shoots were benzyl salicylate and *n*-heneicosane, respectively; *n*-heneicosane and 4-hydroxybenzaldehyde in *D. latiflorus* shoots showed a pronounced increase in content. Methyl salicylate remained the major compound in *P. makinoi* shoots. The results shed light on the aroma characteristics of four major bamboo shoots and provide useful references for promoting their use in cuisine.

Study on novel dyeing methods for green-color preservation of three bamboo culms and their colorfastness. Lee, C., Chang, S., Wang, Y., Chung, M., Cheng, S. (*National Taiwan University, China-Taipei; chiaju@ntu.edu.tw; peter@ntu.edu.tw; m627@ntu.edu.tw; jasonchung@ntu.edu.tw; d89625006@ntu.edu.tw*).

Ma bamboo (*Dendrocalamus latiflorus* Munro), moso bamboo (*Phyllostachys pubescens* Mazel), and makino bamboo (*P. makinoi* Hayata) are widely used as construction materials in Taiwan. Their acreage in sum exceeds 79% of the total bamboo acreage island-wide. This study explored the optimal approach to endowing bamboo culms with an attractive green color without removing their epidermis, which would in turn increase the economic value of bamboo products. The effects of seven dyestuffs were examined. Experimental results revealed that culms of makino bamboo (a^* values of –23.2 and –9.4), moso bamboo (a^* values of –16.1 and –11.9), and ma bamboo (a^* values of –16.7 and –11.5) all exhibited an excellent greenish appearance after treatment in an 80 °C water bath containing 0.25 basic dyes and disperse dyes for 30 min. Moreover, the use of an ultrasonic bath, instead of a water bath, can further reduce the treatment time required for enhancing dyeing effectiveness and color preservation on bamboo epidermis. Indoor lightfastness test also revealed that more uniform dyeing effectiveness and better colorfastness were achieved by color fixation post-treatment with 1% glacial acetic acid. Taken together, these results demonstrated an effective and efficient treatment process for green-color dyeing of the three bamboo culms studied.

Surveillance of bamboo species in an experimental plantation in southern Brazil. Mognon, F., Sanquetta, C., Dalla Corte, A. (*Federal University of Paraná, Brazil; mognonf@gmail.com; carlos_sanquetta@hotmail.com; anapaulacorte@gmail.com*), Novaes, A. (*State University of Southern Bahia (UESB), Brazil; adalberto.brito@globo.com*), Rodrigues, A.L. (*Federal University of Paraná, Brazil; alourencorodrigues@gmail.com*).

Bamboo cultivation has been widely recommended for a range of applications because of its fast growth. However, research on bamboo cultivation is still scarce and experimental studies should be conducted to evaluate species development. The purpose of this research was to evaluate the surveillance of six bamboo species in an experimental plantation conducted since 2009 in southern Brazil. Randomized block design was applied, with four replications. Treatments were as follows: T1– *Guadua angustifolia* Kunth; T2 – *G. chacoensis* (Rojas) Londoño & Peterson; T3 – *Merostachys skvortzovii* Sendulski; T4 – *Dendrocalamus giganteus* Munro; T5 – *Bambusa oldhamii* Munro; and T6 – *B. vulgaris* Schrad. ex J.C. Wendl. Results indicated that, after the first year of evaluation, treatments were not significantly different in relation to the surveillance. In the third year, though, significant differences were found between T1 (73% of surveillance), and T2 (100%), T5 (100%), and T6 (98%). Treatments T3 (87%) and T4 (77%) were found to be similar to all the other treatments. Based on these, the authors conclude preliminarily that all tested species have shown similar and satisfactory surveillance. However, over time, some species have shown increasing mortality, especially *G. chacoensis* (T2).

Vegetative propagation of two bamboo species in southern Brazil. Novaes, A. (*State University of Southern Bahia (UESB), Brazil; adalberto.brito@globo.com*), Mognon, F., Sanquetta, C., Dalla Corte, A., Rodrigues, A.L. (*Federal University of Paraná, Brazil; mognonf@gmail.com; carlos_sanquetta@hotmail.com; anapaulacorte@gmail.com; alourencorodrigues@gmail.com*).

Bamboos are plants from the Poaceae family and are considered a viable alternative for biomass production in Brazil. However, studies related to propagation and cultivation of bamboo species are still scarce. The purpose of this study was to evaluate vegetative propagation of two bamboo species in different types of containers and substrates. The research was conducted in a greenhouse in Curitiba city, southern Brazil. Experiment was established in a 2 × 2 × 2 factorial design (two substrates, with and without fertilizer; two species, *Bambusa vulgaris* Schrad. Ex J. C. Wendl. and *B. oldhamii* Munro; and two containers with 0.023 and 0.016 m³ of volume). Averages were compared by the Tukey's test at a probability of 95%. Percentage of cuttings with shoots, number of shoots per cutting, and percentage of living shoots were evaluated 120 days after implementation of the experiment. Results have shown that containers with larger volume allowed a greater percentage of cuttings with shoots (49%) and a greater number of shoots (18 shoots) for *B. vulgaris*. In relation to the number of living shoots, *B. oldhamii* presented the greater percentage (42%) in a fertilized substrate when compared with *B. vulgaris* (5%).

Study on soil nutrient limiting factors in *Bambusa rigida* on forest land. Tu, S., Li, Z., Guo, X., Niu, D., Liu, S., Zhao, Z. (*Jiangxi Agricultural University, China; tspjxau@163.com; lizhi876@163.com; gxmjxau@163.com; ndk2157@163.com; liushun89@163.com; 568225571@qq.com*).

Main soil nutrient factors for *Bambus arigida* forest land of Jiangxi Ganxian were identified by selecting sorghum as an indicator plant, in order to evaluate soil nutrient status and its limiting factors. Results showed low soil organic matter content. The soil was severely deficient in P, S, Mg, K, and N but not as deficient in Zn. Ca, B, Cu, Fe, and Mn were abundant. Soil adsorption and fixation capacity was larger for P, K, and S than for Zn and Cu, and almost zero for B and Mn. Results from the pot experiment showed that the order of soil nutrient limiting factors based on degree of nutrient deficiency from high to low was P, S, Mg, K, and N. Yields would be reduced by 53%, 38%, 38%, 35%, and 32% without P, S, Mg., K, and N, respectively. The soil is poor, and fertilizer, such as organic fertilizer, has to be applied to improve fertility. Fertilizer must be high in N, P, K but also should contain S and Mg. Results from the pot experiment are consistent with determination of soil nutrients in the laboratory.

Harvesting and coppice management of *Beta vulgaris* (bamboo) in protected and unprotected areas. Wiafe, E. (*Presbyterian University College, Ghana; edward.wiafe@presbyuniversity.edu.gh*), Amoah, M. (*University of Education, Winneba, Kumasi Campus, Ghana; martamoah@yahoo.com*).

The purpose of this study was to compare utilization and its impact on coppice ability of harvested *Beta vulgaris* in Owabi Wildlife Sanctury (Ghana) and the adjacent farmlands. An adaptive sampling method was used on 25 and 35 plots measuring 50 m × 50 m established in the sanctuary and the farmlands, respectively. The population and regenerative capacity of bamboo culms in each site were determined. Site (harvested vs. non-harvested) did not have a significant effect on the regeneration of juvenile culms. The effects of seasonal changes and the interaction between the sites and seasonal changes were significant, with

the bamboo on the farmlands responding more positively to regeneration of juvenile culms (11.7%) than those in the sanctuary (3.6%). The average ratio of juvenile culm production to the number of mature culms per clump before rainy season was 3:10 compared with 8:10 at the end of the rainy season, suggesting that the presence of mature culms could potentially stimulate the regeneration of juvenile culms. Despite the ability of mature culms to stimulate culm regeneration, the contribution of non-harvested site to regeneration was far less compared to that of harvested site, suggesting that optimum regeneration of culms could be achieved if older culms are harvested.

Comparative anatomy of developmental moso bamboo culms. Yang, S., Liu, X., Tian, G., Jiang, Z, Fei, B., Li, Z. (*International Center for Bamboo and Rattan, China; shangke620@hotmail.com; liuxe@icbr.ac.cn; tiangenlin@icbr.ac.cn; liuxe@icnr.ac.cn; feibenhua@icbr.ac.cn; lizq@icbr.ac.cn*).

The purpose of this research is to discuss growth regulation as well as the relationship between structure formation and function in moso bamboo (*Phyllostachys pubescens*). Cell wall characteristics of moso bamboo in different developmental periods (6–18, 30–54, 78–102, and 126 months old) were researched. Vascular bundle frequency and size, tissue proportion, cell wall thickness, cell lumen diameter, and thickness/diameter ratio at different longitudinal and radial locations at the different ages were measured using image-processing technology. Vascular bundle frequency gradually decreases with age, ranging from 1 to 3/mm^2; the size of the vascular bundles decreases from the periphery towards the inner section but increases from the base of culms towards the apex. Vascular bundles vary with age, from 504 to 703 μm deep and from 417 to554 μm wide, with a radial/tangential ratio of 1.09–1.29. Fibre percentage fluctuates with age from 20 to 27%, and decreases from the inner zone to the outer but increases slightly from the base to higher culm. Double cell-wall thickness and wall-lumen ratio of fibre and parenchyma increase, but lumen diameter decreases with bamboo age. Cell wall double-thickness, lumen diameter, and thickness-lumen ratio of fibre ranges are 4–14 μm, 1–10 μm and 0.5–11, respectively.

F-10 Precision land-use management – state and perspectives

Organizers: Hans R. Heinimann (ETH Zurich, Switzerland) & Woodam Chung (Oregon State University, USA)

Validation of timber volume maps derived from remote sensing data. Breschan, J., Hill, A. (*ETH Zurich, Switzerland; jochen.breschan@usys.ethz.ch; andreas.hill@usys.ethz.ch*).

Information about the spatial distribution of timber volume (TimVol, measured in m^3/ha) is a key factor for purposeful harvest planning. Whereas field surveys have been a standard approach for volume estimation, remote sensing data (particularly LiDAR) are providing an effective alternative. Remote sensing-based approaches offer the opportunity to create TimVol maps that represent the complex pattern of spatial volume variability. However, a validation approach is required to ensure that the computed pattern corresponds to reality. Here an approach is presented that links parameters derived from a canopy height model with field data of plot sampling to estimate and validate a TimVol map. One part of the plot data is used to calibrate the TimVol estimator; the other part is used for validation. TimVol estimates based on field data at locations of the latter plots are then compared with the corresponding map values. The authors investigate whether the map accurately estimates TimVol and correctly ranks plots by means of TimVol. The results will support the assessment of the map's usability and give hints for further improvement of the TimVol-estimator. The authors set up and test the approach for an Alpine forest region in Switzerland.

Optimizing the selection of individual tree in thinning treatments to reduce crown fire potential. Contreras Salgado, M. (*University of Kentucky, USA; marco.contreras@uky.edu*), Chung, W. (*University of Montana, USA; woodam.chung@umontana.edu*).

High-intensity wildfires continue to burn large areas of overstocked forested in the western United States. Thinning is being widely used to restore different types of forest stands using prescriptions derived from average stand attributes and applied to landscapes containing numerous stands with varying vegetation conditions. These stand-level prescriptions thus have limitations when applied for reducing the risk of high-intensity wildfires because indicators of crown fire potential (e.g., canopy base height and canopy bulk density) ignore variability of fuels within stands, location of individual cut- and leave-trees after treatments, and the temporal effects of these prescriptions for reducing crown fire potential over time. To address the limitations of current stand-level thinning prescriptions, a computerized tool to optimize the selection of individual trees and produce site-specific tree-level thinning prescriptions was designed. Based on stem maps and tree attributes derived from LiDAR data, the approach predicts individual tree growth over time, quantifies tree-level fuel connectivity, and estimates skidding costs for individual trees. The approach then selects the combination of cut-trees that most efficiently reduces crown fire potential over time while ensuring cost efficiency of the thinning treatment.

Social and economic consequences of eucalyptus plantation management. Engler, B., Vocilka, S., Hoffmann, S., Jaeger, D., Becker, G. (*Albert-Ludwigs-University Freiburg, Germany; benjamin.engler@fobawi.uni-freiburg.de; sebastian.vocilka@web.de; stephan.hoffmann@fobawi.uni-freiburg.de; dirk.jaeger@fobawi.uni-freiburg.de; gero.becker@fobawi.uni-freiburg.de*).

According to the 12th national 5-year-plan and the Forest Industrial Base Development Program (FIBDP), China intends to increase its wood production from plantations to supply the national wood-based industry. This study analyzes economic and social effects of different plantation management regimes, starting with site preparation and planting, continuing through maintenance, and culminating in harvesting biomass. To accomplish these objectives, time studies were conducted in southern Chinese eucalyptus plantations between 2008 and 2011, to gain an understanding of current work processes in Chinese plantation management and harvesting systems. Based on these data and on local yield tables, an economic assessment and optimization of

plantation management were done by using methods of operations research. As current work processes mainly consist of manual activities, results focus on effects on human labor within the plantation management system, taking into account work time and income opportunities for local people as total biomass yields and log sizes. Alternative harvesting systems are discussed in terms of costs and effects on human labor, with a focus on possible changes in work organization and education.

Development and validation of a physically based forest operations model. Grayson, L., Keefe, R. (*University of Idaho, United States; gray7728@vandals.uidaho.edu; robk@uidaho.edu*).

Forest operations models are rapidly expanding in scope and analytical power, yet none are able to fully integrate forest growth and yield models or hydrologic models into their predictions. In this research, a new, physically based geospatial forest operations and mobility model was developed, incorporating these additional variables for a more accurate forecast. The model simulates below-canopy terramechanic relationships among forest microclimate, equipment, and soil physical properties, and their coupled effects on the intra-annual timing and suitability of different operational systems used in forestry. Operational data collected from the northwest United States and predictions from a commonly used forest operations model developed under narrower conditions were used to validate the model.

Design of efficient harvesting units using remote sensing information and field data. Hill, A., Breschan, J. (*ETH Zurich, Switzerland; andreas.hill@usys.ethz.ch; jochen.breschan@env.ethz.ch*).

Efficient harvest layout requires accurate information about the location and volume of available timber resources within the managed forest area. Current forest inventories often provide precise estimations of the overall timber volume for predefined forest units. However, they do not provide precise information about the location of forest areas which are to be harvested with priority due to high standing timber volumes. Identifying such areas of interest and aggregating them into economically optimized harvesting units could be a valuable decision support tool for harvest management. Aims of this study are (1) to use remote sensing data for developing a clustering approach to automatically delineate possible harvest units with similar timber volume properties and (2) to derive precise timber volume estimations for each harvest unit by combining remote sensing data with field information. The approach aims at providing precise spatial as well as quantitative information about available timber resources, thereby supporting the decision process of locating harvesting operations. The concept will be demonstrated for a study site in Switzerland using a remote sensing-derived canopy height model and field information from the National Forest Inventory.

Evaluating the best locations in coniferous plantations for natural regeneration of broadleaved forest. Morimoto, R., Yamada, Y. (*Nagoya University, Japan; morimoto.ryouhei@a.mbox.nagoya-u.ac.jp; yozo@agr.nagoya-u.ac.jp*).

In Japan, planting trees was once widespread due to the demand for wood. Coniferous trees historically have been planted because they grow faster and straighter than broadleaved trees. As a result, natural broadleaved forests have decreased. Trees are very slow growing, and the demand for wood can change between the time when trees are planted and when they are harvested. In order to adapt to changing social conditions, it is important to grow a variety of tree species. Therefore, this study examined how to convert coniferous plantations into broadleaved forests. In Japan, hardwood is used mainly for flooring, bed logs, and pulpwood and the demand for hardwood might increase. Given the cost of planting trees, and to avoid introgression, natural regeneration is preferable where possible. To change forest species composition efficiently and at low cost, it is necessary to identify areas suitable for the natural regeneration of broadleaved trees and to plan forest management practices in advance. Therefore, this study determined the best locations for natural regeneration of broadleaved trees in coniferous plantations and presents an example of identifying the right area.

Key initiatives to enable sustainable and profitable hardwood silviculture. Pelletier, G., Labelle, E., Girouard, M. (*Northern Hardwoods Research Institute, Canada; gaetan.pelletier@umoncton.ca; eric.r.labelle@umoncton.ca; monique.girouard@umoncton.ca*).

Due in large part to the variability in hardwood stands (for example in species distribution, basal area, and development stages) and silviculture that is not defined within a long-term financial and ecological framework, the planning, management, and harvesting of hardwood stands often lead to situations where long-term values and financial returns are compromised, or to operations that are feasible in the short term but not sustainable. For the past 2 years, the Northern Hardwoods Research Institute, located in New Brunswick, Canada, has been developing several initiatives aimed at (1) increasing our understanding of the hardwood resource and its impact on product recovery, (2) adapting silviculture practices to further promote the regeneration and growth of desirable species, and (3) improving forest operations productivity. Imbedded in the principles of value-chain optimization, a novel approach is being implemented by leveraging precision forestry tools and the use of leading-edge technology such as unmanned aerial vehicles and terrestrial LiDAR. We strive to develop financially feasible resource characterization methods and stand management strategies that are operationally feasible and flexible. Significant advancements and research results pertaining to all three research areas will be presented.

An optimization model of Masson pine multifunctional management in south China. Zhang, D., Li, Z. (*Chinese Academy of Forestry, China; zdc@caf.ac.cn; zyli1017@gmail.com*).

A benefits optimization model based on modeled management costs, product prices, and stand growth was developed to determine the optimal forest harvesting intensity for given site conditions evaluated by stand productivity and ecological importance, A case study on Masson pine was conducted in Guangxi Province in China. Ninety stands were measured and a survey of wood costs and prices was conducted. Results indicate that the optimal period of initial harvesting is 19–36 yr, depending on harvesting intensity. The greater the intensity of harvesting, the longer the initial period of harvesting. Harvesting intervals were 15–36 yr, depending on harvesting intensity.

F-11 Forest operations engineering and management – the way ahead

Organizers: Hans R. Heinimann (ETH Zurich, Switzerland) & Woodam Chung (Oregon State University, USA)

Applying the optimal bucking method to maximize profits on Nasunogahara area, Tochigi Prefecture, Japan. Aruga, K. (*Utsunomiya University, Japan; aruga@cc.utsunomiya-u.ac.jp*).

In this study, forestry operations around Nasunogahara area were investigated and the relationships between log sizes and operational costs were analyzed. Then, the equations to estimate operational costs according to log sizes and the optimal bucking methods to maximize profits were developed. The optimal bucking methods were applied to two operational sites of Nasu-machi Forestry Cooperative and feasibility of the extraction of small-diameter logs was discussed based on extraction rates. Results indicated that extraction rates with the optimal bucking method were similar to the actual results compared with other methods, such as the optimal bucking method without consideration of log sizes and the existing optimal bucking method with maximum revenues. Finally, the optimal bucking methods were applied to Nasu Town, Nasunogahara area, using GIS, and effects of a new subsidy system and unit prices for small logs on the feasibility of the extraction of small-diameter logs were discussed. An increase in extracted volumes of small-sized logs was attributed to the new subsidy system and to unit prices with the Feed-In Tariff (FIT) scheme.

Landscape-scale planning for biodiversity in Tasmanian production forests. Koch, A., Chuter, A., Munks, S. (*Forest Practices Authority, Australia; Amy.Koch@fpa.tas.gov.au; Anne.Chuter@fpa.tas.gov.au; Sarah.Munks@fpa.tas.gov.au*).

Landscape planning for forest biodiversity is important to ensure forest management systems cater to the diverse requirements of species, including those with large home ranges, migratory species, and territorial species. Planning for some values at the landscape scale also has the potential to streamline the planning processes. The authors have reviewed approaches to landscape planning for biodiversity and have developed a practical approach that facilitates the application of landscape management ecological principles in on-the-ground practice. The main output of the project is the "Biodiversity landscape planning guideline" (BLPG). This guideline has six major goals relating to biodiversity. These goals are then broken down into more specific and quantified management targets which, if achieved, are expected to achieve the goals. The BLPG also identifies the actions required to achieve these targets and the associated planning tools that can be used to support decision-making. The degree to which the management targets are currently being achieved in Tasmania was assessed. This process identified a number of key areas that require further work, including management of mature forest, catchments, and remnant forest. A theoretical exercise was then undertaken to explore how the guideline could be used by planners to strategically plan for biodiversity across production forest areas.

A new numerical tool to optimize the set-up of a standing skyline and improve cable yarding planning. Dupire, S., Berger, F., Bourrier, F. (*National Research Institute of Science and Technology for Environment and Agriculture, France; sylvain.dupire@irstea.fr; frederic.berger@irstea.fr; franck.bourrier@irstea.fr*).

The use of cable yarding systems constitutes an interesting solution for steep-slope harvesting in mountain forests. However, it requires many specific skills for both forest managers and operators. The purpose of this study is to provide a numerical tool to help managers in planning cable yarding projects and to facilitate the set-up of a cable line by operators. A model was developed and coded in Python language which allows fast calculation of the load path and tensile forces along the cable for different 3D configurations. This model uses theoretical equations initially developed for the mechanical design of cable structures. Its applicability in forestry was validated by field experiments. An additional module using a high-resolution digital terrain model optimizes the cable layout and automatically places required intermediate supports. If geographic information about timber volume is available, it also allows combining technical possibility with harvesting potential. From the managerial point of view, this tool presents significant advantages for forest operations planning. Moreover, operators' productivity can be improved with the technical outputs of this model, which help to shorten the time spent in setting up a cable line and thereby reduce the total cost of a cable project.

Harvesting of heart stumps from poplar and maritime pine forest in south west France. Emeyriat, R., Cloarec, S. (*Forêt Logistique Conseil, France; richard.emeyriat@foretlogistique.eu; sebastien.cloarec@foretlogistique.eu*), Husson, H., Liarcou, J. (*Centre Régional de la Propriété Forestière-Aquitaine, France; h.husson@cnpf.fr; jr.liarcou@crpfaquitaine.fr*), Moreau J. (*École Supérieure du Bois, France; jerome.moreau@ecoledubois.fr*).

Recovery of tree root biomass can be an attractive endeavor. The stump-root system represents a substantial portion of the tree mass. An extracting machine, equipped with a 70-cm-diameter trepan, has been evaluated to harvest the heart of stumps. The impact of this method on soils is lower than that of techniques which extracts all of the roots. Hash content of woodchips is also lower than whole-root extraction techniques. The aim of the study is to investigate poplar and maritime pine root recovery operations in plantations with time studies, to determine the productivity and delivery costs of the operations and to characterize the products for energy use.

Environmental assessment of the technological innovation process on forestry harvesting. Machado, R., Machado, C. (*Federal University of Viçosa, Brazil; raianemachado@ufv.br; machado@ufv.br*), Freitas, L. (*State University of Southwest Bahia, Brazil; luiscarlos_ufv@yahoo.com.br*), Portugal, C. (*Oregon State University, USA; carlamacport@hotmail.com*).

This study aimed to evaluate the environmental impact of the technological innovation process in forestry harvesting. The innovation process was analyzed for the change from the traditional subsystem (chainsaw + forwarder) to the innovative (feller buncher + clambunk skidder). The authors used the consolidated method for environmental impact assessment of technological innovation on agro-livestock, which assesses the environmental performance of a certain methodology or technology in relation to

that previously established. The method was adapted for the impacts evaluation on forestry harvesting. The impacts were analyzed for physical media indicators (air, soil, water), biotic indicators (flora and fauna), and anthropic indicators. Matrices were prepared for each indicator, which were weighted in relation to the occurrence scale and importance scale factor. Technicians in the forest harvesting field filled the matrices using change coefficients previously defined. The impact coefficient resulted from the change coefficient product by weighting factors, being evaluated on a scale of –15 to +15. The overall impact index was determined for the same scale pattern. According to the average of three evaluations, two indicators showed a positive impact coefficient (health and management), six had a negative coefficient (air, soil, flora, fauna, landscape, and employment), and one remained unchanged (water). The overall impact index was positive (1.29), indicating that in the global context adoption of the innovative subsystem had a favorable effect on environmental conditions.

Quantifying potential benefits of implementing computer-generated skid-trail networks. Parrott, D., Contreras Salgado, M., Stringer, J. (*University of Kentucky, USA; david.parrott2@gmail.com; marco.contreras@uky.edu; jeffrey.stringer@uky.edu*).

Well-designed skid-trail networks connecting log-piles to extraction points are necessary to reduce skidding costs and soil disturbances during ground-based timber harvesting. Although computerized models have been develop to optimize skid-trail network designs, there has been no formal evaluation to compare optimized skid-trail networks and operator-designed skid-trail networks. In this study, potential environmental and economic benefits of an optimized network design were quantified by performing a retroactive comparison with a skid-trail network laid out by a skidder operator for a 123-ha harvest area in 2008. The operator-designed skid-trail was obtained by using a combination of GPS data collected with machine-mounted units during harvest, aerial photography, and high-resolution LiDAR-derived digital elevation models. Preharvest conditions were simulated by recontouring the terrain along existing skid-trails to mimic natural slopes and by recreating harvestable volume distribution across the harvest area using harvest records and pre-harvest inventories. The optimized skid-trail network was designed using the simulated pre-harvest conditions and compared to the skid-trail network created by the skidder operator during harvest 5 years ago. Results of this comparison illustrate the potential economic and environmental benefits of implementing a computer-generated skid-trail network and provide a real-world justification for its use.

Forest work studies: who, why, how. Spinelli, R. (*Trees and Timber Institute, Italy; spinelli@ivalsa.cnr.it*), Kosir, B. (*University of Ljubljana, Slovenia; bokosir@gmail.com*).

The authors present the results of a worldwide survey concerning the actors, goals, and methods of forest work studies. The interviews asked questions about the purpose of work studies conducted by the interviewee, the funding sources, and the methods. Interview forms were returned by about 150 established scientists active in the field of forest engineering. The research allowed answering a number of technical and strategic questions, including the treatment of delays, the handling of operator effect, and the workday structure adopted as a reference. Interviewed scientists also offered their opinion about the future of work studies in forestry. The results of this study offer another indicator of the vitality and future perspectives of a classic field of activity in forest engineering.

The future roles of ergonomic research in world forests and forestry. Yamada, Y. (*Nagoya University, Japan; yozo@agr.nagoya-u.ac.jp*), Sowa, J. (*University of Agriculture in Cracow, Poland; rlsowa@cyf-kr.edu.pl*), Yovi, E. (*Bogor Agricultural University, Indonesia; eyyovi@ipb.ac.id*), Garland, J. (*Garland & Associates, USA; johngarland49@gmail.com*), Staal Wästerlund, D. (*Swedish University of Agricultural Sciences, Sweden; dianne.wasterlund@slu.se*), Parker, R.

During the international ergonomic workshop of IUFRO RG3.03 in Nagoya in 2012, the authors recognized that there are still many ergonomic problems that should be resolved in the world: improving work safety, reducing working burden, promoting forest mechanization, and creating better working conditions. Accordingly, the authors agreed that two taskforces should launch activities in the future to (1) raise consciousness with regard to safety, productivity, and the environment; and (2) establish labor safety and health management systems in developing countries. Ergonomic challenges are related not only to improving safety, productivity, and environmental consciousness but also to wider subjects associated with human involvement in forests and forestry around the world: physical and physiological working loads, operator stress, machine design, plans for and construction of forestry roads, transmission of techniques and knowledge, gender problems, environmental and technical ethics, education of engineers, training of workers, social responsibility, socio-life cycle assessment, and others. In this presentation the authors will review ergonomic research activities and articles from 2010 to 2014 and discuss their research roles and strategies for the next term, starting in 2014, to promote and apply ergonomic research results to actual world forests and forestry sites in line with the two taskforces and to expand their research activities in collaboration with other research groups in IUFRO.

Posters

The forest roads information database system. Beguš, J., Trobiš, T. (*Slovenia Forest Service, Slovenia; jurij.begus@zgs.gov.si; tomaz.trobis@zgs.gov.si.*

Slovenia has an extensive network of forest roads, which is primarily designed for forest management. For easier management of forest roads the authors have designed an information system, which represents a smaller but important part of the integrated forestry information system. It consists of a module of records regarding forest roads and skidding trails and a module for monitoring the maintenance of forest roads. Both modules contain attribute and graphic data, which are uniformly managed for the entire country. The design of the system is based on relational database theory; the system is designed to be open, dynamic, and modular. The basic unit of the system is a forest road in its entire length. The system has now been designed as a Web application and is available for all interested users. The NEWFOR project is taking the system to the next level: LiDAR technology is being applied to verify information.

Analysis of factors affecting forest road network planning: a Delphi study. Hayati, E., Abdi, E., Majnounian, B. (*University of Tehran, Iran; hayati_fe@ut.ac.ir; abdie@ut.ac.ir; bmajnoni@ut.ac.ir*).

Today forest road operations are very important and complicated in a multipurpose forest that supports many functions such as wood production, ecotourism, environmental services, and recreation. Forest road managers, therefore, have to develop a road network that meets objectives from both the forestry and the environmental viewpoints of a forest ecosystem. This paper addresses a survey of technical and environmental criteria affecting forest road construction to define the most important criteria in road network analysis in an Iranian Caspian Forest. The survey of criteria was conducted by using Delphi, a multi-criteria analysis technique, in a three-round procedure. Delphi questionnaires were developed and sent to panel members, who were asked to define the effective criteria (round 1), rate the relative importance of the criteria (round 2), and finally reach a consensus on the most important criteria among the panelists (round 3). Results indicate that the Delphi procedure will be very helpful to forest road managers by providing a broad assessment in road network planning. Results also suggest that the method may be useful in forest road maintenance, transportation of wood, and other aspects of forest management that involve many factors and alternatives.

Cultivation of forest regeneration materials under artificial radiant sources—effects of light intensity on energy consumption and seedling development. Hernandez Velasco, M., Mattsson, A. (*Dalarna University, Sweden; mhv@du.se; amn@du.se*).

In times of major environmental challenges and increasing demand for forest products, planted forests have acknowledged advantages compared to other land uses. Despite not being able to completely take the place of natural forests, planted ones have, if properly managed, great potential to contribute in addressing these problems. Besides the ecological benefits such as carbon sequestration, planted forests can help meet the demand for wood products without further depletion of the natural forest. Forest restoration, rehabilitation, and reforestation are limited by the capacity for producing forest regeneration materials. Often, as production is intensified at forest nurseries, the practices begin to have an adverse impact on the environment and stop being truly sustainable. One of the main issues in nurseries is the energy consumption for grow lights during periods of short daylight. By using high-efficiency LED grow lamps and adjusting the light intensity, this study aimed to reduce the energy consumption from lighting per seedling without compromising seedling development. The precultivation of *Picea abies* and *Pinus sylvestris* seedlings was done during 5 weeks under controlled conditions at 20 °C and a relative humidity of 60%. The photoperiod was 16 hours at an intensity ranging from 50 to 350 μmol/m^2/s in intervals of 50 μmol/m^2/s intervals.

Biomechanical evaluation in eucalyptus silviculture operations in Brazil. Marzano, F., Souza, A., Minette, L. Silva, F., de Moraes, A. (*Federal University of Viçosa, Brazil; felipe.marzano@ufv.br; amaury@ufv.br; minette@ufv.br; fabricioardufv@gmail.com; angelo.moraes@ufv.br*).

This paper evaluates biomechanical and static strength capabilities of forest workers in relation to the physical demands of semi-mechanized hole-digging and planting of eucalyptus seedlings with hydrogel operations. Biomechanical evaluation was performed using the 3D Static Strength Prediction Program developed by the University of Michigan (USA). Data were collected in a eucalyptus forest area located in mountainous terrain of a pulp production company in Brazil. The activities were videotaped and analyzed to determine the critical postures. The forces involved were measured using a dynamometer and the angles of the various body segments were taken after "freezing" the images. In the hole-digging operation the critical posture was drilling. In this case the human body joints requiring attention were the hip and the knee, with only 75% and 88% of the workers capable of carrying out the operation, respectively. In the seedling-planting operation the critical posture was filling the container with hydrogel. In this activity the percentages of workers capable were equal to 1% for the wrist, 31% for the shoulder, and 79% for the hip. In both activities the values of the compression force on L4-L5 spine disk were below the recommended limit of 3 400 N.

Comparison of thinning productivities for conventional systems and a new system with a small wheel-mounted harvester and forwarder. Nakazawa, M., Yoshida, C., Sasaki, T., Uemura, T., Yamaguchi, H. (*Forestry and Forest Products Research Institute, Japan; naka1978@ffpri.affrc.go.jp; yoshidac@ffpri.affrc.go.jp; tatsuya@ffpri.affrc.go.jp; takumi@ffpri.affrc.go.jp; hiroy@ffpri.affrc.go.jp*).

Japan has recently imported forest harvesting equipment from Europe under a national subsidized project in order to regenerate Japanese forests and improve forestry operations. One of the harvesting systems was a cut-to-length (CTL) system using harvesters and forwarders, which was expected to increase operator safety and productivity. This study aimed to establish a CTL system in hilly terrain in Japan. To that end, line thinning operations were analyzed using a newly introduced small wheel-mounted harvester and forwarder. For comparison, two conventional systems in Japan were also analyzed. One was a CTL system using a harvester-mounted hydraulic excavator and a forwarder with rubber crawler. The other was a whole-tree yarding system using grapple loaders with one or two winch-drum-mounted hydraulic excavators and a processor-mounted hydraulic excavator. The productivities of these systems were compared, and the productivity of labor of the CTL system using the wheel-mounted machines was found to be higher than for the conventional systems.

Extraction of collapse risk factors for spur road using high-resolution digital terrain models. Saito, M. (*Shinshu University, Japan; m_saito@shinshu-u.ac.jp*).

Roads have to be placed at a high density in road networks for mechanized forestry. Above all, establishment of a spur road is important. Construction methods for spur roads are different from those for forest roads. Surface processing and creation of retaining walls are generally not included so as to reduce costs. Therefore, the risk of collapse due to rainfall increases. Factors that cause the collapse of forest roads have been identified in previous studies, but factors causing collapse of spur roads are not known. It would be difficult, however, to do a field survey across a large area to determine these factors. In this study, the topographical conditions and geometric structure (e.g., slope height, slope angle, width) of the spur road were determined by using high-resolution digital terrain models (DTMs) to analyze a wide area. The results of the study were used to identify spur road routes that are at higher risk of collapse than others.

Generalizing over graph representations of road segments: a zigzag alignment model and a smooth alignment model. Shirasawa, H. (*Kyoto University, Japan; shira@kais.kyoto-u.ac.jp*).

Representing potential road segments by means of a graph structure is an underlying process in formulating road network planning as a combinatorial optimization problem. Traditionally in forest road network planning, graphs have been generated by a zigzag alignment model (ZAM) with eight neighbors. In recent years, however, a smooth alignment model (SAM) with more neighbors has been developed to draw realistic alignment, subject to the constraint of minimum radius for a horizontal curve. This study presents key components characterizing both models and gives a detailed description of a generalized procedure for drawing alignment in both models. Second, a series of computational experiments was conducted for evaluating alignment models in terms of accessibility to targets and graph size. Digital terrain models (DTMs) used in the experiments are synthesized by the fractional Brownian motion (FBM) technique. Results of the experiments demonstrate that when planning road networks in steep terrain, it is imperative to apply elaborate alignment models because of high accessibility even though the size of the generated graph is huge.

Developing dynamic maps of forest roads with routes to GPS navigation receivers. Souza, A., Silva, F., Minette, L., Marzano, F., de Moraes, A. (*Federal University of Viçosa, Brazil; amaury@ufv.br; fabricioardufv@gmail.com; minette@ufv.br; felipe.marzano@ufv.br; angelo.moraes@ufv.br*).

The forest road network is a key component for all forest operations from silviculture to timber harvesting, mainly in steep terrains and large forest areas. However, choosing forest roads in plantation forests for travel to a specific place usually is a challenge because of the large extent of forest areas and roads. Although use of GPS receivers to aid navigation in cities and highways is quite common, it is rare for navigation in large areas of planted forests in Brazil. The objective of this study was to develop dynamic maps of forest roads with routes for GPS navigation receivers. The research was carried out in forest areas of a pulp production company in Brazil. The roads were mapped using appropriate software, and then these maps were converted and transferred to GPS navigation system. The GPS devices with the new maps installed were tested on a previously selected forest road network. These GPS devices allowed faster and more efficient vehicle operations to transport workers, inputs, and wood harvested; allowed the user to get detailed information on forest plantations; improved the progress of data collection in forest inventory; and provided fast combat of forest fire outbreaks.

A new guide for work studies in forestry. Spinelli, R., Magagnotti, N. (*Trees and Timber Institute; spinelli@ivalsa.cnr.it; magagnotti@ivalsa.cnr.it*).

A team of international specialists developed a new guide for conducting forest work studies. The guide is a quick how-to manual designed for the field researcher, and it may contribute to the international harmonization of methods for studying work. This endeavor was supported by the EU through Cooperation in Science and Technology (COST) Action FP0902. However, the author team was not limited to European scientists, and spanned worldwide. The draft was reviewed by three international experts, external to the team and to the Action. Two provisional versions were administered to a test group of students, who chose the current version. Feedback was sought after publishing, through an online survey. Ninety-three researchers responded to the survey. Most respondents indicated that the guide was state-of-the-art and that they were able to do a better job after reading the guide. The guide is available for free download from the forest energy Website (www.forestenergy.org).

Evaluation of complementary working time lengths in timber harvesting and skidding operations. Szewczyk, G., Sowa, J. (*University of Agriculture in Cracow, Poland; rlszewcz@cyf-kr.edu.pl; rlsowa@cyf-kr.edu.pl*), Lubera, A. (*State Forests, Poland, Poland; adamlubera@wp.pl*).

Commonly adopted key tools of technical and technological work site optimization include standardization of time necessary to perform tasks. Standardization is based on measurements of effective and supplementary performance time lengths directly related to work object processing and therefore reflecting the real obstacles to work in a given stand. Supplementary working time lengths, including the work site service time and the preparation and completion time, are determined as a percentage of performance time. Determination of difficulty zones defined by timber harvesting conditions in particular stands is a standard applied in world forestry. By using difficulty zones defined in this way, the whole scope of activity of workers operating in different regions cannot be determined. The supplementary time share in a work shift should reflect timber harvesting and skidding conditions, which differ depending on the area and are mainly related to the degree of accessibility of forest management regions. The aim of the present study was to develop a system of evaluating categories of supplementary working time, observed at work sites connected with timber harvesting and skidding. Normative indices of supplementary time shares were calculated as the sum of partial coefficients: forest complex dispersion degree, stand structure, area diversification, area accessibility, and area management.

Ergonomic and productive effects of replacement steel wire ropes with synthetic ropes for a mobile tower yarder. Watanabe, R., Kondo, M. (*Nagoya University, Japan; rsf49233@gmail.com; mnr.kondo@gmail.com*).

The use of synthetic ropes for cable logging systems has much potential for the reduction of the operator's workload and for the effectiveness of the logging operation. Synthetic ropes made from ultra high molecular weight polyethylene are much lighter and more flexible than steel wire ropes in spite of having similar strength. Cable logging systems place great demands on cable settings. Especially in Japan, it is important for cable logging systems to enhance the mobility of cable settings because Japanese forestry generally has complicated terrain and logging distances tend to become short. Therefore, replacement of steel ropes with synthetic ropes in a mobile tower yarder is expected to reduce the operator's physiological workload for rigging and improve productivity in the cable logging system. This research shows the differences in operator's workload and productivity between synthetic ropes and steel wire ropes by measuring operator's heart rate and time studies in the cable logging operations. The availability of synthetic winch lines and the effects of using them for a mobile tower yarder in Japan are evaluated.

Comparative study of the ergonomic spectrum at the levels of logging entities and prefectures. Yamada, Y., Nakajima, C. (*Nagoya University, Japan; yozo@agr.nagoya-u.ac.jp; nakajima.chika@d.mbox.nagoya-u.ac.jp*).

Forestry conditions and the ergonomic state of forestry work differ among entities and regions. These factors directly or indirectly influence work safety and productivity. However, these complex relationships cannot be analyzed comprehensively by using statistical measures. On the ergonomic spectrum, each factor can be understood as a continuum from a negative to a positive ergonomic status. All of the factors can be placed in a line, and the present state of each logging entity can be indicated by the profile formed by the assembled factors. The location of an entity along the two-dimensional coordinates of the national standard can be realized by using an ergonomic spectrum. This study classified hundreds of logging entities in Japan using cluster analysis and two factors: the work accident rate and labor productivity. The chosen elements of this ergonomic spectrum had three standard deviations of a standardized variable based on more than 80 factors. The authors discuss the characteristics of each group on this ergonomic spectrum and identify ways to realize safer, more efficient logging operations in each group. Similarly, they analyzed the ergonomic spectrum at the prefectural level and discuss the differences in regional conditions, elements chosen, and scale.

Operational efficiency of the containerized seedlings planting machine. Yamada, T., Ochiai, Y. (*Forestry and Forest Products Research Institute, Japan; kenchan@ffpri.affrc.go.jp; yukihito@affrc.go.jp*).

The authors developed a machine for planting containerized seedlings that is attached to an excavator. The planting machine is equipped with a hydraulic planting tube and dual hydraulic augers. It plants containerized seedlings after cultivation to prevent growth of vegetation which will suppress planted seedlings. It is expected to reduce the amount of weeding required after planting. The operational efficiency of this planting machine was investigated on three test sites which have different slope angles. Planting operation by the planting machine had been recorded by video cameras and was analyzed. Results show that operational efficiency decreases as slope angle increases, mainly because of the increase of boom operation time. It is necessary to make improvements to the planting machine to accelerate boom operation on steeper slopes.

F-12 Intensive or ecosystem-based forest management – impact on yield, wood quality and economic return?

Organizers: Pekka Saranpää (Finnish Forest Research Institute, Finland), Alexis Achim (Laval University, Canada), Robert Deal (U.S. Forest Service) & John Moore (Scion, New Zealand)

Lumber value from selection cuttings in uneven-aged northern hardwood forests. Achim, A. (*Université Laval, Canada; alexis.achim@sbf.ulaval.ca*), Havreljuk, F. (*Ministère des Ressources Naturelles du Québec, Canada; Filip.Havreljuk@mrn.gouv.qc.ca*), Auty, D., Pothier, D. (*Université Laval, Canada; auty.david.1@ulaval.ca; david.pothier@sbf.ulaval.ca*).

Northern hardwood forest dynamics are influenced mainly by tree- or gap-level disturbances, which tend to produce uneven-aged stands. Under ecosystem-based management principles, forest managers aim to emulate natural disturbance regimes through the application of selection cuttings. In order to avoid high-grading, a new vigour-based tree marking system has recently been introduced. However, because standing tree quality is not assessed, this system leads to uncertainty in the wood supply and hinders the adoption of silvicultural systems that maintain important stand structural attributes. Models were developed for predicting lumber value in northern hardwoods as a function of visible tree vigour and stem quality criteria. Results show that only certain types of defects—namely fungi and cracks with external signs of decay—affect both tree vigour and value. In contrast, low vigour trees affected by cankers, forked stems, or crown dieback tend to maintain their value, and therefore should be prioritized for harvesting. Lumber value was also found to decrease in larger stems, irrespective of their quality or vigour classification, suggesting that all trees above species-specific diameter thresholds should be harvested. Consideration of both stem size and the impact of defects on lumber value is likely to increase the financial feasibility of selection cutting.

Balancing landowner objectives, society's desire for ecological sustainability, and wood quality in the United States. Barbour, R. (*U.S. Forest Service, USA; jbarbour01@fs.fed.us*), Haynes, R. (*U.S. Forest Service (retired), USA; rhaynes97008@comcast.net*).

The U.S. forest sector has evolved over the past five decades from being dependent on natural native forests to depending on managed forests (of selected native species). This transition has benefited from a mix of policies, regulations, and private investment that provides incentives to the broad groups of U.S. forestland owners: Federal (20%), State and other public (9%), private industry (8%), and private non-industrial (63%). The management objectives of these owner groups are diverse. Federal timberlands are generally assigned to some sort of reserve status or managed in a passive fashion. State timberlands are often managed conservatively for revenue. Private industrial lands are managed for capital returns, often on shorter rotations. Private non industrial timberlands are mostly managed in a custodial fashion with only a small fraction managed more intensively. The result has been improving forest conditions while at the same time meeting increased demands for timber. This shift from natural to managed forests has already led to several changes in the mix of forest products and locations in production. Some of these shifts have contributed to current utilization problems, especially what to do with abundant low-value biomass. But the changes themselves suggest that the U.S. forest sector will continue to adapt to changes in timber quality and availability.

Douglas-fir roundwood quality: impact of growth space on juvenile development, wood density, and branch development for future timber quality. Bruechert, F., Seho, M., Kohnle, U., Sauter, U. (*Forest Research Institute of Baden-Wuerttemberg, Germany; franka.bruechert@forst.bwl.de; muhidin.seho@forst.bwl.de; udo.sauter@forst.bwl.de*).

In the context of climate change, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) is discussed in Central Europe as a promising alternative to Norway spruce for saw timber production. It provides promising adaptation potential combined with

premium mechanical wood characteristics and durability. In the 1960s a series of systematic long-term experiments were established comprising a variation of stand densities (500–4 000 trees/ha) covering the range of situations found in practical forest management. These experiments are now 50 yrs old, and trees have reached a size allowing harvest of sawtimber-dimension logs. Trees grown under different spacing were sampled from these experiments to investigate the effect of varying diameter growth speed on internal roundwood structure and subsequent roundwood quality. The authors applied non-destructive sampling technology to the roundwood (X-ray-based computer tomography and impulse measurements) to quantify longitudinal growth, branch development, sapwood and heartwood content, and variation in wood density. The goal was to assess suitability of the logs cut from different stem heights for structural timber and other purposes. The analysis considers yield in different log quality grades, influence of growth features (ring width-related wood density), juvenile core, heartwood content, knot characteristics (knot volume, internodal length), and modulus of elasticity per log.

Value recovery in intensively managed second-growth forests: Is all volume created equal? Filipescu, C. (*Canadian Forest Service, Canada; cosmin.filipescu@nrcan.gc.ca*).

Forests across the world are under increasing pressure to satisfy multiple and diverse social, economic, and environmental demands. The rising demand for wood is being partially met by intensive forest management regimes that lead to increased yields. However, concerns remain that increased rates of growth will result in reduced wood quality, as well as a narrower range of options for value-added forest products. Therefore, forest planners and policy-makers are currently evaluating a paradigm shift from maximizing volume production to optimizing forest value and economic return. Several scenarios and research examples will be used to illustrate aspects relevant to value recovery in intensively managed second-growth forests. Intensive management practices coupled with inherent regional variability in forest productivity and climate patterns affect forest growth and wood properties, with a direct impact on forest products and value. The concept of valuation will be explored from multiple perspectives: public resource management, industrial use, and market pricing. Potential factors influencing value and its relationship to intensive forest management will also be discussed in this paper.

Profitability of uneven-aged forest harvesting practices: learning from central India. Gotame, B. (*Department of Forest, Nepal; bgotame@gmail.com*).

Profitability of harvesting uneven-aged tropical forest is a new topic of discussion in central India. This study uses the lens of financial maturity to look at uneven-aged silvicultural practices based on Faustmann's model. The objective of the study was to consider existing harvesting strategies and to seek possible silvicultural changes for greater income without impairing sustained yield. With an iterative process using the stand table projection method, this study concluded that it is possible to calculate the land expectation value (LEV) of natural uneven-aged forest in central India. LEVs of each forest division were found to be negative. However, sensitivity analysis showed that profitability status could be improved with a lower interest rate. Species composition and harvesting proportions applied differently in four forest divisions were found to affect profitability. Local forest practitioners in the study area can apply LEV-based economic analysis before adopting their uneven-aged harvesting strategies. This study showed that continuous-cover forest management for a greener future can be ensured by increasing income from tropical forests.

The economics of product quantity vs. product quality in Great Britain's forest resource. Macdonald, E., McLean, J. (*Forest Research UK, UK; elspeth.macdonald@forestry.gsi.gov.uk; paul.mclean@forestry.gsi.gov.uk*), Fonweban, J. (*FAO & Forest Research, UK; john.fonweban@fao.org*).

Planted forests in Great Britain offer a relatively short rotation by northern European standards. Owners have the ability to plant and harvest within their lifetime; this timeframe has an economic benefit for the individual. However, with a relatively short rotation focused on volume production, there may be a compromise in terms of forest product quality, which could affect value recovery. Here definitions of quality will be examined with respect to changing demands for both forests and forest products, including carbon sequestration. In particular existing models of timber quality will be linked with economic models and analyses to assess current systems of forest management and raw material production and to compare them with a range of alternative future scenarios.

Wood quality of uneven-aged Norway spruce sawn goods: a case study in southern Finland. Piispanen, R., Valkonen, S., Saranpää, P. (*Finnish Forest Research Institute, Finland; riikka.piispanen@metla.fi; sauli.valkonen@metla.fi; pekka.saranpaa@metla.fi*).

The quality of sawn goods from six uneven-aged Norway spruce stands was studied. The authors produced heart planks and side boards from sample trees harvested in uneven-aged stands and compared their wood properties and growth patterns with material from the currently predominant even-aged stands. The study plots had been established in the 1990s in stands that had been managed with selection harvests for several decades. Thirty trees with stratification by three diameter classes were sampled in each stand. Butt and top logs (2.5 m) were sawn through the pith to produce two heart planks (50 mm × 10 cm) and side boards (28 mm × 10 cm). Sawn goods were classified according to the Nordic softwood grading rules. Young's modulus was calculated from acoustic and wood density measurements. Annual ring width and branch properties were measured. The amount of compression wood was estimated visually. Variation in the interdependent tree-level factors influencing wood production and quality in uneven-aged stands will be evaluated. Results will also be discussed in the light of the authors' previous study on wood density variation.

Posters

Influence of rot on live Norway spruce wood density and strength properties. Aleinikovas, M., Skema, M. (*Lithuanian Research Center for Agriculture and Forestry, Lithuania; m.aleinikovas@mi.lt; skeminis@yahoo.com*).

When farming in the forest, it is necessary to take care of not only growing the required quantity of wood, but also producing the best quality wood. Wood quality depends on different biotic and abiotic factors that mainly affect the physical and mechanical properties of wood. However, loss in wood quality can be largely attributed to wood rot decay, which primarily destroys industrial roundwood. One of the most important European tree species is Norway spruce (*Picea abies* (L.) Karst.), and it is widely used in the construction industry. However, low resistance to wood rot decreases the durability of spruce wood, limiting its use in outdoor applications. The aim of this study was to evaluate the influence of rot decay on wood properties and particularly on the properties of wood in rot-decayed areas of living Norway spruce trees. Evaluations showed a decrease in wood density and strength properties in the rot-decayed area.

Properties of guapuruvu wood from forest recovery areas in Brazil. Athanázio-Heliodoro, J., Ballarin, A., Lara Palma, H., Pacheco, L. (*University of Saõ Paolo, Brazil; juliaheliodoro@hotmail.com; awballarin@fca.unesp.br; larapalma@fca.unesp.br; lpacheco@fca.unesp.br*).

Guapuruvu (*Schizolobium parahyba* (Vell.) Blake) is an early-successional Atlantic Forest species. It has rapid growth and can reach a height of 10 m in 2 yr. Considered one of the 12 most important species in forest recovery projects due to its ecological function, guapuruvu begins to compete with these individuals after a period. In this phase it may be thinned to open space for growth of other native tree species, and the wood is utilized. Guapuruvu thus serves as an alternative for mitigating the current high pressure on native and other planted forests caused by increasing demand for wood. However, there are few sttudies on the technological potential of its wood. This study evaluated physical and mechanical properties of wood from the species using six trees harvested from a forest recovery area in Botucatu–SP, Brazil. Wood showed compressive strength parallel to grain of 21.47 MPa and was graded in strength class C20 (NBR7190/97). Modulus of elasticity in compression was 5 729 MPa. Density of wood was 280 kg/m^3 and basic specific gravity was 255. In all tests, the samples had low coefficients of variation of properties. In addition to offering an opportunity for financial return to investors in forest recovery projects, this species showed potential for use of its wood in small structures, crates, or industrial panels such as plywood and particleboard.

Modeling the effects of partial harvesting on lumber product assortment and value: a case study in the eastern Canadian boreal forest. Auty, D., Pothier, D., Achim, A. (*Université Laval, Canada; auty.david.1@ulaval.ca; david.pothier@sbf.ulaval.ca; alexis.achim@sbf.ulaval.ca*).

In the eastern Canadian boreal forest, the low frequency of forest fires has resulted in an abundance of irregular stands dominated by black spruce and balsam fir. Partial harvesting strategies are desirable to maintain the structural attributes of these forests, although their implementation is currently limited due to the extra operational costs. To assess their overall profitability, predictions of the lumber product assortment under different partial harvesting treatments must be obtained. The authors' objective was to test the hypothesis that targeting larger stems in a partial cut may offset the increased harvesting costs, while maintaining the distinct structural attributes of irregular stands. Laser scanning data from 1 029 black spruce and balsam fir stems were used to simulate product recovery under different price schedules, and zero-inflated count models were developed for predicting the lumber product breakdown using tree height and diameter as predictors. The developed models were able to accurately predict lumber volume per stem as the sum of the predicted volume in each product category. The models were applied to harvesting data from various partial cutting strategies to simulate the impact of the silvicultural treatments on final product assortment and value recovery.

Specific gravity-driven southern pine silviculture: an opportunity to improve ecosystem services and multifunctional forests. Bragg, D., Guldin, J. (*U.S. Forest Service, USA; dbragg@fs.fed.us; jguldin@fs.fed.us*).

The southeastern United States produces more timber than any other region in the world, with much of this coming from intensively managed loblolly pine (*Pinus taeda*) plantations. Such production comes at the expense of certain ecosystem services and forest functions. Silviculturists can use what has been learned about the specific gravity (SG) of southern pine wood to influence this trend. SG has long been recognized as highly correlated to critical wood attributes and because it is influenced by both genetics and environment, SG can be culturally manipulated. For instance, growing loblolly pine in short-rotation, low-density plantations can maximize volume production but also increases the fraction of juvenile wood. A pine board that is all juvenile wood (SG = 0.4) has only 50–70% of a number of physical attributes (and two-thirds of the carbon) as one that is all mature wood (SG = 0.6). Properly managed natural-origin southern pine stands are more biologically diverse, produce high quality sawtimber in quantity, and require fewer treatments than intensively managed plantations. However, emphasizing increases in southern pine SG over volume per unit area will prove economically viable only if a premium is made that recognizes the additional environmental benefits of such an approach.

Sustained yield forestry in Sweden and Russia: How does it correspond to sustainable forest management policy? Elbakidze, M., Angelstam, P. (*Swedish University of Agricultural Sciences, Sweden; marine.elbakidze@slu.se; per.angelstam@slu.se*).

This study analyzes how sustained yield (SY) forestry is defined and implemented in Sweden and Russia, two countries with different forest-industrial regimes. First, definitions of SY forestry in national legislation and policies were compared. Second, forest management planning was studied in two large forest management units with respect to (1) delivered forest products and values, (2) definition of the harvest level of timber and pulpwood, (3) where logging takes place, and (4) what treatments were used to sustain desired forest products and values. Although the term SY forestry was used in both countries, it had different interpretations. In Russia forestry was based on natural regeneration with minimal investments in silviculture, and in Sweden maximum yield forestry was based on high-input forest management. Imbalances between SY wood production and other dimensions of sustainable forest management provoke continuous public debate and concerns in both countries. The authors discuss the consequences of SY forestry as performed in Sweden and Russia related to its ability to support diverse forest functions, as envisioned in sustainable forest management policy.

Long-term response of natural-origin even-aged southern pine to early competition control and density management in Arkansas (USA). Nelson, A., Bragg, D. (*University of Arkansas, USA; nelsona@uamont.edu; dbragg@fs.fed.us*).

The southeastern United States is well known for its high yield plantations, yet 26% of the 82.5 million forested ha across the region are natural-origin pine and oak-pine stands. This study reports on an experiment established in 1984 on the Crossett Experimental Forest in southeastern Arkansas that tested four herbicide treatments in an even-aged pine stand of natural origin. Initial competition treatments were: (1) untreated check, (2) woody control, (3) herbaceous control, and (4) total control. Treatments were thinned at ages 6, 14, and 21 yr. By the time the stands were commercially thinned at age 14, merchantable pine volume was 48% greater in the total control plots than in the check and 31% greater with total control than either woody or herbaceous control only. At 24 yr, total sawtimber volume production (standing plus harvest) was 30%, 18%, and 11% greater in the total, herbaceous, and woody control treatment than in the check, respectively. Although yields were lower than many pine plantations in the region, this research documents that aggressive competition control and early thinning can accelerate development of natural pine-dominated stands in less than 40 yr at a fraction of the up-front costs of pine plantation.

Integrated ecological and socioeconomic evaluation of ValWood agroforestry in Germany and China and its comparative analysis. Wu, S. (*Chinese Academy of Forestry, China; shuirongwu@126.com*).

The increasing demand for wood and renewable energies requires more intensive land use systems both because scarcity of land resource does not permit extension over new lands and also because already cultivated lands have not been utilized to their full potential. ValWood agroforestry aims to develop an innovative sustainable land use that combines the production of valuable timber from medium rotation (20–40 yr) forestry with short-rotation land use through forestation and landscape restoration of former agricultural lands and secondary and degraded forest lands as an alternative to the traditional agroforestry system. This paper presents an integrated ecological, economic, and social evaluation of the innovative ValWood agroforestry and traditional land use models through cost-benefit analysis and multi-criteria analysis. Ecological and socioeconomic impacts and technical aspects of the sustainable land use patterns are compared for Germany and China. The agroforestry combinations of cherry and poplar trees in Breisach, Germany, and a demonstration plot of ValWood agroforestry established in Pingxiang, China, are selected for empirical study. The conclusions drawn from this study promote more productive, sustainable, and poverty-reducing land management.

F-13 Planted forests: meeting future global forest product needs sustainably

Organizers: Dave Cown (Scion, New Zealand), Jean-Michel Carnus (National Institute for Environmental and Agricultural Science and Research, France), Tim Payn (Scion, New Zealand), João Palma (Technical University of Lisbon, Portugal)

Introduction of Eucalyptus species in Chile. Barros, S. (*Instituto Forestal (INFOR) Chile, Chile; sbarros@infor.cl*).

Chile has 2.4 million ha of forest plantations and 13.2 million ha of native forests, but it is the plantations that sustain the country's well-developed forest industry. Large quantities of primary processing products are destined for foreign markets and generate returns of more than $5 billion. The primary species in Chilean plantations is *Pinus radiata*. In the early 1970s there were 450 000 ha of plantations, 90% of which were *P. radiata*; the rest consisted mainly of poplar and eucalyptus. At the beginning of the 1960s, the Instituto Forestal (INFOR) initiated a program to introduce species and between 1963 and 1974 more than 160 conifer and broadleaf species were tested, 45 of which belonged to the *Eucalyptus* genus. The results of the program and additional research conducted by INFOR (silviculture, management, genetic improvement) promoted species diversification in plantations. Today, there are 0.7 million ha of eucalyptus and 0.2 million ha of other species; the rest of the plantations are is in *P. radiata*. The share of other species rose by 40% with eucalyptus making up 30% of the total. This paper reviews the introduction of eucalyptus and studies how this and other research work have favored its incorporation into the forest sector in the framework of a stable national policy of support for forest plantations since the early 1970s.

Future expectations of forest soils. Clinton, P. (*Scion, New Zealand; Peter.Clinton@scionresearch.com*).

There is increasing demand for timber and non-timber products and services (food, fibre, carbon sequestration, clean water, recreation, biodiversity, erosion mitigation) from both planted and natural forests. Intensification of forest management, particularly of the forest soil resource, will be necessary to meet this demand. Forest managers need to evaluate management practices and strategies for the efficient use of resources and provision of timber and non-timber benefits. Sustainable management is essential if the world's forests are to continue to meet society's expectations of forests, including bioenergy and increased contribution to human health and well-being. Although the interdependence of plant-soil interactions is well recognised particularly in the areas of energy dynamics and nutrient cycling, new advances in molecular biology and plant and microbial science are creating an opportunity to further explore these interactions in a more rigorous fashion in order to inform intensive forest management. The effect of soil properties and processes on cambial activity in plants is one area where this convergence of scientific disciplines may provide important insights and potentially ensure forests continue to provide a diversity of values. Identifying links between forest soil properties and processes and human health is proposed as an emerging area that needs to be considered during intensification.

Contribution of planted forest to sustainable production of forest products and ecosystem services. Fox, T. (*Virginia Polytechnic Institute and State University, USA; trfox@vt.edu*).

The planted pine forests of the southern United States are some of the most intensively managed and productive in the world. They also represent one of the greatest conservation success stories in world. There are currently 14 million ha of pine plantations in the region. Research and technology transfer over the last 50 yr has more than doubled productivity, increasing from around

5 m^3/ha/yr to more than 20 m^3/ha/yr. At the same time, rotation lengths have been cut in half. This presentation will describe the evolution of the pine plantation silviculture in the southern United States that has led to these gains in productivity and how these plantation forests fit into a sustainable forest landscape.

Management and valuation of stone pine stands in Tunisia: innovations for better governance. Khaldi, A., Khouja, M., El Khorchani, A. (*Institute for Research on Rural Engineering, Water and Forests (INRGREF), Tunisia; khalditn@yahoo.fr; khouja.medlarbi@iresa.agrinet.tn; ali_el_khorchani@yahoo.fr*).

The stone pine (*Pinus pinea* L.) is a Mediterranean forest species which has important roles on economic, social, landscape, and heritage levels. More than 21 000 ha of stone pine were planted in northern Tunisia during the last five decades. These forests, most of which are on government land, are managed by the Forest Services with a low participatory approach. The local populations, often poor, harvest the pine fruit illegally, increasingly early, and at lower potential value. Within the framework of a research project funded by the International Development Research Centre (IDRC), we experienced for the first time, a system of participative and innovative management concerned with the fruit harvesting period, branch pruning, and the valuation of needles from the pruning. The results we obtained are likely to significantly improve the mode of local governance in the forest areas covered by this resource. Harvesting the pine nuts later improved their quality, which brought more income to the local population. We were able to derive value from small pruned branches by making charcoal for traditional use and by extracting essential oils from the needles of the same branches. In addition to acceptance by the local population, the technical and economic feasibility of these innovative experiments was tested.

Complexity of governance of planted forests. Kleinschmit, D. (*Swedish University of Agricultural Sciences, Sweden; daniela.kleinschmit@slu.se*).

The aim of this presentation is a perspective of social science, in particular political science, on planted forests. Planted forests are a possible response to the increasing demands on forests, comprising the traditional demand for wood products (e.g., for construction and bioenergy) but also demands for biodiversity and mitigation of climate change impacts. Furthermore, planted forests can contribute to rural development and sustainable livelihoods. The development and management of planted forests is affected by an expanding system of institutions, including organizations and rules at multiple levels and across multiple sectors. This complexity is amplified by market and political globalization on the one hand and decentralization on the other hand. Partly as a cause and partly as a response, new modes of governance have emerged. These modes of governance are characterized by less top-down, state-led, command-and-control action and instead by an increased involvement of non-state actors and a shift towards market-based instruments. This presentation will address how complex and multilevel governance on planted forests affects land tenure and in which way (coordinated) good governance can contribute to sustainable livelihood and forest management.

Integrating our understanding of water, nutrition and physiology to manage tropical Eucalyptus and Acacia plantations. Mendham, D. (*Commonwealth Scientific and Industrial Research Organisation, Australia; Daniel.Mendham@csiro.au*).

Tropical Eucalyptus and Acacia plantations can be extremely productive biophysically, they can help bring wealth to rural areas in the Tropics, and they have potential in the future to provide the feedstock for mills that are currently obtaining timber from natural forests. However, tropical plantations need to be managed carefully to ensure sustained yield. This presentation will synthesise work conducted in Indonesia, India, and Vietnam, exploring the sustainable management of nutrients, water, and site, and interactions with tree physiology to help target optimal management. This paper will describe the adaptation of the CABALA model, a process-based growth model that seeks to model the water, nutrient, and carbon dynamics of planted forests, which has been primarily applied in temperate plantations, and the development of simple decision support systems based on this modeling.

Modeling potential site productivity for Japanese cedar for selecting suitable sites for planted forests. Mitsuda, Y., Ito, S. (*University of Miyazaki, Japan; mitsuda@cc.miyazaki-u.ac.jp; s.ito@cc.miyazaki-u.ac.jp*).

The objective of this study was to develop a model to predict potential site productivity for Japanese cedar, which is the tree species planted the most in Japan. With spatially explicit information on potential site productivity, suitable sites can be selected for establishing planted forests. A model was developed to predict the spatial distribution of Japanese cedar site index, which was the most commonly used measure of potential site productivity, using topographic factors derived from digital terrain analysis with a digital elevation model. As the site index is defined as the height of dominant trees at a reference age, it is often difficult to acquire sufficient data for modeling the site index by measuring the height of dominant tree in stands at the reference age because there will be few stands at the reference age within the target area. To exploit the data set of dominant tree height and age from stands of various ages, the authors combined a site index model, which describes the relationship between the site index and topographic factors, with a height curve model, which describes the tree height growth pattern with age. The proposed combined model was parameterized by the Markov chain Monte Carlo method.

Future role of plantations in Europe. Nabuurs, G. (*Alterra & Wageningen University and Research, Netherlands; gert-jan.nabuurs@wur.nl*), Schelhaas, M. (*Wageningen University and Research, Netherlands; MartJan.Schelhaas@wur.nl*), Hengeveld, G. (*Wageningen University & Alterra, Netherlands; geerten.hengeveld@wur.nl*).

European forests (177 million ha of forest and other wooded land in EU27) are mostly characterised as semi-natural, multifunctional forests. Only 12.9 million ha are characterised as plantations. For many of the 16 million small private owners, income from wood production is only a minor part of their total income including other sources. These circumstances and low demand under the current economic crisis hamper any investment in plantations, despite signals that the forest sector must play a role in the green economy. Here wood supply is projected with the European Forest Information Scenario (EFISCEN) model for the total of the EU forests under both a baseline where forest management stays as it is today, and a scenario where investments are expected in plantations. The authors assess to what degree these new plantations could cover any shortfall in wood supply in the future.

Using a criteria and indicators framework to explore future impacts of planted forests on New Zealand's economy, environment, and society. Payn, T., Hock, B., Barnard, T., Clinton, P., Garrett, L. (*Scion, New Zealand; tim.payn@scionresearch.com; barbara.hock@scionresearch.com; tim.barnard@scionresearch.com; Peter.Clinton@scionresearch.com*); *loretta.garrett@scionresearch.com*), Harrison, D., Yao, R.

The state of New Zealand's planted forests has been described using a suite of 77 indicators. These indicators, based on the international Montreal Process and national forest management-based frameworks, can be used to give an indication of the forests' sustainability. These indicators have a more important application than describing the current state, however. The indicators can be used as a basis for scenario and impacts analysis of potential futures. Somewhat like a graphic equaliser in a music system, changes in one or more components of the forest system can affect the sustainability or balance of that system. The forest system is complex and the indicators interact with each other. A change in the state of one can affect others, ultimately in a chain reaction leading to overall change, sometimes in potentially unexpected ways with unintended consequences over the life of a forest. The authors developed a systems model using the interconnectedness of the indicators to explore the potential long-term impacts of changes in New Zealand's planted forests on the economy, the environment, and society due to intensification—a doubling of forest biological productivity, expansion in forest product and service mixes, and the impacts of climate change.

Sustainability of the Portuguese eucalyptus forest under different scenarios of wood and biomass demand, forest management, and climate. Tomé, M., Miguel Barreiro, S. (*Technical University of Lisbon, Portugal; magatome@isa.utl.pt; smb@isa.utl.pt*), Palma, J. (*University of Lisbon, Portugal; joaopalma@isa.ulisboa.pt*), Crous, J. (*Technical University of Lisbon, Portugal; jcrous@isa.utl.pt*).

Production forestry, in particular *Eucalyptus globulus* plantations, has gained importance for the Portuguese economy in the last decades. Recently, higher wood demand in response to increased pulp industry capacity, together with demand for biomass for energy and a high incidence of forest fires, has jeopardized the sustainability of eucalyptus forests in Portugal. Climate change, particularly spring and summer drought, has also affected the stocks due to an increase in mortality and a decrease in growth. The use of process-based models to make projections of production forest development is therefore gaining relevance. The 3PG model, a simple process-based stand model requiring few parameter values and only readily available data as input, has been parameterized for eucalyptus in Portugal. Several equations/modules were added to obtain detailed outputs similar to the ones produced by the growth and yield model usually used in the country. The resulting model has been implemented in a regional simulator, SIMPLOT, that uses data from the Portuguese National Inventory to make long-term projections of the eucalyptus forest under different scenarios. The presentation will illustrate the predicted evolution of Portuguese eucalyptus plantations under different scenarios of wood demand, biomass demand, annual rate of afforestation (wood and bioenergy plantations) and deforestation, and annual area of burned stands.

F-14 Forestry for desired wood quality and products from underutilized forest species

Organizers: Andrew Wong (Universiti Malaysia Sarawak, Malaysia) & Pekka Saranpää (Finnish Forest Research Institute, Finland)

Assessing wood quality and developing markets for landowners growing high-value native hardwoods in Hawaii. Friday, J. (*University of Hawaii, USA; jbfriday@hawaii.edu*), Lowell, E., Wiedenbeck, J. (*U.S. Forest Service, USA; elowell@fs.fed.us; jwiedenbeck@fs.fed.us*).

Hawaii's forest and woodworking industries are largely based on harvest of old-growth stands of the native hardwood *Acacia koa* or koa, one of the most valuable woods in the world. Small private landowners are reforesting pastures with koa with the intention of harvesting timber. Today's market, however, is for old-growth lumber, not wood harvested from young or planted trees. The authors harvested and milled lumber from 31 young koa trees between 25 and 34 yr old. Wood density was measured from a cross section of each butt log. Lumber from the trees was distributed to local woodworkers, who used the wood to create furniture, bowls, and other crafts. The young koa wood tended to be lighter in color and less dense than old-growth wood. Woodworkers' reactions to the young koa wood were mixed: some woodworkers valued the wood as highly as old-growth koa, and others did not think it was usable for fine furniture. All agreed that a market for young koa does not exist now but should be developed. When potentially lower stumpage values for plantation-grown versus old-growth koa are incorporated into financial models for private landowners, the results indicate lower net present values and longer rotations.

High-value lesser known timber species from secondary tropical dry forests in Colombia. Paredes Alvarado, A., Becker, G. (*University of Freiburg, Germany; angelaparedes@gmail.com; gero.becker@fobawi.uni-freiburg.de*).

Secondary tropical dry forests (TDF) resulting from anthropogenic disturbance frequently lack economic value and are continuously threatened by land use change. These forests are relevant for production of goods and services although those characteristics are usually not recognized. A strategy for secondary forest conservation might be the production of valuable timber by utilization of suitable lesser known species (LKS). This study evaluated the status of secondary TDF relicts in the Sierra Nevada de Santa Marta, in northern Colombia, and aimed to find options for their conservation based on LKS. Sixty-four tree species were identified from a forest inventory. The results indicated an evenness index of 0.83, confirming high species diversity, comparable with primary TDF. From the 64 species, 8 abundant LKS were selected based on traditional knowledge. In wood quality analyses these eight species showed excellent timber properties, comparable with well known high-value tropical timber species. The outcomes of the study indicated a pool of species in the secondary TDF suitable to provide high quality timber. It is concluded that the use of LKS under sustainable management will increase the secondary forest value and thereby minimize the tendencies for land transformation.

Mechanical characterization of *Quercus* spp. Mexican wood by non-destructive methods. Ramirez Perez, M., Sotomayor-Castellanos, J. (*Universidad Michoacana de San Nicolás de Hidalgo, Mexico; mbc7a@yahoo.com; madera999@yahoo.com*).

Mexico has a great diversity of species belonging to the *Quercus* genus, which, due to a lack of technological information, have limited uses. A way to promote sustainable use of the Mexican *Quercus* wood is by researching the mechanical characteristics of the wood so it can be utilized in products of high aggregated value. Sixty-seven iso-standard specimens of *Quercus* spp. wood collected from the State of Michoacán, were tested by non-destructive methods: ultrasound, stress waves, and transversal vibration. The specimens were kept in a conditioning chamber for 2 yr. The specimens had an average density of 898 kg/m^3 and a moisture content of 10%. For the modulus of elasticity, the results were 23 128 MPa, 11 053 MPa, and 17 611 MPa for ultrasound, stress waves, and transversal vibrations, respectively. The speed of wave was 5 018 m/s for ultrasound and 3 462 m/s for stress waves. For transversal vibration, a frequency of 887 Hz was registered. Non-destructive evaluation of wood is a quick and cost-efficient way to determine technological information that can aid in optimizing forest resource management.

Indian sandalwood, an important bio-resource of India, and its scope in greening India. Sundararaj, R. (*Institute of Wood Science and Technology, India; rsundariwst@gmail.com*).

This paper evaluates the role of emerging plantations of Indian sandalwood (*Santalum album* L.). in areas outside forests. This tree is synonymous with ancient Indian culture, and gained importance as a source of scented heartwood and oil. It is a semi-root parasite and its successful regeneration requires suitable host plants. It is distributed all over India and state governments recently relaxed the rules on sandal cultivation such that "every occupant or the holder of land shall be legally entitled to the sandalwood trees in his land." This decision is encouraging community and private entrepreneurs to cultivate *S. album* in agroforestry, farm forestry, and various agri-silvi-horticultural and mixed plantation systems based on the choice of tree growers. Surveys revealed that *S. album* is commonly grown with forest trees and horticultural and agricultural crops. Forest trees such as *Tectona grandis*, *Grevilliea robusta*, *Azadirachta indica*, *Tamaridnus indica*, *Melia dubea*, *Simarouba glauca*, *Pongamia pinnata*, *Cassia siamea*, and *Ailanthus excelsa*; horticultural crops such as *Aacardium occidentale*, *Areca catechu*, *Cocos nucifera*, *Phyllanthus emblica*, *Moringa oleifera*, *Citrus reticulata*, *Punica granatum*, *Psidium guajava*, and *Musa* spp.; and agricultural crops such as cucurbitaceous vegetables, chilies, and lemon grass were found commonly grown with *S. album*. Considering these emerging mixed plantations of *S. album*, its role in greening India and meeting the demand of sandal-based products is discussed.

F-15 Applications of nanotechnology and biotechnology in forest products research

Organizers: Jeff Morrell (Oregon State University, US) and Andrew Wong (Universiti Malaysia Sarawak, Malaysia)

Applying electrospinning technology to produce lignin fibers. Chang, F. (*National Taiwan University, China-Taipei; fcchang@ntu.edu.tw*).

In this study, electrospinning was used to produce lignin fiber; the optimum parameters of production and various properties were investigated. Results indicate that due to the relatively small molecular weight of lignin, at least 1% of poly-ethyleneoxide (PEO) is needed to form fibers. The optimum formulation in this study was a ratio of lignin to PEO of 97:3. The concentration of solution also influenced the formation of fibers, and 20 and 30% weight concentrations were found to produce fibers of better quality. The applied voltages were controlled within 10–20 kV, and the collecting distance was adjusted accordingly; generally, 15 cm was the proper distance in this study. Moreover, the needle gauge affected the diameter of fibers; the smaller the needle gauge, the smaller the fiber diameters. However, the variation was significant. Moreover, evaporation of solvent considerably affected the quality of fibers. In this study, some fibers of greater diameters and fused structures were observed due to slow evaporation of the solvent, for which further research would be needed. In addition, multi-needle electrospinning is applicable to produce lignin fiber sheet of fine quality; however, some problems caused by slow evaporation of the solvent still need to be solved.

Cellulose nanoparticle-reinforced polymethylmethacrylate composites: effect of acid hydrolysis conditions. Han, G. (*Northeast Forestry University, China; guangpingh@hotmail.com*), Wu, Q. (*Louisiana State University, USA; wuqing@lsu.edu*).

Cellulose nanoparticles (CNPs) were prepared from microcrystalline cellulose using different concentrations of sulfuric acid (i.e., 48 and 64 wt%; the obtained CNPs were designated CNPs-48 and CNPs-64, respectively) followed by high-pressure homogenization. CNP-reinforced polymethylmethacrylate (PMMA) composite films at various CNP loadings were prepared using the solvent exchange and solution casting methods. The UV-Vis transmittance spectra between 400 and 800 nm showed that CNPs-64/PMMA had significantly higher optical transmittance than CNPs-48/PMMA at the same CNP loading level. Their transmittance decreased with increasing CNP loading. The addition of CNPs to the PMMA matrix reduced the coefficient of thermal expansion (CTE). CNPs-64/PMMA had a lower CTE than CNPs-48/PMMA. A strong reinforcement effect was achieved with the addition of CNPs to the PMMA matrix. The modulus of CNPs-64/PMMA was about 9500% (3 047 MPa) of that of the pure PMMA (32 MPa) at 100 °C. CNPs-64/PMMA exhibited a higher storage modulus than CNPs-48/PMMA, especially at higher CNP loadings. All CNP-reinforced composites showed higher Young's moduli and tensile strengths than pure PMMA. The tensile properties were enhanced with increasing CNP loading in the PMMA matrix for both CNPs-64/ and CNPs-48/PMMA. CNPs affected the Young's modulus more than they affected the tensile strength.

Effect of nanomaterials on the wearing resistance and hardness of water-based wood coating. Long, L., Xu, J., Peng, X. (*Chinese Academy of Forestry, China; longling@caf.ac.cn; xujianfeng198216@aliyun.com; pengxr@caf.ac.cn*).

Water-based wood coatings not only protect and beautify wood products, but also reduce harm to the environment and to human health, because the dispersion medium is water. However, compared with solvent-based wood coatings, water-based wood

coatings have relatively weak abrasion resistance and hardness. It is found that these undesirable properties can be significantly improved by applying inorganic nanomaterials to the coating paints. In this paper, three types of surface-modified nanomaterials, (nano-alumina, nano-silicon dioxide, and a combination of the two) were added to polyacrylate water-based wood coating. Effects of the kind of nanomaterial, the method of adding the materials, and the dosage of each component on the wearing resistance and hardness of water-based wood coating were investigated. The results showed that when nano-alumina and nano-silicon dioxide were added together with the mole ratio 2:1, the wearing resistance and hardness of coating were higher than that when just one type was chosen. When 1.5 wt% amount of nano slurry was mixed with water-based polyacrylate emulsion to hybrid during the preemulsification phase, the wear points of wood coating film appeared until 2000 r and the hardness was 2H.

Classification of agarwood quality by electronic nose technology. Mohamad Ali, N., Lias, S., Jamil, M., Saidin, S., Zainal, M. (*Forest Research Institute Malaysia; norazah@frim.gov.my; sahrim@frim.gov.my; mailina@frim.gov.my; saidatul@frim.gov.my; hafizi@frim.gov.my*), Jalil, A., Zollpatah, M., Arip, M.

Agarwood (gaharu) is an expensive resinous heartwood usually produced from Aquilaria trees. Agarwood is highly sought for its medicinal and fragrance properties and is mainly collected from the forest. Currently listed in Appendix II of CITES, cultivation efforts are ongoing in order to reduce overexploitation of natural agarwood from the forest. The quality and price of agarwood and oils are subject to its different colour, odour, and fixative properties. Agarwood is normally divided into various grades such as A, B, C, and D. Grading is usually performed by traders and thus has its advantages in terms of repeatability. The Forest Research Institute Malaysia (FRIM) has embarked on quality control assessment of agarwood by chemical profiling (resin content, HS-SPME-GCMS), pattern recognition processes, and electronic nose sensor technology. These methods were found capable of generating characterized print smells to differentiate agarwood quality and will be useful in addressing quality and trade issues in the agarwood industry.

Novel nanotechnology for protection of forests and forest products. Qi, Y. (*Southern University, USA; yadong.qi@gmail.com*), Lian, K., Wu, Q. (*Lousiana State University, USA; klian@lsu.edu; QWu@agcenter.lsu.edu*), Klepzig, K., Menard, R. (*U.S. Forest Service, USA; kklepzig@fs.fed.us; rmenard@fs.fed.us*).

This paper describes a new nanotechnology that uses copper-carbon core-shell nanoparticles (CCCSNs) to provide long-term effective biological and physiological functions as a fungicide and as a wood preservative. The project developed suitable dosages of CCCSNs against three blue-stain fungi, a white rot, and a brown rot through in-vitro studies. Field studies indicated that proper CCCSN applications were not harmful to trees, yet enhanced antifungal activities in trees. Laboratory studies provided strong evidence that wood samples treated with CCCSNs were resistant to decay pathogen and Formosa termite attack. The CCCSN technology will result in a new fungicide against forest decay pathogens and a new wood preservative against wood decay and Formosa termite. This novel nanotechnology can be regarded as a new generation of more stable functional and environmentally friendly nanomaterial because of its unique chemical and physical properties and because of its lower usage of copper.

Life cycle assessment of cellulose nanowhiskers prepared with ionic liquid. Xu, W., Mao, J., Becker, B., Laborie, M. (*Albert-Ludwigs-University Freiburg, Germany; wei.xu@fobawi.uni-freiburg.de; jia.mao@fobawi.uni-freiburg.de; gero.becker@fobawi.uni-freiburg.de; marie-pierre.laborie@fobawi.uni-freiburg.de*).

Cellulose nanowhiskers (CNWs) are foreseen as the drivers of new technologies in the forest products and bio-based material industries. CNWs have outstanding mechanical performance with great potential for a wide range of applications. However, many researchers have stated that preparation of CNWs requires very high energy consumption. New technologies to produce CNWs by using green solvents of ionic liquid are expected to generate a higher environmental performance. The methodology of life cycle assessment (LCA) was used in this study to evaluate the environmental performance of CNWs prepared with a mildly acidic aqueous ionic liquid, by adopting a "cradle-to-gate" perspective. All corresponding inputs and outputs were compiled with regard to the functional unit of 1 g dry mass of the end product of CNWs produced at the laboratory. Inventory data were collected at laboratory scale. System modeling and life-cycle inventory were carried out with Umberto®. The overall environmental impacts of this ionic liquid route were examined with the Eco-indicator 99 impact assessment method by including the most frequently analysed impact categories (e.g., global warming, human toxicity, fossil fuel depletion). Hot-spot operations within the ionic liquid route leading to higher environmental burdens were identified and optimization options were proposed for achieving better performance.

F-16 Bio-based composite and engineered products from wood and non-wood forest resources

Organizers: Salim Hiziroglu (Oklahoma State University, USA) & Andrew Wong (Universiti Malaysia Sarawak, Malaysia)

An engineered wood composite pole of superior in-service performance at a commanding price. Erickson, R. (*University of Minnesota, USA; erick117@umn.edu*).

The Wall Street Journal (17 December 2012) quotes the chief executive officer of the Ohio-based American Electric Company: "Utilities need to get smarter about what they install. It may not make sense to replace broken wood poles with more wooden poles. We're putting up steel and concrete poles." More than 600 utility companies are said to be using steel. Conventional-distribution wood poles perform poorly in storms, causing power outages. Woodpeckers are an ongoing problem. Therefore, work is proceeding on a viable alternative. Staves are sawn from laminated 2-layer flitch. The lower layer has edge-glued 1.5-inch-thick lumber and the upper has 1.0-inch-thick edge-glued southern yellow pine sapwood. Concurrently, during face gluing, a strength

enhancer is added at groundline area and wire cloth is added to the woodpecker-vulnerable area. A 40-foot class 4 pole has flitch dimensions near 2–5 inches × 40 inches × 40 feet. After glue application, staves are nested and minor strap clamping applied. Each pole end has an air-tight cap. One has access to a vacuum line. With the hollow core depressurized, the ambient air provides uniformly distributed outer surface pressure. A hollow, lightweight pole of advanced serviceability is attainable at a competitive price.

Strength of red Meranti (*Shorea leprosula* Miq) three-layer particleboard from natural and plantation forests. Indrayani, Y., Hardiansyah, G. (*Tanjungpura University, Indonesia; mandaupermai@yahoo.com; gusti.hardiansyah@gmail.com*).

This study was carried out to evaluate the quality of three-layer resin-bonded particleboard. *Shorea leprosula* collected from both natural and plantation forest (planted with intensive silviculture technique) were used as raw materials. Target densities of boards were 0.6 g/cm^3, 0.7 g/cm^3, and 0.8 g/cm^3. Two sizes of particles, fine and coarse, were applied for board manufactured with ratio of 40:60. Commercial urea formaldehyde resin was used as an adhesive with 9% resin content for middle layer and 11% resin content for surfaces layer based on dry weight of particle. Hot press condition was 160 °C and 6 minutes. Mechanical properties such as modulus of rupture, modulus of elasticity, and internal bond were determined. In addition, thickness swelling was calculated after 24 hr of water immersion. The results indicate that the particleboard of *S. leprosula* from plantation forest exceeds the requirements of Japanese Industrial Standard (JIS) A 5905-1994, as well as particleboard of *S. leprosula* from natural forest. The specific methods for composite manufacturing will be discussed, including detailed results.

Development of tannin-based adhesives and their applications in the biocomposites. Osman, Z. (*National Center for Research, Sudan; zeinabosm@yahoo.com*).

Optimal conditions for the extraction and spray drying of tannins extracted from Sudanese Acacia species (*Acacia nilotica* subspecies nilotica (Ann), subspecies tomentosa (Ant), and subspecies. Adansonii (Ana)) were developed. The Acacia species are found in pure stands in forests sustainably managed by the National Forests Corporation to produce railway sleeper cars. Bark is considered as waste and accumulate unused around the sawmills. The extracted tannins were used alone or in combination with other hardeners (urea, paraformaldehyde, and PMDI) for the preparation of different resin formulations which were thermo mechanically analysized (TMA). Their autocondensation reactions were studied and compared with their polycondensation reactions upon addition of different hardeners such as paraformaldehyde, urea, and PMDI at the same pH values. The interference between autocondensation reaction and polycondensation was also studied and evaluated. The TMA results concluded that the tannins derived from those acacia species were very reactive, and therefore, could be a potential precursor for particleboard bioadhesives. Results also indicated that the tannins could be used alone, and would possibly produce zero-emissions environmentally friendly particleboard. The obtained panels were also suitable for exterior uses and their formaldehyde emissions were reduced.

Liquefaction and pyrolysis conversion of forest resources into bio-oil: for a greener epoxy and potential wood composite applications. Via, B., Auad, M., Adhikari, S. (*Auburn University, USA; bkv0003@auburn.edu mla0001@auburn.edu*).

Liquefaction and pyrolysis of forest biomass is an emerging option in the biofuels area with some pyrolysis industrial startups sprouting internationally. But there is increased interest in the development of value-added products to diversify the options of a biorefinery. One possible product stream is to develop phenolic-like chemicals from biomass to act as crosslinking agents for epoxy adhesives and then use these adhesives in forest product composites. The results of this research have found that *Pinus* spp. (southeastern United States) can be converted into bio-oil through pyrolysis or liquefaction and then used as a feedstock to modify the epoxy for superior mechanical and thermal properties. The matrix properties of the polymer matrix have been found to be highly variable and dependent on the thermal or chemical conversion process, or both. The authors' research has shown that the thermal severity and solvent type can be adjusted to tailor the OH number of the bio-oil feedstock for optimal reaction with the epoxy polymer, resulting in a densely cross-linked network. Work is currently ongoing to determine the utility of these adhesives for bonding wood.

Posters

Use of wood and agricultural residues in brick production: an environmentally friendly alternative to cement blocks in Ghana. Appiah-Kubi, E., Essien, C., Tekpetey, S. (*Forestry Research Institute of Ghana, Ghana; appiahkemma@yahoo.com; caessien@ymail.com; nii9lartey@gmail.com*).

Construction of buildings is an expensive undertaking, especially in Ghana where cement for building is imported. Wood and agricultural residues can be used as composites in building materials as an environmentally friendly alternative to cement blocks. Agricultural residues such as corn husks, rice husks, and sawdust from processing industries are burnt in open air, causing pollution. In this study, sawdust and agricultural residues were investigated to determine their suitability as composite materials in brick production using the geo-polymerization process. Several parameters were investigated to determine the optimum amount of constituents in making suitable bricks using the polymerization process. These parameters include the curing method and the influence of time on the strength of the bricks, the optimum amount of residue to use, and the optimum amount of water and NaOH (polymerization agent) in a mix. The compressive strength of the specimens was also determined and analysed. Results indicate that compressive strength decreased with increasing amount of NaOH in bricks. The best condition for curing was to allow the bricks to dry under ambient conditions as they steadily gained strength with time.

Cross-laminated bamboo-Guadua panels for construction. Archila Santos, H. (*World Bamboo Organization, UK; hector_archila@yahoo.com*), Ansell, M., Walker, P. (*University of Bath, UK; M.P.Ansell@bath.ac.uk.; P.Walker@bath.ac.uk*).

Guadua (*Guadua angustifolia Kunth*) is a bamboo species native to South and Central America that has been widely used for structural applications in small and large-scale buildings, bridges, and temporary structures. Guadua remains a material for

vernacular construction associated with high levels of manual labour and structural unpredictability. The aim of this work is to develop standardised industrial structural products from Guadua and to measure and predict their mechanical behaviour. Cross-laminated Guadua (CLG) panels composed of three and five layers were manufactured and their mechanical properties evaluated by testing small and large specimens in compression and shear. The digital image correlation (DIC) method was used to measure strain variations in the X, Y, and Z axes on the surface of small CLG panels with strain gauge measurements on the reverse face. The deformation of large CLG panels was measured using DIC on the front face and transducers on the reverse face. Results from mechanical tests and DIC were compared and a finite element (FE) model developed that predicts the response of the material. Overall, this study provides guidelines for structural design with engineered bamboo products, which are of key importance for their mainstream use.

Maritime pine bark extraction for tannin-lignin adhesives. Chupin, L., Charrier, F., Charrier, B. (*Université de Pau et des Pays de l'Adour, France; lucie.chupin@univ-pau.fr; fatima.charrier@univ-pau.fr; bertrand.charrier@univ-pau.fr*).

Five lignin derivates from maritime pine (*Pinus pinaster*), co-products from the paper industry, were mixed with commercial mimosa tannins and hexamine as a hardener to obtain wood adhesives. For each lignin, at least two ratios of tannin-lignin adhesives were developed and four ratios were tested for one of the lignins. All the adhesive formulations were analysed by TMA, TGA, DSC, and low resolution 1H NMR. The most efficient adhesives were obtained with 60% of lignin. TGA and DSC analyses showed that all adhesives once polymerised were stable until 200 °C. When comparing the cured adhesives made with different lignins by low resolution 1H NMR, it appeared that there was not the same amount of free and bound water for each adhesive and one to three proton populations were distinguished. Then tannins from maritime pine bark were extracted using three methods based on maceration. These tannins were extracted to develop wood adhesive formulations. Tannin-lignin adhesives using maritime pine bark tannins were prepared and analysed by TMA, TGA, and DSC. Particle boards were bonded with adhesive formulations containing mimosa tannins or maritime pine tannins. The internal bond test and formaldehyde emission test were carried out to assess the performance of these boards.

Flexural properties of wood I-beams flanged with pine (*Pinus* sp).and curupixá (*Micropholis velunosa*) wood. Del Menezzi, C., Shiba, G., de Souza, M. (*University of Brasília, Brazil; cmenezzi@unb.br; gushiba@gmail.com; mario.souza@florestal.gov.br*).

The objective of this paper was to evaluate the flexural properties of wood I-beams flanged with pine (*Pinus* sp.) and curupixá (*Micropholis velunosa*) wood. Twenty-one medium density fiberboard webbed I-beams were manufactured and tested according to three assembly types: seven flanged with pine wood, seven with curupixá wood, and seven flanged with both wood species. The bending strength (f_m) and the bending stiffness (E_M) were assessed. *Pinus*-flanged I-beam presented E_M value about 6 638 N/mm^2 and fm value 19.6 N/mm^2, whereas curupixá flanged I-beams obtained 12 190 N/mm^2 and 22.6 N/mm^2, respectively. I-beams assembled with mixed flanges showed flexural properties between the values cited above: 9 027 N/mm^2 and 20.5 N/mm^2. A significant difference between the E_M value of pine- and curupixá-flanged I-beams was observed. However, the bending strength was not affected by the wood used as the flange. It was observed that a third of the I-beams showed insufficient glue transference, mainly those made from curupixá wood; thus maximum bending strength was not achieved. It could be concluded the flexural properties of I-beams reach values close to those usually found in the literature, but they could be higher if better compatibility between the tropical wood and the resin were obtained.

Properties of wood plastic composite made with nano-clay added to eastern redcedar. Hiziroglu, S., Karumuri, S., Kalkan, K. (*Oklahoma State University, USA; salim.hiziroglu@okstate.edu; karumur@ostatemail.okstate.edu; kaan.kalkan@okstate.edu*).

The objective of this work was to evaluate some properties of experimental wood plastic composite (WPC) samples manufactured from eastern redcedar (*Juniperus virginiana* L.) particles and plastic. Three percent and 6% nano-clay was added to a mixture containing 40% wood particles and 60% high density polyethylene (HDPE). All samples including the control samples, which were made without any clay, were mixed with 1% maleic anhydride polypropylene (MAPP) as a coupling agent. The compound was fed through a screw-type extruder before shredding the mixture, and samples in the shape of dog bones were produced using an injection molding setup. Physical and mechanical properties including thickness swelling, water absorption, tensile strength, and surface roughness of the samples were tested. Control samples had the lowest dimensional stability; those manufactured with 6% clay had enhanced thickness swelling and water absorption characteristics. Tensile strength of the samples increased slightly with increasing clay content. Surface roughness defined by average roughness (R_a) of all three types of samples increased when they were exposed to the water soaking test for 8 hr. Addition of 6% nano-clay to the samples also improved surface roughness 31% as compared to that of control samples.

Improving Mexican forest viability by technological characterization of commercial wood composites by nondestructive methods. Sotomayor-Castellanos, J., Ramirez Perez, M. (*Universidad Michoacana de San Nicolás de Hidalgo, Mexico; madera999@yahoo.com; mbc7a@yahoo.com*).

Mexican forest species are underutilized because of a shortage of technical information on wood composites. Plywood and medium density fiberboard (MDF) panels that are sold as materials for the construction market are not labeled with the mechanical characteristics that could be applied for engineering design. To contribute to the solution of this problem, the objective of this research was to assess the density and the modulus of elasticity (MOE) of plywood and MDF panels by nondestructive methods. Stress waves and transversal vibration tests were applied to a sample of commercial plywood and MDF panels. Density, stress wave speed, natural vibration, and MOE were calculated. Main results show a density of 532 kg/m^3 for plywood and 628 kg/m^3 for MDF. The stress wave speed average is 3 319 m/s and 2 126 m/s, with a MOE of 5 915 MPa and 2 843 MPa for plywood and MDF panels, respectively. A natural frequency of 472 Hz and 696 Hz for plywood and MDF, respectively, was registered. The MOE in transversal vibration is 1 584 MPa and 3 592 MPa for plywood and MDF, respectively. The main conclusion is that plywood and MDF panels sold in the Mexican market have density and MOE characteristics appropriate for engineering design.

***Caryocar villosum* (Aubl.) Pers. as a bioresource: evaluation of particleboard technological properties.** Surdi, P., Junior, G. B., Castro, V., Ribeiro, V. (*University of Saõ Paolo-ESALQ, Brazil; paulasurdi@usp.br; gbjunior@usp.br; vresende@gmail.com; vcrribeiro@usp.br*), Filho, M.T. (*University of Saõ Paolo, Brazil; mtomazel@usp.br*).

The purpose of this research is to evaluate the potential use of residues from mechanical processing of *Caryocar villosum* (Aubl.) Pers. wood in particleboard production. Three panels were produced from this tropical species, with adhesive based on phenol formaldehyde, nominal density of 850 kg/m^3, and dimensions of 400 mm × 400 mm × 15.7 mm (width, length, and thickness, respectively). The panels were then put in a climate-controlled room at the Wood and Derivatives Mechanical Assay Laboratory at University of Saõ Paolo-ESALQ, at a temperature of 295.15 ± 8 K and 65% ± 5% relative moisture. The basic density and chemical properties of the wood were determined. Specimens from the particleboards will be prepared and conditioned to then evaluate their physical (water absorption and thickness swelling) and mechanical (internal bond, modulus of elasticity and modulus of rupture) properties. Resistance to decay fungi will be evaluated. The density profiles of the panels will be characterized by X-ray attenuation. Results are expected to show an economic utilization of residues from mechanical processing of tropical species explored sustainably as well as to generate options for consumers looking for products different from those generally marketed.

Reinforcement of plant fiber-based ultra low density material with sodium silicate. Xie, Y. (*Fujian Agriculture and Forestry University, China; fjxieyq@hotmail.com*).

This presentation will show that inorganic materials such as sodium silicate and aluminum sulfate can be used as additives to improve mechanical and fire-resistance performances of plant fiber-based ultra low density material (ULDM) during the production process with the liquid frothing approach. The following process was used to make sample mats. After fibers were pulped in a refiner, resin and a surface-active agent were added to the pulp solution. Then sodium silicate and aluminum sulfate were added and thoroughly mixed into the solution. After solution frothing, the mat was formed and dried, producing a plant fiber-based ultra low density mat. The reinforced ULDM had an internal bonding strength of 1.0 MPa, compared to 0. 1 MPa in material without the inorganic additives. In reinforced ULDM as compared to unreinforced material, the modulus of elasticity was 87.3 MPa and 12.4 MPa, modulus of rupture was 7.3 mPa and 0.2 MPa, and compressive strength (at 10% strain) was 3.7 MPa and 0.2 MPa, respectively. Reinforcement with sodium silicate can also increase fire resistance, and the oxygen index can reach a higher level, 42%. No significant weight loss and exothermic decomposition could be observed below 700 °C.

F-17 Recovery, reuse, and recycling of wood products for a greener future

Organizers: Phil Araman (U.S. Forest Service), Robert Bush & Robert Smith (Virginia Tech, USA)

Wood pallet production, disposal, recovery, reuse, and recycling in the United States. Araman, P. (*U.S. Forest Service, USA; paraman@vt.edu*), Bush, R. (*Virginia Polytechnic Institute and State University, USA; rbush@vt.edu*).

In the United States, large volumes of wood in the form of pallets are used to move, store, and ship products. For example, the authors estimate that 7.26 billion board feet (approximately 441 million pallets) of new solid wood were utilized by the U.S. wood container and pallet manufacturing industry (North American Industry Classification System 321920). They also estimate that 7.57 billion board feet (approx. 460 million pallets) were recovered for reuse and recycling. Of the total pallets recovered, 309 million were sold to pallet users. The remaining pallets and material from repaired pallets were recycled into other products after grinding and further processing. Nevertheless, many pallets still end up at landfills, and ways to divert those pallets to recyclers will be presented. The audience will get a slide tour of a typical pallet recovery operation pursuing zero wood waste. The tour will include ways to collect the waste pallets, separation of incoming pallets, repair techniques, pallet disassembly, and pallet grinding and the various fiber products produced.

Home construction waste and potential recycling options. Araman, P. (*U.S. Forest Service, USA; paraman@vt.edu*), Hindman, D. (*Virginia Polytechnic Institute and State University, USA; dhindman@vt.edu*).

Construction waste represents a significant portion of landfill waste, estimated as 17% of the total waste stream. Estimates on the amount of wood construction waste for a typical 2 000-ft^2 single family home is more than 5 000 pounds, including 3 000 pounds of solid-sawn wood, and 1 500 pounds of engineered wood products (EWP). Most of the solid-sawn lumber and EWPs can be recycled. Through a partnership with Green Valley Builders (Blacksburg, Virginia, USA), an EarthCraft House certified builder, the authors have studied their wood construction waste and recycling options. Wood products studied included solid-sawn lumber, oriented strand board, particleboard, laminated veneer lumber (LVL), and preservative-treated wood. Wood waste was collected for each house during the construction process. The waste was measured, weighed, and sorted according to material type and size. Potential uses included finger-jointing to produce non-structural stud material or sill plates, web material in open web floor trusses, temporary stair treads and risers, shelving, pallet parts, and finger-jointed panels for sheathing. Grinding would be used to convert smaller pieces to mulch and fuel. Zero wood waste is possible. Data for 15 homes will be presented.

Green building: dimensional stability of block produced from sawdust and sand. Badejo, S., Adejoba, O. (*Forestry Research Institute of Nigeria; solomonbadejo@yahoo.com; jatsod2009@gmail.com*), Adelusi, E. (*Federal College of Forestry, Ibadan, Nigeria; adelusi_ade@yahoo.com*).

The present study investigates the potential utilization of wood waste in the production of building blocks. Sawdust, sand, and cement were mixed together at three different mixing ratios of 1:1:3.5, 1:1:4, and 1:1:5. The blocks were subjected to water absorption, thickness swelling, and compression tests. The effects of this production variable (mixing ratios) on dimensional movement and compressive strength were determined. After a period of 120 hr of cold water immersion, the mean water absorption values of the wood waste block were 40%, 39%, and 25% for a mixing ratio of 1:1:3.5, 1:1:4, and 1:1:5, respectively. Ratio 1:1:5 produced a more dimensionally stable block with the lowest water absorption percentage. The mean compressive strength examined was 11.63 N/m^2, 11.68 N/mm^2, and 12.80 N/mm^2 for a mixing ratio of 1:1:3.5, 1:1:4 and 1:1:5, respectively. In conclusion the use of sawdust in construction block making is possible.

Paper honeycomb panels and sustainability. Bíldík, A., Özden, Ö. (*Istanbul University, Turkey; ahsenezel.bildik@istanbul.edu.tr; ozdeno@istanbul.edu.tr*).

With the decrease in forested areas and increasing pressure on natural resources, more research is being done regarding environmentally friendly new products. Studies on alternative products for this area are also important. Recycling and products made from recycled material are crucial for protection of the environment, but green products have to be commercially economical. This study considers paper honeycomb panels, which are made entirely from recycled products. As an alternative to wood panels, they are light, sturdy, and economical. Paper honeycomb panels are produced from 100% recycled paper. They are used in packing to protect corners and in packages and pallets during transportation. Paper honeycomb panels, which are a combination of kraft and testliner, are made by special technical methods. In recent years, they have been used as a raw material in the furniture, door, and automotive industry. They do not require fumigation or heat treatment and are not subject to the International Standards for Phytosanitary Measures (ISPM) 15 standard. Therefore, this products is more environmentally friendly than wood panels.

Local experience with the use of wood residues from a sawmill in Cuba. Manzanares Ayala, K., Velazquez Viera, D., Guyat Dupuy, M. (*Instituto de Investigaciones Agro Forestales, Cuba; katia@forestales.co.cu; mguyat@forestales.co.cu*).

The poor technology used in the process of sawing wood in Cuba produces large quantities of waste, which then becomes an environmental pollutant and a host for insects and diseases. Most of these residues accumulate in the yards of sawmills. In most cases, these residues are converted into ash, releasing a high amount of CO_2 into the atmosphere and thereby threatening the environment. This study suggests productive management of industrial residues from the processing of *Pinus caribaea* and *P. tropicalis* at the sawmill of Minas de Matahambre, Pinar del Río province, Cuba, in order to diversify the production of forest products. The means will be by implementing short-chain technologies and estimating the levels of environmental costs caused by the burning practice. It was found that waste recycling in the production of packaging material, construction elements, charcoal, and wood crafts was feasible from technical, social, and environmental standpoints. Furthermore, recycling allows value to be added to the primary production of the sawmill, reduces the pollutant load and helps mitigate climate change effects, guarantees food security and housing for the local settlers, and gives access to widely used products in high demand.

F-18 Emerging green and sustainable alternatives to classical wood preservative to protect forest products

Organizers: Donatien Pascal Kamdem (Michigan State University, USA), Jöran Jermer (SP Technical Research Institute of Sweden), Andrew Wong (Universiti Malaysia Sarawak) & Nasko Terziev (Swedish University of Agricultural Sciences)

Superheated steam heat treatment for pitch pine (*Pinus rigida*) lumber. Park, Y., Han, Y., Park, J., Chang, Y., Yang, S. (*Seoul National University, Republic of Korea; gunny007@snu.ac.kr; jack2001@snu.ac.kr; gentleice@nate.com; jang646@snu.ac.kr; sly1357@snu.ac.kr*), Lee, J., Yeo, H.

A heat treatment (HT) using hot air in the approximate range of 160–260 °C is a conventional method to improve the physico-mechanical performance and durability of wood. Many HT methods have been studied since the early 2000s. In addition, many researchers have measured and compared several properties of wood treated by these HT methods. In this study, to find the optimized condition leading to maximized performance of treated wood, pitch pine (*Pinus rigida*) wood was dried and heat-treated with superheated steam (SHS) at different temperatures and pressures. Properties of the treated wood were measured and compared to each other. Treatments were carried out under the following conditions; 180 °C air HT, 220 °C air HT, 0.1 MPa-180 °C SHS HT, 0.1 MPa-220 °C SHS HT, 0.5 MPa-180 °C SHS HT, and 0.5 MPa-220 °C SHS HT. No drying checks and the lowest equilibrium moisture content were observed in the specimens (500 mm × 150 mm × 50 mm) treated at 0.5 MPa and 220 °C SHS. A low equilibrium moisture content (EMC) affects many physico-mechanical and biological properties, including shrinkage, compressive strength parallel to the grain, bending strength, hardness, and degree of decay resistance. The results show that heat-treating green wood by the SHS HT process without the occurrence of drying checks is possible.

Stilbenes from the bark of Norway Spruce (*Picea abies* [L.] Karst.) as protective agents. Saranpää, P., Sarjala, T., Latva-Mäenpää, H., Wähälä Hase, K., Jyske, T. (*Finnish Forest Research Institute, Finland; pekka.saranpaa@metla.fi; tytti.sarjala@metla.fi; harri.latva-maenpaa@metla.fi; kristiina.wahala@helsinki.fi; tuula.jyske@metla.fi*), Laakso, T.

Conifer bark is rich in bioactive polyphenolic compounds and thus forest residue offers a vast source of biochemicals which could be utilised after extraction and isolation. The authors have been studying Norway spruce roots, stumps, and bark as a source of bioactive compounds. The bark contains stilbene glycosides, and their concentration varies between 0.53 and 8.29% (w/w, dry weight) with isorhapontin being the major compound. The bark of the root neck is an especially rich source of stilbenes like trans-astringin and trans-isorhapontin for commercial utilisation. These compounds have been reported to be potential antioxidant and antimicrobial agents. In addition, they have been found to be effective against termites. Our interest is in the genetic and environmental variation in stilbene content and the application of stilbenes to improve durability of wood products. Does the northern origin and provenance have higher content of stilbenes than the southern provenance? Could the chemical composition of bark be manipulated? There is the possibility of improving mould resistance with stilbenes. Preliminary results will be discussed.

Temperate woods in tropical climates: How durable? Shanbhag, R., Sundararaj, R. (*Institute of Wood Science and Technology, India; rashmishanbhags@gmail.com; rsundariwst@gmail.com*).

Some imported timber is well known for its durability, and its reputation has carried it far from its original home. Some has not maintained its reputation under different conditions or where new varieties of pests have appeared. It is necessary to know the

behaviour of wood species under different environmental conditions and their durability class before the timber or timber product is put into use. The degree of wood deterioration depends on conditions such as soil, rainfall, altitude, temperature, and other environmental conditions under which the timber is used. This paper describes the natural resistance of important imported timber species of India against termites in different agro-ecological zones. Field experiments were carried out under five Indian agro-ecological zones with the aim of evaluating the natural resistance of 20 species of imported woods. Wood stakes measuring 30.5 cm × 3.8 cm × 3.8 cm as per IS:401-1982 standards were implanted in the soil and observed for a period of 4 yr. Damage was assessed visually. Results revealed significant differences in rate of degradation of wood species, and differences in climatic zones led to significant differences as well. The possible reasons were discussed.

Wood modification through acetylation process on three lesser-used timber species of Myanmar. Win, C. (*Forest Research Institute, Myanmar (Burma); chochosnow1@gmail.com*), Oo, S. (*Environmental Conservation Department, Myanmar (Burma); sthandaroo@gmail.com*), Win, W. (*University of Forestry, Myanmar (Burma); juumyitt@gmail.com*).

Widespread utilization and increasing demand for commercial wood species have led to research seeking appropriate ways to utilize lesser-used timber species (LUS). Because many of these species are lower in durability, the need for wood preservation is almost inevitable. Acetylation is a new approach to preserve wood against biological damages with environmentally friendly chemicals and to improve dimensional stability. Three Myanmar LUS, *Adina cordifolia*, *Lagerstromia tomentosa*, and *L. speciosa*, were acetylated using acetic anhydride. The tested species have good utilization potential, but lower durability and less dimensional stability. The objective was to investigate the effectiveness of acetylation on the durability, dimensional stability, and mechanical properties. Results showed that acetylated samples reduced fungal attack and durability can be improved significantly from Class III to Class I with a weight percent gain (WPG) of 30%. Radial and tangential shrinkage of acetylated samples were significantly reduced and anti-swelling efficiency (ASE) of the acetylated wood was enhanced by 50–70% with a WPG of 30%. Mechanical properties of acetylated samples were significantly improved except in compression perpendicular to grain and hardness. It can be concluded that wood modification through acetylation can significantly enhance the wood properties of the tested species.

Posters

Antifungal potential and chemical composition of *Chamaecyparis formosensis* and *C. obtusa* var. formosana essential oils in liquid and vapor phase against plant pathogenic fungi. Chen, Y. (*National Taiwan University, China-Taipei; d00625003@ntu.edu.tw*), Ruo-Yun, Y. Huai-Wen, H. (*Taiwan Forestry Research Institute, China-Taipei; zoeyeh@tfri.gov.tw; huaiwan@tfri.gov.tw*), Chang, S. (*National Taiwan University, China-Taipei; peter@ntu.edu.tw*).

The essential oils (EO) isolated by hydro-distillation from the leaf and wood of *Chamaecyparis formosensis* and *C. obtusa* var. *formosana* were analyzed by GC-MS and GC-FID. The leaf EO of *C. formosensis* contained a predominance of monoterpene hydrocarbons (92%); in contrast, *C. obtusa* var. *formosana* contained a lower proportion in monterpene hydrocarbons (60%) and higher proportion in sesquiterpene hydrocarbons (23%). Sesquiterpene hydrocarbons (36%, 52%) and oxygenated sesquiterpene (54%, 36%) were the major components found in the wood oils of both *C. formosensis* and *C. obtusa* var. *formosana*, respectively. The antifungal activity of the oils was tested by poisoned food (PF) technique and the volatile activity (VA) assay against four plant pathogenic fungi: *Gloeophyllum trabeum*, *Trichoderma* sp., *Trametes versicolo*, and *Lenzites betulina*. The leaf oil exhibited stronger activity in the VA assay, whereas significantly higher antifungal activity of wood oil was observed in the PF assay, indicating that different EO components would be suitable for different application operations.

Cinnamomum osmophloeum* leaf oils act as antifungal agents for wood rot fungus *Phellinus noxius. Cheng, S., Lin, C., Chung, M., Chang, S., Wang, Y. (*National Taiwan University, China-Taipei; d89625006@ntu.edu.tw; aisiteru555@gmail.com; jasonchung@ntu.edu.tw; peter@ntu.edu.tw; m627@ntu.edu.tw*).

The essential oils isolated from 15 geographical provenances of *Cinnamomum osmophloeum* leaves were examined by GC-MS and their chemical constituents were compared. According to GC-MS and cluster analyses the leaf essential oils of the provenances and their relative contents were classified into eight chemotypes: cinnamaldehyde type, cinnamaldehyde/cinnamyl acetate type, cinnamaldehyde/linalool type, linalool type, linalool/camphor type, camphor/bornyl acetate type, 1,8-cineole/p-cymene type, and mixed type. In addition, the antifungal activities of leaf essential oils and their constituents from eight chemotypes of *C. osmophloeum* against *Phellinus noxius* were investigated. Results from the antifungal tests demonstrated that the leaf essential oils of cinnamaldehyde type and cinnamaldehyde/cinnamyl acetate type had an excellent inhibitory effect against *P. noxius* and their antifungal indices at the level of 200 mg/ml were 100%. The strongest antifungal activity was found in *trans*-cinnamaldehyde in comparison with other constituents of the leaf essential oils from the cinnamaldehyde type; at the level of 200 mg/ml its antifungal index against *P. noxius* was 100%. Thus, *trans*-cinnamaldehyde as well as the leaf essential oils of cinnamaldehyde type and cinnamaldehyde/cinnamyl acetate type are renewable natural products and may be further explored as a potential source for the development of antifungal agents or fumigants.

Crude tall oil impregnation as a wood preservation method. Heräjärvi, H., Mottonen, V., Stöd, R., Venäläinen, M. (*Finnish Forest Research Institute, Finland; henrik.herajarvi@metla.fi; veikko.mottonen@metla.fi; reeta.stod@storaenso.com; martti.venalainen@metla.fi*).

Alternatives to wood products preserved with copper salt are sought because of environmental concerns and increased expectations for product performance. The Finnish Forest Research Institute has carried out experiments regarding the impacts of crude tall oil preservation on the properties of Scots pine (*Pinus sylvestris* L.) wood. Here, the authors summarize the findings of these tests and discuss the possibilities of commercializing tall oil-treated products. The material consisted of Scots pine from central Finland that was impregnated with tall oil using the method of Ekopine Ltd. Specimens were prepared for destructive bending, water absorption, dimensional stability, and decay resistance tests. Results indicated that tall oil impregnation had minor negative

effects on bending properties of wood. On the other hand, dimensional stability and water resistance of tall oil-impregnated wood were considerably improved compared to non-treated and copper salt-impregnated reference specimens. Weather and decay exposure tests in ground contact indicate challenges in terms of leaching, mostly resulting from heat caused by sunshine. Therefore, the authors conclude that with regard to the impregnation method used in this study, tall oil-impregnated products should not be used in direct sunlight exposure, but these products are very promising for uses in protected structures requiring high moisture resistance.

Chemical treatments to sanitize *Phytophthora ramorum*-colonized timber material and mitigate the risk of accidental sudden oak death dissemination. Hulbert, J., Morrell, J. Hansen, E. (*Oregon State University, USA; joseph.hulbert@oregonstate.edu; jeff.morrell@oregonstate.edu; hansene@science.oregonstate.edu*).

In 2009, *Phytophthora ramorum*—the causal organism of sudden oak death—was listed in regulatory legislation, or present in regulated pest lists, for 68 countries. *P. ramorum* continues to spread to new areas of the world and accidental dissemination on timber material is considered a potential pathway. Several major commercial timber species in global trade are host species, making it critical to develop mitigation methods for minimizing spread on timber materials. Heat treatments are known to be effective but are difficult to implement on large quantities of whole logs; therefore, it is important to investigate alternative options. Combinations of diffusible borates and two organic biocides were evaluated for activity against *P. ramorum.* Borates were capable of diffusing through the bark of smaller-diameter Douglas-fir (*Pseudotsuga menziesii*). These methods may be suitable for sanitizing other pathogens and may allow for transportation of host timber material outside of quarantined areas.

Fungal decay of *Pinus kesiya* fascia boards on external joinery in Zambia. Ncube, E., Chungu, D., Ngándwe, P. (*Copperbelt University, Zambia; enncube@yahoo.com; donald.chungu@gmail.com; pngandwe2002@yahoo.co.uk*), Kamdem, D. (*Michigan State University, USA; Kamdem@msu.edu*), Mwewa, M. (*Copperbelt University, Zambia; Matanda.mwewa@gmail.com*).

Fascia boards on urban housing in Zambia deteriorate rapidly because of fungal infection and environmental factors. The aim of this study was to identify wood-degrading fungi and the durability of common construction timber *Pinus kesiya* Royle ex Gord against these factors with a view to improve the performance of fascia boards in the country. Decayed fascia boards were collected from at least three sampling sites in Lusaka, Kabwe, and Kitwe. Several fungi were isolated from the boards and identified based on morphological characteristics. Wood blocks (10 mm × 5 mm × 50 mm) were exposed to the identified fungi for 12 weeks to determine their decay resistance based on weight loss. Fungi of the genera *Gloeophyllum* and *Tyromyces*, both brown rot, were isolated from decayed wood collected in Lusaka. Brown rots, (*Monilia*, *Coniophora,* and *Poria*), and a white rot (*Ceratosystis*), were found in decayed wood from Kabwe. *Gloeophyllum* and *Coniophora* were isolated from decayed wood collected in Kitwe. Block tests revealed that timber from *P. kesiya* was least resistant to fungi in the genus *Poria* as seen with a weight loss of 16%. These results provide an opportunity for Zambia to consider the use of *Poria* species as standard microorganisms to determine the natural durability of softwood against fungi and the preservative treatment of fascia boards.

The role of Fenton-derived hydroxyl radicals in oxidative and enzymatic degradation of furfurylated wood. Pilgård, A., Richter, K. (*Munich University of Technology, Germany; pilgard@hfm.tum.de*); *richter@hfm.tum.de*), Ringman, R. (*SP Technical Research Institute of Sweden; rebecka.ringman@sp.se*).

The mode of action of modified wood has long been debated. Current theories include: (1) enzyme non-recognition, (2) micro-pore blocking, (3) moisture exclusion due to blocking of OH-groups, and (4) moisture exclusion due to decrease in void volume. Current research points out the importance of water exclusion inside the wood cell wall as the protection mode of modified wood. Theoretically, moisture exclusion would inhibit all diffusion of fungal molecules into the wood cell wall and thereby inhibit both oxidative and enzymatic degradation. It has also been shown that fungal cellulases and hemicellulases are less efficient when degrading modified wood compared to untreated wood. Recent research has shown that cellulase efficiency is partly restored in wood treated with 1,3-dimethylol-4,5-dihydroxyethyleneurea *(DMDHEU)* by pre-treatment with Fenton's reagent, simulating the oxidative degradation phase in initial brown rot decay. These results suggest that, under natural conditions, enzymatic degradation may not be inhibited in modified wood, but instead inhibition of oxidative degradation may be the mode of action. In this study, the authors investigated the efficiency of Fenton-derived hydroxyl radicals to enhance cellulase degradation in wood modified with furfuryl alcohol. The results show the efficiency of the oxidative agents and the fungal enzymes on furfurylated wood.

Utilization of naturally durable tropical woods in society for a greener future. Wong, A. (*Universiti Malaysia Sarawak, Malaysia; awong.unimas@gmail.com*), Ling, W. (*Forest Department Sarawak (retired), Malaysia; wangchoon@gmail.com*), Singh, A. (*Scion, New Zealand; adyasingh@hotmail.com*), Kim, Y. (*Chonnam National University, Republic of Korea; kimys@chonnam.ac.kr*).

The timber resources of the world play an unequivocal role in economic development of both the timber producing and importing regions. Use of naturally durable wood has been critical since the dawn of civilization and was accomplished even before the advent of industrial wood protection and preservation strategies. Considerable research as well as environmental considerations in wood protection has led public perception to favour naturally durable woods again, in pursuit of green building environment initiatives. This paper describes natural durability as a preferred wood quality with emphasis on Malaysian hardwoods, characteristics of tropical hardwood durability, hardwood utilization and biological hazards of different global regions, and the "evolution" of tropical hardwood resource usage including the introduction of planted durable woods. This paper also discusses the increased use of wood composites of questionable wood durability and studies on the causes of the natural durability of tropical hardwood heartwood, especially the influences of both heartwood extractives and wood lignin. Opportunities await for successful genetic manipulation of wood quality in plantation forestry, yielding transgenic naturally durable species. Treated wood does not always provide economical wood protection outdoors, and naturally durable wood can help fulfill society's quest for a more durable substitute.

Theme G: Forest Health in a Changing World

G-01 Air pollution as a factor affecting global forest health

Organizers: Algirdas Augustaitis (Aleksandras Stulginskis University, Lithuania), Andrzej Bytnerowicz (U.S. Forest Service) & Robert Jandl (Research and Training Centre for Forests, Natural Hazards and Landscape, Austria)

Evidence of inhibited and reinforced effects of climate change on tree responses to the integrated effect of air pollutants on forest sustainability. Augustaitis, A., Augustaitiene, I., Kliucius, A., Marozas, V. (*Aleksandras Stulginskis University, Lithuania; algirdas.augustaitis@asu.lt; iaugustaitiene@gmail.com; almantas.kliucius@asu.lt; vitas.marozas@asu.lt*).

The United Nations Economic Commission for Europe Integrated Monitoring Programme, which has been annually performed since 1994 in Lithuania, provides data for solving one of the most relevant problems: whether changing meteorology reduces or enhances air pollution effects on tree condition. A 20-year dataset on the crown condition of 43 Scots pine stands located in different regions of Lithuania was used to meet the objectives of the study. The obtained data revealed that air concentrations of ΣNH_4^+ and SO^2 and deposition of SO_4^{2-} over the first half of the dormant period as well as deposition of NO_3^- over the vegetation were the key parameters explaining spatial and temporal variability in pine defoliation. The precipitation amount alone had a significant effect on temporal and spatial variation in acidifying compounds and their deposition, whereas air temperature affected the formation of surface ozone. Air temperatures of the mid dormant period and mid vegetation period were key parameters explaining pine increment variability. Decrease in sulphur air concentration and its deposition, together with ammonium deposition, reinforced pine tree growth. Only the effect of surface ozone was not significant. Recent changes in meteorology should reduce pine tree vulnerability to acid deposition, and enhance resiliency to ozone damage.

Update on impacts of air pollution and climate change on the Carpathian forests. Bytnerowicz, A. (*U.S. Forest Service, USA; abytnerowicz@fs.fed.us*), Badea, O. (*Forest Research and Management Institute, Romania; badea63@yahoo.com*), Grodzki, W. (*Forest Research Institute, Poland; W.Grodzki@ibles.waw.pol*), Lomsky, B., Sramek, V. (*Forestry and Game Management Research Institute, Czech Republic; lomsky@vulhm.cz; sramek@vulhm.cz*), Bihun, Y. (*Shelterwood Systems, USA; shelterwoodsystems@comcast.net*), Priwitzer, T. (*National Forest Centre, Slovakia; priwitzer@nlcsk.org*).

Carpathian forests are affected by climate change and air pollution. Ozone has the highest phytotoxic potential among air pollutants. Nitrogenous pollutants and sulfur dioxide are phytotoxic and also contribute to elevated nitrogen and sulfur deposition and acidification. Increased nitrogen deposition may stimulate tree growth and change ecosystem biodiversity. Increasing and highly variable temperatures, unpredictable precipitation patterns, prolonged droughts, and increasing frequency of strong winds are the most important climatic factors affecting forests. Climate change can affect impacts of air pollution on forests, and vice versa, responses of forests to specific climatic change can be modified by air pollutants. Climate change and air pollution interactively affect tree nutritional status, physiology, and biochemistry which in turn influence their ability to withstand multiple stressors. The resulting changes in forests include plant damage, altered growth, increased susceptibility to pests and diseases, changes in biodiversity, reduced water resources, increased fuel built-up and fire danger, and changes in recreation value of forests. We will address impacts of these factors from a perspective of future risks to ecosystems and development of science-based management strategies and their implementation in a manner that would allow for optimal adaptation of the Carpathian forests to these changes.

Soil amelioration for combatting acid rain: an appraisal of past efforts. Jandl, R. (*Forest Research Center, Austria; robert.jandl@bfw.gv.at*).

About 30 years ago, forest soils received considerable attention when acid rain was considered to cause lasting soil degradation. The need for action was well substantiated by soil chemical process understanding. However, the costs were considerable. Hence, the efforts for soil amelioration were adopted with variable rates of enthusiasm. We evaluated the results of the amelioration programmes from the perspective of the long-term results and based on forest soil monitoring programmes that were not available in the 1980s. We show the general trend of soil chemical changes and assess whether the soil amelioration programmes have been successful and effective.

Drought and tropospheric ozone limit intra-annual stem growth of European beech (*Fagus sylvatica*) across Bavaria, Germany. Kühn, A. (*Munich University of Technology, Germany; angelika.kuehn@tum.de),* Baumgarten, M. *(Munich University of Technology and Bavarian State Institute of Forestry, Germany; manuela.baumgarten1@gmail.com),* Matyssek, R. *(Munich University of Technology, Germany; matyssek@wzw.tum.de).*

Limitations by drought and ozone uptake, acting separately or in combination, are known to potentially reduce stem growth. For evaluating impacts of both stressors on beech (*Fagus sylvatica*), 10 forest sites differing by soil moisture were selected across Bavaria, Germany along a gradient of precipitation and ambient ozone regimes (eight Level II plus two research sites). At all sites, climatic parameters were measured in parallel to xylem sap flow and radial stem growth at high time resolution and linked with a water budget model. We hypothesized that soil water limitation reduced ozone uptake due to drought-induced stomatal closure. Incorporated ozone doses, transpiration rates, and radial stem growth were examined for seasonal drought and ozone-related effects between water-limited and non-limited sites. In relation to potential ozone uptake (presuming site-specific maximum canopy conductance), high-altitude sites with ample water supply and water-limited low-level sites showed reduced ozone uptake, but not so non-limited low-level sites. Already under incipient soil water limitation beech growth was significantly reduced. Multiple regression analysis confirmed significant intra-annual reductions due to ozone uptake. Interactions in stem growth were indicated between water limitation and ozone stress. Water-limited sites in Bavaria seem to be at risk for productivity loss under progressive climate change.

State of European forest under environmental changes. Lorenz, M., Fischer, R. (*Thünen Institute, Germany; martin.lorenz@ti.bund.de; richard.fischer@ti.bund.de*).

The state of the forests in Europe has been assessed for 29 years by the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) using harmonised methods and standards. Established by the Convention on Long-range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE), ICP Forests now rests on a revised monitoring system aimed at assessing relationships between air pollution, climate change, carbon fluxes, forest growth, forest health, and biodiversity. The revision of the monitoring system constituted a project co-financed under the LIFE Regulation of the European Commission. Results show that, in particular, N deposition still affects forest trees, forest ground vegetation, and forest soils on most of the monitoring plots. Studies of subsamples of these plots revealed an acceleration of critical load exceedance of N due to climate change. They also revealed that the proportion of plots acting as C sinks was higher than the proportion of plots acting as C sources. This sink function increases under expected future climate conditions. A positive effect on tree growth was observed for N deposition and above-average temperature.

The complex and surprising interaction of climate change and forest critical acid load exceedance. McNulty, S., Sun, G., Cohen, E. (*U.S. Forest Service, USA; smcnulty@fs.fed.us; gesun@fs.fed.us; eccohen@fs.fed.us*).

The first assessment (2007) of forest soil critical acid load exceedance for the conterminous United States (US) using a simple mass balance equation estimated that 15% of US forests were in exceedance of the soil critical acid load. This study expanded the original study by modifying the simple mass balance equation, using a process-based forest growth and water use model (WaSSI) and a series of climate change scenario runs, to assess the combined impact of climate change and acidic deposition on forest soil critical acid exceedance. Most of the historical forest critical load exceedance occurred in New England, where conditions associated with climate change such as tree growth and nutrient uptake, evapotranspiration and water yield, and base cation weathering, were all favorable to the reduction of forest soil critical load exceedance. Therefore, across the conterminous US, climate change was predicted to reduce the amount of forest area with the highest levels of acid exceedance by approximately 25%. Although encouraging, the study did not incorporate other factors that could significantly change the trend in forest sustainability such as increased wildfire, drought, and insect outbreak. Additional study is needed to fully assess these complex and surprising environmental interactions.

Effects of air pollution and climate change on forests in China. Shang, H., Chen, Z. (*Chinese Academy of Forestry, China; shanghechina@126.com; chenzhan0508@126.com*).

More and more attention has been paid to anthropogenic air pollution, greenhouse effects, and their impacts on global climate and eco-environment changes. Air pollution and climate change affects the forest ecosystem, which inversely gives a feedback to a certain extent. As an important part of the global terrestrial ecosystem, the response of the forest ecosystem in China to both air pollution and future global climate changes has become a very important issue. This paper summarizes systemically the monitoring, yearly changes, and the status quo of acidic deposition, nitrogen deposition and its ecological impact, as well as the impacts of global climate change on forest distribution, forest productivity, forest species composition, and forest soil. This paper also points out the main problems in present research, such as lack of long-term and systematic observations, rarely taking into account extreme climate events, ignoring the interaction between different forest species, separately addressing of the air pollution and climate change effects on forests, etc. In the end, the core issues and key contents about future research in this field are advanced.

The state of forest health in the United States and assessment of future risks from climate change, invasive species, and air pollution. Tkacz, B., Potter, K., Sapio, F. (*U.S. Forest Service, USA; btkacz@fs.fed.us; kevinpotter@fs.fed.us; fsapio@fs.fed.us*).

The forests of the United States (US) provide many benefits and services, including clean water, recreation, wildlife habitat, carbon sequestration, and a variety of forest products. While most of the forests appear healthy and green they face many threats to forest health and long-term sustainability. In the western US, outbreaks of native pests have killed trees on millions of acres, fires are burning larger areas than in the past, and severe droughts have led to additional stress on forest ecosystems. In the eastern US, the combined effects of invasive forest pests, atmospheric deposition, and human development have changed the structure and composition of many forests. Many of these threats may be exacerbated by a changing climate. This paper summarizes the current status and impact of forest health threats in the US and projects likely future risks.

G-02 Ozone and forest health

Organizers: Zhaozhong Feng (Chinese Academy of Sciences) & Elena Paoletti (National Research Council, Institute of Plant Protection, Italy)

Ozone changes and impacts in North American forests. Bytnerowicz, A. (*U.S. Forest Service, USA; abytnerowicz@fs.fed.us*).

Ambient ozone (O_3) is one of the most important air pollutants affecting growth and health of North American forests. Ozone significantly contributes to global warming 1) directly as a greenhouse gas, and 2) indirectly because it reduces photosynthesis and consequently CO_2 sequestration. Therefore, reducing O_3 concentrations is important for controlling global warming and improvement of forest health. In North America a slow but steady decline of ambient O_3 has occurred since the 1970s due to a strict implementation of the air pollution regulations aimed at reducing O_3 generation. These positive changes have resulted in lowering O_3 negative impacts on forests and other ecosystems. Spatial and temporal changes in ambient O_3 concentrations and its effects on health of sensitive species, changes in biodiversity, and forest growth will be presented with examples from various areas in North America with a special emphasis on California. Additionally, the importance of long-term O_3 monitoring will be discussed from a perspective of the effects of local O_3 generation and long-range transport of polluted air masses from Asia. Additionally, impacts of emissions from wildland fires on ambient O_3 will be presented.

Interaction of altered tropospheric ozone concentrations with loblolly pine decline. Chieppa, J., Chappelka, A., Eckhardt, L. (*Auburn University, USA; jjc0022@auburn.edu; chappah@auburn.edu; eckhalg@auburn.edu*).

Loblolly pine decline (LPD) is a cause of premature death of *Pinus taeda.* Two fungi associated with LPD are *Leptographium terebrantis* and *Grosmannia huntii.* This study was undertaken to determine how altered climate scenarios will affect LPD in the future. Our hypothesis was that exposure to increased ozone concentration would reduce vigor of *P. taeda* and exacerbate LPD by increasing susceptibility to *L. terebrantis* and *G. huntii*. The experiment used four families of *P. taeda*. Two were susceptible and two were more resistant to LPD associated fungi. Seedlings were deployed into open-top chambers. The four families had five inoculation treatments (wound, no wound, wound+media, *L. terebrantis*, and *G. huntii*). The experiment was conducted using three ozone treatments (ambient, charcoal-filtered, and 2X ambient). Treatments were replicated three times over 4 months. Field measurements included chlorophyll content, visible ozone injury, plant height, and root collar diameter. Laboratory measurements included lesion area, tissue occlusion, water potential, and dry weight biomass. Data were analyzed using SAS ANOVA procedures. Preliminary results show susceptible families showed greater ozone symptomology than resistant families. Overall results will give insight into future challenges in *P. taeda* production as well as examine the interactions between abiotic and biotic stresses of plants.

Interactions of ozone and selected physiological characteristics of mountain spruce forest in Beskydy Mts., Czech Republic. Cudlin, P. (*Academy of Sciences of the Czech Republic; pavelcu@usbe.cas.cz*), Zapletal, M., Chroust, P. (*Ekotoxa s.r.o., Czech Republic; milos.zapletal@ekotoxa.cz; petr.chroust@ekotoxa.cz*), Urban, O., Pokorný, R., Edwards, M., Havránková, K., Janouš, D., Večeřa, Z., Mikuška, P. (*Academy of Sciences of the Czech Republic; urban.o@czechglobe.cz; pokorny.r@czechglobe.cz; edwards.m@czechglobe.cz; havrankova.k@czechglobe.cz; janous.d@czechglobe.cz; vecera@iach.cz; mikuska@iach.cz*).

Daily ozone deposition and stomatal ozone flux of mountain spruce (*Picea abies* L. Karst) forest was measured using the gradient method and consequently modelled for selected summer periods (2007, 2008) as well as a whole growing season (2009). In addition, net ecosystem production (NEP), measured by eddy covariance techniques, tree stem increment, and sap flow were correlated with O_3 concentrations at 15 m above ground level, total O_3 deposition, and stomatal O_3 uptake. The experiments were done at Bílý Kříž experimental station (Beskydy Mts., Czech Republic). The O_3 exposition exceeded by almost two-fold the critical level of 5 000 ppb/h in all measured periods. The stomatal ozone uptake exceeded 8 mmol/m^2, the critical flux level suggested by the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (2010) for the protection of Norway spruce. NEP was negatively correlated with ozone concentration after treating solar radiation and air temperature as covariates. Based on these results, it is possible to hypothesize that NEP can be reduced by 10–15% due to stomatal ozone uptake during the growing season. The relationships between stomatal flux values and other physiological characteristics of Norway spruce will be discussed.

Reducing modelling uncertainties in ozone risk assessment for Mediterranean forests from comparison of modelled and measured phytotoxic ozone dose (POD) data. De Marco, A. (*National Agency for New Technologies (ENEA), Italy; alessandra.demarco@enea.it*), Sicard, P. (*ACRI-ST, France; pierre.sicard@acri-st.fr*), Fares, S. (*Agricultural Research Council, Italy; silvano.fares@entecra.it*), Renou, C. (*ACRI-ST, France; Camille.Renou@acri-st.fr*), Paoletti, E. (*National Research Council, Italy; e.paoletti@ipp.cnr.it*).

At present, the European standard for forest protection is the AOT40 index which is based on atmospheric O_3 concentration, although many studies suggest that a stomatal flux-based approach is scientifically sound and would be a useful tool for O_3 risk assessment. AOT40 and stomatal ozone uptake (POD0) were calculated for eight Mediterranean forest species in southeastern France and across Italy (4–18°E; 41–51°N). Meteorology, soil and canopy data, and ozone concentrations were calculated from the coupled WRF-CHIMERE modelling system, with a spatial resolution of 6 km. The Deposition of Ozone for Stomatal Exchange (DO3SE) model has been evaluated against observations for a number of different ecosystem types but has not been extensively tested under Mediterranean conditions. The maps showed different distributions of AOT40 and POD0 in this area. Four experimental sites, inside the study domain, provided eddy covariance towers for measurements of stomatal ozone flux over *Pinus pinea, Quercus ilex*, and *Pinus halepensis* canopies. The project provided an opportunity to infer an evaluation of the DO3SE model parameterisation through a comparison of observed and modelled total O_3 deposition. The DO3SE model POD was consistent with POD measured, if parameterization was correct. Generic tree parameterization was not working in assessing POD values.

Leaf mass per area elucidates ozone sensitivity of woody species. Feng, Z. (*Chinese Academy of Sciences, China; zhzhfeng201@hotmail.com*), Büker, P. (*University of York, UK; patrick.bueker@york.ac.uk*), Pleijel, H. (*University of Gothenburg, Sweden; hakan.pleijel@bioenv.gu.se*), Emberson, L. (*University of York, UK; l.emberson@york.ac.uk*), Uddling, J. (*University of Gothenburg, Sweden; johan.uddling@bioenv.gu.se*).

There is a large variation in the sensitivity to ozone (O_3) among different plant species and functional types as well as different climatic regions. Some evidence suggests that leaf dry mass per area (LMA) discriminates between O_3-sensitive and O_3-tolerant species. Being easily measured, LMA represents a potential approach to assess the O_3 sensitivity of species once a quantitative relationship between LMA and O_3 sensitivity is available. Results indicate that LMA was positively related to O_3 tolerance. Although no exact LMA threshold for O_3 tolerance could be determined, species with LMA >100 g/m^2 were usually tolerant to O_3. Evergreen species had higher LMA and were more tolerant to O_3 than deciduous species. A stomatal O_3 flux-response relationship across seven European forest tree species was strongly improved if flux was expressed per unit leaf mass compared to per unit leaf area. This study demonstrates that LMA plays a key role in determining O_3 sensitivity of woody plants and that it can be used for improving current O_3 flux-response relationships. Furthermore, it suggests that species with high LMA should be prioritized in afforestation and urban greening in O_3 polluted regions.

Can we predict tree response to ozone under climate change? Current status and perspectives. Matyssek, R. (*Munich University of Technology, Germany; matyssek@wzw.tum.de*), Wieser, G. (*Research Centre for Forests, Austria; Gerhard.Wieser@uibk.ac.at*).

Why still raise the question about predicting tree response to ozone (O_3) as part of climate change? Present knowledge has predominantly originated from O_3 experiments of limited relevance to growth conditions and tree age in forest ecosystems. Also, scientific awareness has moved from rating O_3 per se as a factor of tree death towards considering O_3 to be a stressor that in concert with other factors may weaken stress tolerance, competitiveness, and, ultimately, carbon sink strength. Such a pathway can be considered significant for climate change, although the plant's intrinsic plasticity for stress defence and multi-factorial complexes drive stress responses in the field. Databases are lacking, however, for advance modelling of O_3 risk. Ozone impact will be elucidated, therefore, as nested within multiple factorial interrelationships, exemplifying tree responses to interactions with nitrogen, drought, altitude/temperature, CO_2 and biotic influences. These are tree-associated (genotype, age) responses or may arise from competitive, host-parasitic/endophytic, and rhizospheric relationships. As predictability is limited on such grounds, systemic stand-level understanding is necessary. Conducive concepts will be addressed that integrate innovative field and indoor approaches. Such methods comprise the recently suggested supersites for forest research for unifying research, monitoring, and modelling of O_3 effects as part of climate change.

Ambient ozone and the occurrence of damage symptoms in sensitive plants in Beijing, China. Wang, X., Wan, W. (*Chinese Academy of Sciences, China; wangxk@rcees.ac.cn; wan.wx1972@126.com*).

Although decreasing in North America and Europe, ozone (O_3) concentration is rising in China. However, it has not been investigated whether wild plants have been damaged by high O_3 exposure in China, although the observed ambient O_3 concentration has exceeded the critical concentration (e.g., 40 ppbv) for plant injury in USA and Europe. This study aimed to discover if the high O_3 exposure has caused leaf damage in urban, suburban, and exurban areas of Beijing, where occurrences of high O_3 concentrations are common. In this study, Ogawa O_3 passive samplers were installed on10 sites to monitor O_3 concentration. Remarkably high mean ozone concentrations in exurban areas were observed. There was a linear relationship between the number of species having O_3 injury and the mean concentration of O_3 on all but one site. Obvious ozone-like foliar injury symptoms were found in 20 plant species. The observed ozone-damaged folia symptoms included stippling and mottling in adaxial leaf surfaces except veins, and were similar to the symptoms reported in USA and Europe. Intensive field surveys and confirmation of additional damage symptoms are required to assess the ozone impact on vegetation.

Posters

Stomatal ozone flux-response relationship for visible injury and net photosynthesis in poplar trees treated with or without EDU. Paoletti, E., Hoshika, Y., Pignattelli, S., Lazzara, M. Bartolini, P., Pecori, F. (*National Research Council, Italy; e.paoletti@ipp.cnr.it; hoshika0803@gmail.com; sara.pignattelli@gmail.com; m.lazzara@ipp.cnr.it; p.bartolini@ipp.cnr.it; f.pecori@ipp.cnr.it*).

We investigated ozone-induced visible injury and leaf gas exchange in an ozone-sensitive poplar clone (Oxford clone, *Populus maximoviczii* Henry × *berolinensis* Dippel) after 6 years of treatment with the ozone-protectant ethylenediurea (EDU) or with only water (WAT) under field conditions. Parameterization of the multiplicative stomatal conductance model was carried out to estimate stomatal ozone flux for both EDU and WAT treatments. We then analyzed the stomatal ozone flux-response relationship for both visible injury and net photosynthetic rate. Net photosynthetic rate decreased with leaf age in both treatments. Also lower net photosynthetic rate of WAT-treated plants was found, especially after onset of visible injury in autumn, although we observed slightly lower photosynthetic rate in WAT treatment during summer. Visible injury spread earlier in WAT treatment in autumn even when stomatal ozone flux was similar to those in EDU-treated poplars. As a result, earlier leaf abscission was observed in WAT plants. It appears that the relationship between stomatal ozone flux and ozone-induced damage to leaves was modified by EDU, thus leading to maintaining the leaves longer in EDU-treated plants.

Ecophysiological responses of beech (*Fagus crenata*) stressed by ozone exposure and/or water shortage. Shimizu, H., Ito, S. (*National Institute for Environmental Studies, Japan; hshimizu@nies.go.jp; kobayashi.shoko@nies.go.jp*), Aihara, K. (*Kanagawa Prefecture Natural Environment Conservation Center, Japan; aihara.ebh@pref.kanagawa.jp*), Suda, R. (*Fukuoka Institute of Health and Environmental Sciences, Japan; suda@fihes.pref.fukuoka.jp*).

Recently, beech forest decline has been reported at many mountainous areas in Japan, such as Tanzawa Mountains in the Kanagawa Prefecture. Extensive studies have been conducted in the Tanzawa Mountains since the 1980s, and ozone (O_3), water shortage, and beech sawfly were suspected as causal factors of the decline. We examined the ecophysiological characteristics of beech seedlings using environment-controlled growth cabinets, to clarify the acute and chronic effects of O_3 exposure and water shortage, singly or in combination, on this species. Seedlings were exposed to 70, 50, or 0 ppb O_3 with different water shortage condition such as 100% (1 300 mm), 80%, 60%, and 40% precipitation during 22 weeks; these values are similar to field data from the Tanzawa area. With increasing O_3 concentration or decreasing water supply, the dry weight growth of beech seedlings was decreased. The net assimilation rate (NAR) and the relative growth rate (RGR) tended to decrease with O_3 increase or water shortage. In the present experiment, some ecophysiological activities such as photosynthesis and transpiration were damaged by chronic treatments of O_3 and/or water stresses. These two factors acted additively (from the ANOVA), which strongly suggested that O_3 and water shortage induced the observed decline of beech forests in the Tanzawa Mountains.

Ozone stomatal flux-based critical levels translated into real-world forest impacts. Sicard, P. (*ACRI-ST, France; pierre.sicard@acri-st.fr*), De Marco, A. (*Elabore Ltda, Italy; alessandra.demarco@casaccia.enea.it*), Dalstein-Richier, L. (*GIEFS, France; ldalstein@aol.com*), Paoletti, E. (*National Research Council, Italy; e.paoletti@ipp.cnr.it*).

In the western European Mediterranean area, ozone pollution is a major air quality issue in both remote and urban atmospheres. Surface ozone is a pressing sanitary problem affecting trees. To date, most experiments to establish biologically relevant plant

responses to ozone have been performed under controlled conditions, not representative of actual field conditions, and the results may not provide realistic results for developing standards. The FO3REST project allows testing the current ozone critical levels (CL) for Mediterranean forest species and suggesting new ozone CLs for forest protection against ozone pollution. An assessment based on phytotoxic ozone dose (PODY) and on real plant damage is appropriate. Stomatal ozone fluxes were modelled and correlated to real-world forest impacts in terms of visible injury in 2012 and 2013. A field survey of ozone-induced symptoms was carried out in 52 plots in southeastern France and northwestern Italy. The indicators POD0 and POD1 were calculated with the DO3SE model using the available parameterization for Mediterranean and continental deciduous broadleaf forests and conifers. Spearman tests were carried out to understand the relative contribution of O_3 to visible injury occurrence. From the dose-response function, we proposed new stomatal flux-based and concentration-based critical levels for policymakers.

G-03 Critical loads for nutritional nitrogen deposition: Progress and problems

Organizers: Sarah Jovan, Andrzej Bytnerowicz & Mark Fenn (U.S. Forest Service)

Using nitrogen critical loads to develop research priorities, ecosystem condition assessments, and restoration strategies for U.S. National Park Service lands. Blett, T. (*National Park Service, USA; tamara_blett@nps.gov*).

A critical loads approach utilizes both science and policy. On the science side, researchers establish ecosystem response thresholds to atmospheric deposition, by either modeling or using empirical studies to document excess nitrogen impacts on ecosystems under various deposition loading regimes. The policy side utilizes critical loads to set ecosystem management or air quality goals (target loads) that meet the needs of land and air management and regulatory agencies. These target loads can be compared to current and future deposition levels to determine where exceedances are occurring, and identify areas where air pollution may be impacting ecosystems. We will describe ways in which National Park Service (NPS) land managers are using nitrogen critical loads in the U.S. to identify gaps in knowledge, understand ecosystem conditions, and promote recovery where sensitive resources are impacted. We will discuss approaches being used to advance critical loads collaboration and synthesis with land management and air regulatory agencies, universities, and other partners. Case studies will be presented showing how critical loads science in national parks is being used in policy and management decisions that support emissions reductions in areas where they are needed to allow ecosystem recovery.

Critical loads for nitrogen and sulfur atmospheric deposition in the Great Smoky Mountains National Park, USA. Fakhraei, H., Driscoll, C. (*Syracuse University, USA; hfakhrae@syr.edu; ctdrisco@syr.edu*), Moore, S., Kulp, M. (*National Park Service, USA; Steve_E_Moore@nps.gov; Matt_Kulp@nps.gov*), Schwartz, J. (*University of Tennessee, USA; jschwart@utk.edu*).

Critical loads (CLs) for nitrogen and sulfur were estimated for stream-watersheds in the Great Smoky Mountains National Park (GRSM). Among 18 stream-watersheds studied in this research, nine sites are listed under Section 303(d) of the Clean Water Act as impaired due to elevated acidity. We investigated the potential recovery of these sites in response to recent and future projected declines in atmospheric deposition. We used a dynamic biogeochemical model, PnET-BGC, to develop CLs to recover the acid neutralizing capacity of streams above three target values of 0, 20, and 50 μeq/L. As important inputs of the model, spatial and temporal patterns of atmospheric deposition and climatic drivers were estimated by developing empirical models of collected data from monitoring stations inside and near the GRSM. The PnET-BGC model parameters were calibrated based on long-term observed stream chemistry. The calibrated model was run for different reduction levels of atmospheric deposition to develop S and N load-response curves. Using these response curves, the CLs and exceedances of atmospheric S and N deposition were calculated and depicted through GIS maps. Sensitivity and uncertainty analyses were conducted on the most sensitive model parameters and inputs to determine 90% level of confidence for future model projections.

Nitrogen flux measurements: toward ecosystem effects and critical load development. Fenn, M., Bytnerowicz, A (*U.S. Forest Service, USA; mfenn@fs.fed.us; abytnerowicz@fs.fed.us*).

Quantifying nitrogen (N) deposition fluxes in forests and other ecosystems is difficult, especially when deposition fluxes are needed at multiple sites. Because of the inherent strengths and weaknesses of the various methods used to measure N deposition, often multiple approaches are needed. Empirical site-specific measurements are usually preferred for developing critical loads or dose-response relationships, or to evaluate biological or ecological responses across spatial deposition gradients. Simulated deposition models are particularly useful for broad scale evaluations and to provide deposition data where empirical data are not available. Empirical deposition data can be used for model evaluation and hybrid simulation models benefit from empirical data input where they are available. The use of passive samplers for measuring throughfall deposition, and for collecting data on atmospheric concentrations of the primary pollutants that drive N deposition, can greatly expand our capacity to quantify N deposition and its ecological effects across the landscape. We will describe a modified inferential method providing fine-scale calculated N deposition based on air quality data from passive samplers collected in the summers of 2002–2006 in the San Bernardino Mountains in southern California. Applications to critical loads development and exceedance mapping will be discussed.

Atmospheric nitrogen deposition and critical loads for holm oak forests in Spain. García-Gómez, H. (*Research Centre for Energy, Environment and Technology (CIEMAT), Spain; hector.garcia@ciemat.es*), Aguillaume, L. (*Universitat Autònoma de Barcelona, Spain; aguillaume.laura@gmail.com*), Izquieta, S. (*Universidad de Navarra, Spain; sizquieta@alumni.unav.es*), Valiño, F. (*Research Centre for Energy, Environment and Technology (CIEMAT), Spain; fernando.valino@ciemat.es*), Âvila, A. (*Universitat Autònoma de Barcelona, Spain; anna.avila@uab.es*), Elustondo, D., Santamaría, J. (*Universidad de Navarra, Spain; delusto@unav.es; chusmi@unav.es*), Calvete-Sogo, H., González-Fernández, I., Alonso del Amo, R. (*Research Centre for Energy, Environment and Technology (CIEMAT), Spain; hector.calvete@ciemat.es; ignacio.gonzalez@ciemat.es; rocio.alonso@ciemat.es*).

Atmospheric nitrogen deposition in Spain (10–30 kg N/ha/year) is lower than loads recorded in central Europe, but some evidence indicates that N enrichment is already occurring in some ecosystems. Little information is available on thresholds of

atmospheric N deposition for the protection of Mediterranean ecosystems. Moreover, dry deposition can represent about 40–75% of total atmospheric N deposition, but characterizing dry deposition is still challenging since no standard method is available. A study was carried out throughout 2011–2012 in three *Quercus ilex* forests located in Spain under different edaphic and climatic conditions. Atmospheric concentration of N pollutants and wet and dry N deposition were assessed at the three sites using the same methodology. Different methods were tested; bulk and throughfall samples were collected weekly and dry deposition was estimated seasonally using rinsing techniques of natural and lyophilized branches. Throughfall did not result a good indicator of N deposition in these forests since canopy uptake occurs during part of the year. Loss of NO_3^- in soil water was detected when atmospheric N inputs occurred in periods of low biological activity. The results highlight the importance of synchronicity between N deposition and biological demand for critical load estimations.

Lichen-based critical loads of nitrogen for forested ecoregions of the United States. Geiser, L., Jovan, S. (*U.S. Forest Service, USA; lgeiser@fs.fed.us; sjovan@fs.fed.us*).

Epiphytic lichen community composition is highly sensitive to nutrient nitrogen (N) deposition; therefore, lichen-based critical loads can be broadly protective of forested ecosystems. Lichen data from 10 000+ systematic surveys following the U.S. Forest Service Forest Inventory and Analysis lichen community protocol were compiled into a national database together with ecoregion, stand, deposition, and climate variables. Lichen-based nutrient N critical loads were calculated by 1) rating the N-sensitivity of all common lichens within each ecoregion based on the deposition intervals in which they were most likely to occur; 2) scoring the relative abundance of tolerant to sensitive species at each survey site, and 3) quantifying the relationship between the site scores and N deposition as determined by the Community Multi-Scale Air Quality Model (CMAQ) after accounting for climate, acidic deposition, and stand composition. In all ecoregions, as N deposition increased, lichen community composition shifted, increasingly favoring tolerant over sensitive species. Because all response curves were continuous and the greatest shifts in species composition were typically associated with the first 2–7 kg of added N, we conclude that critical loads protective of the natural range of lichen community composition are best represented by the upper limit for the ecoregion's natural background deposition range, or 2–3 kg N/ha/year.

Evaluating effects of atmospheric N and S deposition and climate on forest ecosystem services based on the critical loads paradigm. McDonnell, T., Sullivan, T. (*E&S Environmental Chemistry, USA; todd.mcdonnell@esenvironmental.com; tim.sullivan@esenvironmental.com*).

Atmospheric nitrogen (N) and sulfur (S) deposition are known to affect forest ecosystem health, biodiversity, and associated ecosystem services (ES). These effects are exacerbated by changes in temperature and precipitation. The critical load (CL) is the level of sustained atmospheric deposition of N, S, or acidity below which significant harm to sensitive ecosystems is not expected to occur. It can be used to evaluate inherent ecosystem sensitivity and changes in key drivers of ecosystem biodiversity. When combined with estimates of ambient pollutant exposure, the CL reflects the risk of ecosystem damage in response to pollutant inputs. Ambient deposition which is greater than the calculated CL indicates that the CL is in exceedance, ecosystem damage is likely, and ES are threatened. We have applied the CL concept in the U.S. to evaluate the effectiveness of the Clean Air Act (CAA) and the 1990 CAA amendments. Recent modeling efforts and gradient studies to characterize terrestrial and aquatic ecosystem sensitivity will be discussed with a focus on how the CL concept can be used to evaluate effects on ES. Results from ongoing studies to evaluate terrestrial effects thresholds to facilitate more accurate CL estimates for protecting vegetation conditions will also be presented.

Critical load of atmospheric nitrogen deposition in French forests: modelling soil and vegetation responses in the context of climate change. Rizzetto, S., Gaudio, N. (*École Nationale Superieure Agronomique de Toulouse (CNRS-EcoLab), France; simon.rizzetto@ensat.fr; noemie.gaudio@gmail.com*), Belyazid, S. (*Lund University, Sweden; salim@belyazid.com*), Gégout, J. (*National School of Rural Engineering, Water Resources and Forestry (ENGREF), France; jean-claude.gegout@agroparistech.fr*), Alard, D., Corcket, E. (*National Institute for Agricultural Research (INRA), France; d.alard@ecologie.u-bordeaux1.fr; e.corcket@ecologie.u-bordeaux1.fr*), Sverdrup, H. (*Lund University, Sweden; harald.sverdrup@chemeng.lth.se*), Probst, A. (*École Nationale Superieure Agronomique de Toulouse (CNRS-EcoLab), France; anne.probst@ensat.fr*).

Anthropogenic activities highly contributed to increased nitrogen and sulfur atmospheric emissions since 1880. Nitrogen deposition is known to severely impact ecosystem functioning by influencing soil biogeochemistry, nutrient balance, and consequently tree growth, forest health, and biodiversity. Since the 1980s, within the Geneva Convention on Long-Range Transboundary Air Pollution, European countries have joined their efforts to abate atmospheric pollution. The concept of N critical loads was developed to mitigate the impacts of N deposition. Moreover, because climate greatly influences soil processes, climate change and atmospheric deposition must be jointly taken into account to assess the evolution of forest ecosystem status over time. The purpose of this study was to predict forest vegetation response to the combined effects of nitrogen atmospheric deposition and climate change by using a dynamic coupled biogeochemical-ecological model (ForSAFE). We ran this model for various climatic and deposition scenarios on several temperate French forest sites, from today to 2100. The outputs of the biogeochemical model were used as inputs to a vegetation table compiling reference ecological parameters for more than 450 species. We present the results of the biogeochemical response, namely the changes in soil parameters, and illustrate the response of the vegetation groups regarding vegetation cover.

Critical loads and climate change in the Polish-Saxon border region. Scheuschner, T. (*OEKO-DATA GmbH, Germany; thomas.scheuschner@oekodata.com*).

Threshold values for the effects of air pollutants have attained great importance in the derivation of environmental goals as they are the most convincing criteria for tolerable intensities of anthropogenic interference with ecosystems or their sensitive components. Critical loads are such threshold values. By definition they are quantitative estimates of an exposure to a deposition of one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. They are derived by combinations of chemical, physical, biological, or geo-scientific indicators.

These can include pH, concentrations of toxic aluminum ions, leaching terms, or acid neutralization capacity. These values are purely scientific and unbiased but, while they reflect the state of present knowledge, are subject to revision as science further develops. The application of the critical loads concept is suitable to describe the limit to which a receptor system may be exposed to pollution without a risk of detectable damage in the long term, or the threshold below which present loading has to be reduced for recovery.

Does low-dose N addition enhance growth in fertile *Picea abies* forests? Sikström, U., Högbom, L. (*Skogforsk, Sweden; ulf.sikstrom@skogforsk.se; lars.hogbom@skogforsk.se*).

It is under debate to what extent deposited air-borne N contributes to increased sequestration of atmospheric CO_2 into wood. We studied the effects of different application rates of N on tree growth at three, for Swedish standards quite fertile, experimental sites with 30-year-old *Picea abies* (L. Karst) stands in southern Sweden. The treatments included untreated control, 20 kg N/ha every year, 60 kg N/ha every third year, and, 120 kg N/ha every sixth year; N was applied as NH_4NO_3. The experiment had a randomized block design with three replicates per site and a plot size of 30 m × 30 m. It was hypothesized that, given the same total amount of N, annual N additions at low doses would lead to a smaller uptake of N by the trees, and, thus, lower tree growth, compared to less frequent applications at higher doses. Tree stem growth was assessed 12 years after the start of treatment, i.e., after two treatment cycles. The results suggest a minor or negligible impact of atmospheric deposition of N on tree growth and adherent C-sequestration in the examined Norway spruce forest stands on fertile mineral soils located within the boreonemoral zone.

G-04 Emerging invasive forest pathogens

Organizers: Phil Cannon (U.S. Forest Service), JP Skovsgaard (Swedish University of Agricultural Sciences), Ned Klopfenstein (U.S. Forest Service) & Steve Woodward (University of Aberdeen, UK)

Role of infection pressure and cuticle in leaf infection by *Hymenoscyphus pseudoalbidus*. Børja, I., Nagy, N., Hietala, A., Timmermann, V., Solheim, H. (*Norwegian Forest and Landscape Institute, Norway; isabella.borja@skogoglandskap.no; nina.nagy@skogoglandskap.no); ari.hietala@skogoglandskap.no; volkmar.timmermann@skogoglandskap.no; halvor.solheim@skogoglandskap.no*).

Ash dieback caused by the ascomycete *Hymenoscyphus pseudoalbidus* has rapidly spread throughout most of Europe during the past 20 years, causing serious damage on ash trees. Although it is known that infection occurs via airborne ascospores, there is little knowledge about the infection pressure necessary to cause the disease and the conditions for successful establishment of the disease. To answer these questions, leaves of uninfected 3-year-old ash trees were repeatedly inoculated with different concentrations of ascospores under controlled phytotron conditions, and health status was subsequently monitored. In a second group of trees grown outdoors, we mechanically removed the cuticle before inoculation. We found that inoculation by dipping leaflets in suspensions with up to 192 500 spores/ml gave no leaf symptoms on leaves of plants in phytotron during the 8-week-long incubation period. However, leaves with prior cuticle damage showed necrotic veins typical to ash dieback 8 weeks post infection (with spore suspension 192 500 spores/ml), suggesting that young, emerging leaves with thin or mechanically damaged cuticles are more prone to infection. Our results indicate that although infection pressure may be important, other factors such as leaf age and leaf cuticle condition also play a decisive role in the infection process.

Characterization and distribution of fungi associated with needle defoliation of eastern white pine (*Pinus strobus*). Broders, K., Wyka, S. (*University of New Hampshire, USA; kirk.broders@unh.edu; StephenWyka@gmail.com*), Munck, I. (*U.S. Forest Service, USA; imunck@fs.fed.us*).

Eastern white pine is a crucial ecological and economic component of forests in the northern United States and eastern Canada and is facing an emerging problem with white pine needle defoliation (WPND). It is unclear whether WPND is caused by one or a combination of multiple fungal pathogens. Therefore, the objective of this study was to characterize the fungi associated with WPND in the northeastern United States. To date, 16 species of fungi, either cultured from diseased pine needles or from fruiting bodies on pine needles, were identified based on morphology and sequence data. *Lecanosticta acicola* (*Mycosphaerella dearnessii*), a historically southern pine pathogen, and a putative new species of *Septorioides* were the species most frequently recovered from diseased needles. We also provide the first phylogenetic analysis of *Canavirgella bandfieldii* and *Bifusella linearis*, two obligate biotrophic fungi frequently observed on pine needles in the Northeast, for which no sequence data was previously available. In addition, putative new species of *Stagonospora* and *Hemiphacidium* found on eastern white pine are described. While *L. acicola* appears to be the primary pathogen causing WPND, several other new emerging pathogens as well as common needle pathogens are being more frequently observed. Current research is investigating the role of climate on epidemics of WPND and the potential northerly migration of *L. acicula* into northeastern pine populations.

The impact of different strains of *Puccinia psidii* on Hawaii's ohia (*Metrosideros polymorpha*). Cannon, P. (*U.S. Forest Service, USA; pcannon@fs.fed.us*), Costa da Silva, A., Alfenas, A. (*Federal University of Viçosa, Brazil; andrec_agro@yahoo.com.br; aalfenas@ufv.br*), Graca Neves, R. (*Futuragene, Brazil; rodrigo@futuragene.com*).

By 2005, one strain of *Puccinia psidii* had already made it to Hawaii. It caused substantial damage to some myrtaceous tree and shrub species found on the islands of this state but was causing little damage to the ohia (*Metrosideros polymorpha*) which is, by far, the most prevalent tree species found in the native forests of Hawaii. There was concern that other strains of *P. psidii*, not yet in Hawaii, might be more pathogenic to ohia. Research was done in Brazil, first to discover other strains of *P. psidii* and then to test five of these strains for their pathogenicity to ohia. Three of the five strains were determined to be very pathogenic to ohia. These results were presented to Hawaii's quarantine regulators recently and some appropriate action has been taken. The results of this research almost certainly have wider implications as the Myrtaceae family includes a very large number of important and widely distributed tree species.

Dieback of European ash: understanding the inherent host resistance and conservation strategies for this ecologically and economically important tree species. Cleary, M., Elfstrand, M., Brandström-Durling, M. (*Swedish University of Agricultural Sciences, Sweden; Michelle.Cleary@slu.se; Malin.Elfstrand@slu.se; Mikael.Durling@slu.se*), Stener, L. (*Skogforsk, Sweden; lars-goran.stener@skogforsk.se*), Vasaitis, R., Stenlid, J. (*Swedish University of Agricultural Sciences, Sweden; Rimvys.Vasaitis@slu.se; jan.stenlid@slu.se*).

Hymenoscyphus pseudoalbidus, the causal agent of ash dieback, is currently threatening common ash (*Fraxinus excelsior*) populations across Europe. This presentation will give an overview of the history, current status, and future prospects of this emerging invasive disease, with special emphasis on Sweden where ash is now a Red-Listed species. Much research has been done to understand the infection biology and fungal lifecycle, metabolites, and population structure both in Europe and in its native environment in East Asia where it does not cause any symptoms on *Fraxinus* spp. The indigenous saprophyte *H. albidus* is morphologically similar to, and occupies the same ecological niche as, *H. pseudoalbidus* but is now locally extinct in some areas. The sequenced genomes of both *Hymenoscyphus* spp. reveal unique and expanded gene families in *H. pseudoalbidus*, possibly associated with pathogenicity. Evidence of natural resistance against *H. pseudoalbidus* has been observed in heavily damaged stands. Assessments of clonal seed orchards in Sweden and elsewhere suggest a strong genetic, heritable component in the host population for resistance against the disease. Through transcriptomic studies focused on host defense strategies, the mechanisms behind this observed resistance can facilitate better selection of tolerant ash genotypes for future propagation and breeding for increased resistance.

Laboratory and field experiments to test the susceptibility of several conifers to the pitch canker disease. Diez-Casero, J., Martínez-Álvarez, P., Pando, V. (*University of Valladolid, Spain; jdcasero@pvs.uva.es; pmtnez@pvs.uva.es; vpando@eio.uva.es*), De Vallejo, M., Blanco, J. (*Government of Cantabria, Spain; vallejo_m@cantabria.es; blanco_j@cantabria.es*).

Since 2004, when the pitch canker pathogen *Fusarium circinatum* was first found to cause damage in nurseries and pine plantations in northern Spain, establishment of pine plantations in the region has decreased as a result of the prohibitions placed on planting *Pinus* spp. and *Pseudotsuga menziesii* in areas affected by the disease. Some experiments has been performed to test the susceptibility of several pine species in nurseries, but still little is known about how the fungus affects the trees in field conditions. Furthermore, it is not known whether some of the native or exotic species commonly planted in the area are also susceptible to *F. circinatum*. The objective of this study was to evaluate the susceptibility to the pitch canker pathogen of several conifer species commonly planted in northern Spain. We carried out two different trials, one under controlled laboratory conditions and the other in the field. Although in the laboratory tests most of the conifers were affected by the pathogen, in the field only *P. radiata*, *P. nigra*, *P. pinaster*, and *P. uncinata* were susceptible to the pathogen.

Genetic diversity of *Puccinia psidii*, the cause of guava/eucalypt/myrtle rust, and preliminary predictions of global areas at risk. Graça, R. (*Federal University of Viçosa, Brazil; rnevesg@gmail.com*), Peever, T. (*Washington State University, USA; tpeever@wsu.edu*), Uchida, J., Kadooka, C. (*University of Hawaii at Manoa, USA; juchida@hawaii.edu; kadooka@hawaii.edu*), Kim, M. (*Kookmin University, Republic of Korea; mkim@kookmin.ac.kr*), Cannon, P. (*U.S. Forest Service, USA; pcannon@fs.fed.us*), Namba, S. (*University of Tokyo, Japan; anamba@mail.ecc.u-tokyo.ac.jp*), Simeto, S. (*National Agricultural Research Institute of Uruguay, Uruguay; ssimeto@tb.inia.org.uy*), Pérez, C. (*University of the Republic, Uruguay; caperez@fagro.edu.uy*), Rayamajhi, M. (*Agricultural Research Service, USA; min.rayamajhi@ars.usda.gov*), Moran, M. (*Desarrollos Madereros S.A., Paraguay; mmoran@pomera.com.ar*), Lodge, D. (*U.S. Forest Service, USA; dlodge@fs.fed.us*), Arguedas, M. (*Costa Rica Institute of Technology, Costa Rica; marguedas@itcr.ac.cr*), Medel-Ortiz, R., López-Ramirez, M. (*University of Veracruz, Mexico; romedel@uv.mx; armlopez@uv.mx*), Tennant, P. (*University of the West Indies, Jamaica; paula.tennant@uwimona.edu.jm*), Glen, M. (*University of Tasmania, Australia; morag.glen@utas.edu.au*), McTaggart, A. (*University of Queensland, Australia; a.mctaggart@uq.edu.au*), Klopfenstein, N. (*U.S. Forest Service, USA; nklopfenstein@fs.fed.us*), Hauff, R. (*Hawaii Department of Land and Natural Resources, USA; Robert.d.hauff@hawaii.gov*), Hanna, J., Ross-Davis, A (*U.S. Forest Service, USA; jhanna@fs.fed.us; arossdavis@fs.fed.us*), Alfenas, A. (*Federal University of Viçosa, Brazil; aalfenas@ufv.br*).

The biotrophic rust fungus, *Puccinia psidii*, first reported in Brazil from guava in 1884 and later from eucalyptus in 1912, has recently been detected on diverse myrtaceous hosts in South America, Central America, the Caribbean, Mexico, the USA, Japan, Australia, China, South Africa, and New Caledonia. Given the alarming rate at which the pathogen is spreading and its wide host range, the objectives of this study were to 1) evaluate the genetic diversity within and among populations across the pathogen's putative native range as well as areas of recent introduction, 2) assess possible pathways of spread, and 3) predict geographic locations that are climatically suitable for the disease in an effort to determine global areas at risk of invasion. Microsatellite markers revealed several unique multilocus genotypes among samples which clustered into distinct genetic groups. Global predictions of suitable climate space for *P. psidii* were determined via bioclimatic modeling performed using all documented rust occurrences as well as a reduced set of the global pandemic records of occurrence, each coupled with 19 bioclimatic variables. This work builds on previous research that shows that genetic diversity must be considered when assessing the invasive threat posed by this pathogen to myrtaceous hosts worldwide.

Emerging diseases threaten the white pine resource in eastern North America. Munck, I. (*U.S. Forest Service, USA; imunck@fs.fed.us*), Broders, K. (*University of New Hampshire, USA; kirk.broders@unh.edu*), Schultz, B. (*Vermont Department of Forests, Parks and Recreation, USA; barbara.schultz@state.vt.us*), Ostrofsky, W. (*Maine Forest Service, USA; bill.ostrofsky@maine.gov*), Lombard, K. (*New Hampshire Division of Forests and Lands, USA; Kyle.Lombard@dred.state.nh.us*), Cox, K. (*Cornell University, USA; kdc33@cornell.edu*), Livingston, W. (*University of Maine, USA; WilliamL@maine.edu*), Weimer, J. (*New Hampshire Division of Forests and Lands, USA; jennifer.weimer@dred.state.nh.us*), Luther, T. (*U.S. Forest Service, USA; tluther@fs.fed.us*).

Eastern white pine (*Pinus strobus*) is a crucial ecological and economic component of eastern forests. Three emerging disease problems threaten this resource. White pine blister rust (WPBR) has threatened both forests and agricultural commodities since its introduction in the early 1900s. The fungus produces spores on gooseberries that kill white pines. A federal quarantine was

instituted in the 1920s prohibiting gooseberry cultivation. After the lifting of the Federal quarantine and the more recent availability of disease-resistant gooseberries, States in the Northeast amended their restrictions. In 2011 a breakdown of WPBR immunity in cultivated gooseberries was discovered in Connecticut. A second problem, an unprecedented epidemic of foliar pathogens, has repeatedly defoliated white pines since 2010 following an unusually wet spring. Thirdly, Caliciopsis canker is a native disease that has been receiving renewed interest because of its association with declining white pine health. Cooperative efforts have been established among the U.S. Forest Service, Canadian Forest Service, Cornell University, University of New Hampshire, University of Maine, and forest health cooperators from New England to 1) continue regional surveys to evaluate the impact of WPBR, 2) monitor and evaluate impact of foliar diseases, 3) develop management guidelines for Caliciopsis canker, and 4) provide disease information products.

Alien invasive threats to UK forests: a reassessment in the wake of ash dieback. Woodward, S., Boa, E. (*University of Aberdeen, UK; s.woodward@abdn.ac.uk; e.boa@cabi.org*).

UK forests and woodlands, and trees in other situations, are facing unprecedented challenges from the influx of alien invasive pests and pathogens resulting from increased global trade. Confirmation of the presence of ash dieback, caused by *Hymenoscyphus pseudoalbidus*, in UK woodlands in late 2012 provided a wake-up call to the authorities, leading to a flurry of activity from the government, sometimes prompted by the noisy clamour raised by the media on the subject, aimed initially at containing the problem, but rapidly evolving into planning for a future without substantial numbers of *Fraxinus excelsior* in the environment. The arrival of this new disease, however, should not have been a surprise. Ash dieback was well-known from a steady advance across Europe. Ash dieback, however, is only one of many known pests and pathogens threatening trees in the UK. Add the potential numbers of unknown pathogens, and the number of threats could become very large indeed. Current threats, including the panoply of *Phytophthora* spp. already present in Europe, along with pathogens such as *Ceratocystis platani* and *Fusarium circinatum*, will be put in perspective against the potential hosts present and grown widely in the UK. In addition, the recommendations of the UK Government's Tree Health Task Force will be presented for discussion.

G-05 Global approaches to the biological control of invasive Eucalyptus pests

Organizers: Simon Lawson (Queensland Department of Agriculture, Fisheries and Forestry, Australia), Toni Withers (Scion, New Zealand) & Helen Nahrung (University of the Sunshine Coast, Australia)

Biological control of the eucalyptus gall wasp, *Leptocybe invasa*, in South Africa. Hurley, B., Dittrich-Schröder, G., Baffoe, K., Wingfield, M., Slippers, B., Garnas, J. (*FABI, University of Pretoria, South Africa; brett.hurley@up.ac.za; Gudrun.Dittrich@fabi.up.ac.za; kwabena.baffoe@fabi.up.ac.za; mike.wingfield@fabi.up.ac.za; Bernard.Slippers@fabi.up.ac.za; jeff.garnas@fabi.up.ac.za*).

The eucalyptus gall wasp, *Leptocybe invasa* (Hymenoptera, Eulophidae), is native to Australia, but since 2000 has spread to all continents where *Eucalyptus* spp. are grown commercially. The insect causes leaf and petiole galls which result in deformation and stunted growth in numerous species of *Eucalyptus,* causing substantial losses in countries where it has been introduced. Biological control is one of the most viable options for the management of this pest. The parasitic wasp, *Selitrichodes neseri* (Hymenoptera, Eulophidae), was discovered in Australia in 2010, and successfully reared in quarantine and later released in South Africa. *Selitrichodes neseri* has displayed many favorable characteristics as a potential biological control agent, including high rates of parasitism on *L. invasa*, short developmental time, lack of a pre-oviposition period, long adult lifespan, ability to utilize a range of different gall ages, and high host specificity. Post-release studies have shown a high establishment success, but the impact of these releases on *L. invasa* populations must still be determined. Research is also underway to investigate the influence of temperature and other climatic factors on *S. neseri* survival and establishment, and to better understand host behaviors.

BiCEP: Australia's key role in providing biocontrol solutions for global Australian-origin eucalypt pests. Lawson, S., Griffiths, M., Nahrung, H. (*University of the Sunshine Coast, Australia; Simon.Lawson@daff.qld.gov.au; manon.griffiths@daff.qld.gov.au; hnahrung@usc.edu.au*).

Australian-origin insect pests threaten the productivity and sustainability of eucalypt plantations worldwide. New pests such as the bronze bug (*Thaumastocoris peregrinus*), two gall wasps (*Leptocybe invasa* and *Ophelimus maskelli*) and the lerp psyllid (*Glycaspis brimblecombei*) have emerged as key global pests, while longer-established pests such as the eucalyptus snout beetle (*Gonipterus* spp. complex) are re-emerging as significant issues. The speed at which these pests have emerged, invaded, and spread globally has taxed industry's ability to manage them effectively. Global issues such as these require global solutions. The Biological Control of Eucalypt Pest Research Alliance (BiCEP) has been established in Australia to provide a focus for developing biological control solutions for key eucalypt pests. BiCEP is funded by eucalypt plantation industry partners and delivers the research and development required to underpin effective biological control of pests in three categories of need: discovery (pests that do not have known effective biocontrol agents), application (pests with known but not yet established or evaluated biocontrol agents), and fine-tuning (pests that have established biocontrol agents but which require better climate/host matching). BiCEP is funded pro rata on area of partner's plantations. Examples of research in these categories will be outlined.

Towards biological control strategies for the bronze bug, *Thaumastocoris peregrinus*, on eucalyptus plantations in South America. Martinez, G. (*National Agricultural Research Institute, Uruguay; gmartinez@tb.inia.org.uy*), Barbosa, L. (*EMBRAPA, Brazil; leonardo.r.barbosa@embrapa.br*), Botto, E. (*Instituto Nacional de Tecnología Agropecuaria, Argentina; enbotto@cnia.inta.gov.ar*), Wilcken, C. (*São Paulo State University, Brazil; cwilcken@fca.unesp.br*).

The bronze bug is an invasive Australian pest that has reached eucalypt production areas worldwide in <10 years. The first record in South America was in 2005 in Argentina. Collaboration in the region towards a unified strategy for the management of the

bronze bug started soon after the dispersal of the pest into Brazil and Uruguay was confirmed. Here, we present the main achievements of this collaboration in four main topics: 1) biology of the pest, 2) monitoring, 3) biological control, and 4) cooperative networks. Two mass rearing procedures have been implemented in the region with relative success, allowing basic biological studies on the pest. Continuous monitoring in the region for >5 years has provided a reasonable knowledge on seasonal patterns of *T. peregrinus*. Biological control strategies developed include the use of local natural enemies of *T. peregrinus*, the development of biopesticides, and the introduction of *Cleruchoides noackae*, an egg parasitoid of *T. peregrinus* from Australia. We review the main achievements in each country. Finally, a regional network of institutions, researchers, and students has strengthened in the region, providing a solid background for future collaboration.

Lessons from successful classical biological control in Israel of *Leptocybe invasa* and *Ophelimus maskelli*. Mendel, Z., Protasov, A. (*Agricultural Research Organization, Israel; zmendel@volcani.agri.gov.il; protasov@volcani.agri.gov.il*), Brand, D. (*Keren Kayemeth LeIsrael, Israel; davidb@kkl.org.il*), Branco, M. (*Technical University of Lisbon, Portugal; mrbranco@isa.utl.pt*).

Two gall wasps were the targets of a biological control project in Israel. Approximately a decade after the liberation of seven parasitoid species, both gallers have become quite rare. In each galler case, it was eventually difficult to predict which parasitoid species might be the best agent for biocontrol. Here, the dominant parasitoid species during the early stage of colonization and the outbreak situation was not necessarily the common species when the galler population had reached the latent phase. Another question is how many and what groups of parasitoids are required to achieve desirable and stable biological control. It is interesting to note that local parasitoid species adopted the gallers as new hosts. The question whether the above-mentioned imported natural enemies may have a negative impact on populations of non-target indigenous galler species needs to be addressed. Importation of alien parasitoids and testing their host specificity were revealed as major challenges. Among these were reluctance of the quarantine authority to issue an introduction license for unidentified species, the problematic mass rearing of the host galler, and the selection of appropriate species for testing non-target organisms. Another important take-home lesson is that the accomplishment of such biological control programs depends very much on international collaboration. All these and other related issues will be discussed.

The Californian experience of eucalypt insect biological control with special emphasis on the red gum lerp psyllid *Glycaspis brimblecombei*. Paine, T. (*University of California, USA; timothy.paine@ucr.edu*).

Although insect free for almost 150 years in California, eucalyptus has accumulated approximately 20 insect herbivores in the last 2 decades. Biological control efforts have been attempted against two wood borers, two folivores, and four fluid-feeding insects. The introduction of two strains of an encyrtid egg parasitoid has resulted in complete or nearly complete biological control of two cerambysid borers. Complete biological control of a leaf feeding weevil was achieved with the introduction of another egg parasitoid and this has been maintained for more than a decade despite breaking down in other parts of the world. Attempts to establish biological control of a chrysomelid leaf beetle with a fourth species of egg parasitoid failed. Complete successful biological control of one psyllid was achieved with intentional introduction of a parasitoid and partial success has been observed against two other psyllids following the serendipitous invasion of two parasitoids and, unfortunately, their hyperparasitoids. The biological control of red gum lerp psyllid following introduction of a hymenopteran parasitoid has been very successful in some parts of California and less successful in other regions. The reasons for the differences in success are not clearly resolved but may include different responses to local climate and the presence of an endosymbiotic bacterium in the psyllid.

Biological control of the bronze bug, *Thaumastocoris peregrinus*, in eucalyptus plantations in Brazil. Wilcken, C. (*São Paulo State University, Brazil; cwilcken@fca.unesp.br*), Barbosa, L. (*EMBRAPA, Brazil; leonardo.r.barbosa@embrapa.br*), Zache, B., Firmino, A. (*São Paulo State University, Brazil; bzache@bol.com.br; anacarfir@gmail.com*), Sa, L. (*EMBRAPA, Brazil; luiz.sa@embrapa.br*), Zanuncio, J. (*Federal University of Viçosa, Brazil; zanuncio@ufv.br*), Junqueira, L. (*Forestry Science and Research Institute (IPEF), Brazil; renato@ipef.br*).

The bronze bug *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae) was detected in Brazil in 2008 and infested >180 000 ha of eucalyptus plantations in 2011. The bronze bug can cause a reduction of 10–15% in wood productivity after 2 years of heavy infestation. Although there is not an effective control method known, biological control is the main control strategy studied. An exotic egg parasitoid, *Cleruchoides noackae* (Hymenoptera: Mymaridae), was imported from Australia in 2012, reared in a laboratory and released in three Brazilian regions. Parasitoids were recovered at release points after 20–30 d. In 2013, preliminary evaluations demonstrated parasitoid establishment in these areas, and the parasitoid was recovered in adjacent areas after 1 year of release. Bioassays confirmed egg parasitism of 15–20% by *C. noackae*. Other native natural enemies were studied. We found green lacewing *Chrysoperla externa* and predatory bugs *Supputius cincticeps* and *Atopozelus opsimus* preying on nymphs and/or adults of *T. peregrinus*. Another promising possibility is entomopathogenic fungi. Commercial formulations of *Beauveria bassiana* were tested with success in lab and field conditions. *Fusarium proliferatum* and *Paecilomyces cateniannulatus* caused mortality of *T. peregrinus* in natural epizooties. After 5 years of research, it is possible to develop an integrated pest management system (IPM) for eucalyptus plantations based on biocontrol strategy for bronze bug.

An island downwind of Australia has a unique experience of eucalyptus pest biological control: the New Zealand story. Withers, T., Sopow, S. (*Scion, New Zealand; toni.withers@scionresearch.com; stephanie.sopow@scionresearch.com*), Murray, T. (*University of Canterbury, New Zealand; tara.murray@canterbury.ac.nz*).

Eucalyptus trees are not native to New Zealand, but since the 1860s, Australian insects have steadily colonised them. Currently there are 30 specialist eucalypt insects established in New Zealand which is 1 800 km downwind from Australia across the Tasman Sea. In some cases, the major insect pests are those shared by other countries (e.g., *Gonipterus platensis* and *Thaumastocoris peregrinus)*. Some other important insect pests have been rare or not described from Australia, prior to their appearance as a pest in New Zealand (e.g., *Paropsis charybdis, Nambouria xanthops*, and *Ophelimus eucalypti).* Of most interest has been the introduction of biological control agents. In some cases the natural enemy arrived with its host (e.g., *Psyllaephagus pilosus*

against *Ctenarytaina eucalypti*), in other cases intentional introductions have resulted in successful biological control (e.g., *Enoggera nassaui* against *Paropsis charybdis* and *Bracon phylaceophagus* against *Phylacteophaga froggatti*), while in other cases biological control agents mysteriously self-introduced years later (e.g., *Neopolycystus insectifurax* against *Paropsis charybdis* and *Psyllaephagus gemitus* against *Cardiaspina fiscella).* Along with beneficial self-introductions, some troublesome hyperparasitoids have also established (e.g., *Baeoanusia albifunicle* attacking *Enoggera nassaui* on *Paropsis charybdis* and *Coccidoctonus psyllae* attacking *Psyllaephagus* spp. on *Cardiaspina fiscella).* New Zealand has played an active part in global approaches to the biological control of invasive eucalyptus pests, re-exporting many of the successful biological control agents around the world.

G-06 Mechanisms of tree defense across forest insect feeding guilds: can a comparative approach help predict responses to climate change?

Organizers: Barbara Bentz (U.S. Forest Service) & Ken Raffa (University of Wisconsin, USA)

Temperature affects the outcome of tritrophic interactions mediated by tree resistance among pine sawflies and willow leaf beetles. Bjorkman, C., Bylund, H., Kollberg, I., Stenberg, J. (*Swedish University of Agricultural Sciences, Sweden; christer.bjorkman@slu.se; helena.bylund@slu.se; ida.kollberg@slu.se; johan.stenberg@slu.se*).

Predicting the outcome of a changing climate on interactions in even rather simple food webs is difficult because all the interacting species respond individually, but not independently, to changes in the environment. Here we present results from two systems, pine sawflies and willow leaf beetles, where the effect of temperature on herbivore performance, survival, and/or abundance is explored in a tritrophic setting, including plants, herbivores, and natural enemies, mediated by differences in host plant resistance. The results indicate that the effect of temperature varies with level of host plant resistance in both systems and that direct effects of tree defenses and bottom-up cascading effects to the third trophic level are important to consider in order to predicting herbivore responses to climate change.

Mining spruce genomes for defence genes and functions. Bohlmann, J. (*University of British Columbia, Canada; bohlmann@msl.ubc.ca*).

The draft genome sequence assemblies of two spruce species, white spruce and Norway spruce, have recently been reported. We will present a summary update of the status and challenges of the spruce genome assemblies and a status update on genome annotations with focus on genes involved in conifer defense. In detail, we will present new results from the identification of different sets of genes and gene functions which contribute to spruce resistance against either white pine weevil or spruce budworm. We will present 1) insights into a network of genes and enzymes contributing to the chemical diversity of diterpene oleoresin defenses, 2) a newly discovered glucosyl hydrolase gene function that is important for spruce budworm resistance, and 3) a detailed characterization of stone cells, an important anatomical defense with a major role in resistance of Sitka spruce against white pine weevil.

Interactions of evolutionary adaptation with environmental variables in expression of ash resistance mechanisms to emerald ash borer. Bonello, P., Herms, D. (*Ohio State University, USA; bonello.2@osu.edu; herms.2@osu.edu*).

Agrilus planipennis (emerald ash borer, EAB) is an invasive alien wood-boring beetle that is threatening the survival of most North American ash species. Due to coevolutionary adaptation, Manchurian ash, an Asiatic species, is resistant, while the closely phylogenetically related North American species, black ash, is highly susceptible. Non-adaptation/maladaptation of black ash to EAB is emblematic of the situation in North America and is reflected in differential expression of several constitutive and inducible resistance traits relative to Manchurian ash. Such maladaptation may be further exacerbated by environmental conditions that favor susceptibility. For example, global warming will likely lead to more frequent and intense extreme weather events, including prolonged droughts and excessive precipitation. It is expected that these weather extremes will negatively impact trees both directly and indirectly via reduced resistance to pests, including wood-boring beetles such as EAB. Our limited knowledge of environmental effects on mechanisms of resistance in woody plants is clearly detrimental to formulating hypotheses aimed at understanding how both constitutive and induced defense mechanisms affect tree interactions with emergent pests and pathogens. This situation must be rectified if we are to make informed decisions about the future management of entire ecosystems in a changing world.

Mechanisms of tree defense against the spruce bark beetle *Ips typographus*. Krokene, P. (*Norwegian Forest and Landscape Institute, Norway; krp@skogoglandskap.no*), Gershenzon, J. (*Max Planck Institute for Chemical Ecology, Germany; gershenzon@ice.mpg.de*), Bohlmann, J. (*University of British Columbia, Canada; bohlmann@msl.ubc.ca*).

The spruce bark beetle (*Ips typographus*) is one of the few insects that can kill healthy Norway spruce (*Picea abies*) trees. Norway spruce has an arsenal of constitutive and inducible defenses that successfully protects against attack most of the time. When beetle populations are low, the beetles breed in weakened or downed trees. However, following disturbance (e.g., extensive storm felling), beetle populations increase and the beetles can overwhelm the defenses of relatively healthy standing trees through pheromone-mediated mass attacks. Recent research on the *Ips typographus-Picea abies* system has demonstrated the importance of effective inducible defenses in tree resistance. Trees that respond vigorously to a sublethal challenge (e.g., inoculation with fungi) are more resistant to subsequent bark beetle attack than trees with a weaker induced response. The level of terpenoid induction in response to a localized treatment with the defense-inducing phytohormone methyl jasmonate also correlates with resistance to bark beetle attack. Highly inducible trees successfully fend off bark beetle attacks, whereas less inducible trees are mass-attacked and killed. The bluestain fungus *Ceratocystis polonica* carried by the beetles seems to play an important role in engaging tree defenses. The fungus has recently been demonstrated to metabolize tree chemical defenses, such as phenolics, and probably terpenoids as well.

Mechanisms of aspen (*Populus tremuloides*) defense against gypsy moths and forest tent caterpillars. Lindroth, R. (*University of Wisconsin-Madison, USA; lindroth@wisc.edu*).

Aspen (*Populus tremuloides*) is a foundation tree species in forest ecosystems throughout northern and western North America. Although subject to damage by hundreds of species of herbivores, aspen has persisted in these environments largely due to a suite of defense strategies, including resistance, tolerance, and escape. The signature resistance compounds of aspen are the salicylate phenolic glycosides and condensed tannins. Damage-induced protease inhibitors may also afford protection against insects. Aspen exhibits striking variation in secondary chemistry because of genetic, ontogenetic, and environmental factors, and interactions among them. Genetic variation in chemical defense is related to a strong trade-off between growth and defense, and expresses itself as differential resistance to herbivores. Phenolic glycosides, but not condensed tannins, provide protection against the major defoliating species, gypsy moth (*Lymantria dispar*) and forest tent caterpillar (*Malacosoma disstria*). At outbreak densities, however, these species cause extensive defoliation of aspen independent of chemical resistance traits, and likely select for traits conferring tolerance. Global change factors such as increased atmospheric CO_2 and ozone, and climate warming, influence aspen defense traits and will alter aspen-insect interactions in environments of the future.

Trophic responses to climate change: host species, spruce budworm, and natural enemies. Pureswaran, D., De Grandpré, L., Martel, V. (*Canadian Forest Service, Canada; dpureswa@nrcan.gc.ca; louis.degrandpre@nrcan.gc.ca; veronique.martel@nrcan.gc.ca*), Neau, M., Monerris, J., Kneeshaw, D. (*Université du Québec à Montréal, Canada; nomade15@hotmail.com; jorgemonerris@yahoo.es; kneeshaw.daniel@gmail.com*).

A milder northern climate is permitting forest insect distribution ranges to expand to areas where cold temperatures previously limited their long-term persistence. Current outbreak centers of eastern spruce budworm, a North American epidemic species, have appeared in regions further north than in the recent past. Balsam fir and white spruce are host species most susceptible to defoliation and mortality by spruce budworm. Northern black spruce forests that escaped severe defoliation due to short summers and phenological mismatch between budburst and larval emergence are now suffering herbivory. Spruce budworm populations are controlled not only by host quality but also by natural enemy abundance and diversity. Responses of all three trophic levels to warmer temperatures will determine the severity and extent of future disturbance regimes. In phenological studies we observed plasticity in spruce budworm and its host species suggesting adaptation of spruce budworm to the phenology of black spruce, formerly a secondary host. We are investigating whether predicted lower relative diversity of understory vegetation and parasitoid species in black spruce forests versus balsam fir dominated forests will lighten top-down natural enemy control on spruce budworm population growth, increasing outbreak severity, thereby resulting in greater economic losses for the forest industry.

Using water- and nutrient-stress phenotypes to identify ash biomarkers of resistance to emerald ash borer. Showalter, D., Hansen, R., Herms, D., Bonello, P. (*Ohio State University, USA; showalter.53@osu.edu; hansen.2@osu.edu; herms.2@osu.edu; bonello.2@osu.edu*).

Emerald ash borer (EAB) is an alien invasive, wood-boring beetle that is devastating North American ash (*Fraxinus* spp.) populations in urban and natural forest settings. The only viable, long term management strategy is deployment of host resistance, which has not yet been characterized in ash. It is well known that defense physiology is significantly affected by resource availability or hormonal treatment. In principle, such treatments can therefore be used to identify resistance mechanisms. Hence, two ash cultivars previously identified as resistant and susceptible to EAB were subjected to different levels of water-, nutrient-, and phytohormone-stress to generate phenotypes that represent a gradient of resistance. Association studies were then used to correlate specific phloem metabolic and transcriptomic profiles with EAB-larval growth and development. Traits identified in this study may be used as biomarkers for selective breeding. The results will also increase understanding of effects of resource availability on interactions between trees and wood-borers. This understanding will be important as trees respond to changes in resource availability predicted by climate change models.

Potential role of alkaloids and monoamines in ash resistance to emerald ash borer. Villari, C., Chakraborty, S. (*Ohio State University, USA; villari.2@osu.edu; chakraborty27osu@gmail.com*), Rigsby, C., Cipollini, D. (*Wright State University, USA; chad3332@gmail.com; don.cipollini@wright.edu*), Herms, D., Bonello, P. (*Ohio State University, USA; herms.2@osu.edu; bonello.2@osu.edu*).

Previous work to dissect mechanisms of resistance of ash to emerald ash borer (EAB), an alien invasive wood-boring beetle that threatens to extirpate North American green, white, and black ash, has implicated a role for constitutive and induced phloem proteins and phenolics. However, nothing is known about the potential role of alkaloids or non-amino acid amines. In particular, resistant Manchurian ash contains 9 to142 times more tyramine (a known neurotransmitter) than susceptible North American ash. Furthermore, EAB genes potentially involved in neurotransmitter detoxification were up-regulated in the midgut of larvae feeding on Manchurian ash phloem. Recently, we have shown that low water availability increases ash susceptibility, but does not affect induced phloem phenolics. The aim of this study was to determine if alkaloids and tyramine contribute to the differential resistance of Manchurian and black ash to EAB attack, and if their concentration is influenced by water availability. HPLC-PDA-MS and GC-MS were employed to characterize phloem chemical composition, while artificial diet bioassays were used to test effects of candidate resistance compounds, including tyramine, on growth and survival of EAB larvae.

G-07 Is climatic change modifying the characteristics of insect damage in forests?

Organizers: Francois Lieutier (University of Orleans, France), Timothy Paine (University of California, Riverside, USA) & Rodney Keenan (University of Melbourne, Australia)

***Dendroctonus ponderosae*, the tree killer, confronts climate change.** Bentz, B. (*U.S. Forest Service, USA; bbentz@fs.fed.us*).

Warming temperatures associated with climate change are ongoing and many plant and insect species have the capacity to respond, although the response differs by species. *Dendroctonus ponderosae* is a tree-killing bark beetle species native to western

North America that is responding to a changing climate. *D. ponderosae* population activity is currently further north and tree mortality in high elevation habitats is more persistent than previously recorded in the past 100 years. It is clear that cool habitats, within the realized range of this insect, are being affected more than warm habitats. Evolved adaptations in thermally dependent physiological processes suggest this insect evolved in cool rather than warm habitats, and help to explain the current response to temperature increases that are specific to certain latitudes and elevations. Population expansion in warm habitats may be limited. The potential for continued response across the range of this insect will be discussed in light of known physiological constraints.

Insect outbreaks and oak decline interact to shape drier forests of the future. Haavik, L. (*Canadian Forest Service, Canada; ljhaavik@gmail.com*), Billings, S. (*University of Kansas, USA; sharonb@ku.edu*), Guldin, J. (*U.S. Forest Service, USA; jguldin@fs.fed.us*), Stephen, F. (*University of Arkansas, USA; fstephen@uark.edu*).

Recent attention has been devoted to how changing climate, particularly more frequent and severe drought, has already affected and will likely affect forest insect populations. Many studies focus on introduced, invasive species and species (native or introduced) inhabiting conifer-dominated forests. Considerably less is known about native insects in hardwood ecosystems and how changing environmental conditions are likely to affect interactions with their host trees and, more broadly, their population dynamics. Drought has been linked to notable outbreaks of multiple, native hardwood insects. We address questions prompted by those outbreaks by synthesizing more than a decade of research on an emergent oak pest, red oak borer (*Enaphalodes rufulus* Haldeman, Coleoptera: Cerambycidae) as a case study to explore this issue. Drought, as a component of oak decline, played a central role in the red oak borer outbreak: directly through its positive effect on borer population growth, and indirectly by compromising oak vigor and resistance to the borer. Case studies such as this one can identify patterns, suggest causal mechanisms, and prompt refined, testable hypotheses for investigations of the role of drought on and the future likelihood of such unprecedented events.

Climate change and insect dynamics in temperate forests of North America. Herms, D. (*Ohio State University, USA; herms.2@osu.edu*).

Native and invasive insects are causing tree mortality in temperate forests of North America on an unprecedented scale. Climate change has the potential to change the trajectory of outbreak dynamics of forest insects in complex ways by altering voltinism patterns and overwintering survival, decoupling species interactions via phenological asynchrony, creating novel interactions via asynchronous migration, and direct effects on host plant quality. For example, global warming has altered the distribution of mountain pine beetle so that it now interacts with evolutionarily naïve hosts with lower resistance than coevolved populations. Minimum winter temperatures can limit the impact of hemlock woolly adelgid, emerald ash borer, and gypsy moth at their northern reaches. Consequently, as climate warms, the impact of these invasive insects may expand. Conversely, the impact of northern species such as bronze birch borer is predicted to intensify at the southern limits of its distribution as host trees are stressed by higher temperatures and more frequent drought. Higher trophic levels will also respond to climate change. Although complex and difficult to predict, it is clear that climate change will have pervasive effects on the ecology and evolutionary trajectories of forest insects.

Biological characteristics of Mediterranean forest insects. Lieutier, F. (*University of Orleans, France; francois.lieutier@univ-orleans.fr*), Paine, T. (*University of California, USA; timothy.paine@ucr.edu*).

This study is a tentative effort to identify biological traits characterizing Mediterranean forest insects, which would indeed greatly help in predicting the modification of their damage in the context of global change. The methodology is to determine the main characteristics of Mediterranean forest ecosystems, and then to infer, from their life traits, the consequences of phyllophagous and xylophagous insects inhabiting those ecosystems. Although important differences exist depending on region, the following characteristics appear to be a general description of Mediterranean forest ecosystems: isolated and small-sized ecosystems, hot dry summers and mild rainy winters, periodic droughts, poor soils, dominance of sclerophyll and evergreen woodlands, high biodiversity (at both species and communities levels) and endemicity, moderate biomass, interference of fire, dramatic modifications by human actions, introduced tree species (mainly pines and eucalypts), and invasion by exotic species. The expected consequences for insect species are discussed and a comparison is developed with the life traits of present forest pests. Finally, based on the predictions regarding climate change in the present Mediterranean areas, biological characteristics of future forest pests are proposed.

General characteristics of boreal forest insects. Niemela, P. (*University of Turku, Finland; pekka.niemela@utu.fi*).

In boreal forests, where seasonal climatic variation is high, changes both in winter and in summer temperatures modify the characteristics of insect damages. Several lepidopteran and hymenopteran forest defoliators overwinter as an egg stage and variation in egg winter mortality is crucial in their population dynamics. The autumnal moth (*Epirrita autumnata*) and the winter moth (*Operopthera brumata*) are the main defoliators in boreal birch forests in Fennoscandia. Outbreaks of both species have increased and have expanded into new areas. The obvious reason for the trend is that increasing winter temperatures have decreased the winter mortality of eggs. A diprionid sawfly, *Neodiprion sertifer,* which is the main insect defoliator in boreal coniferous forests, also overwinters as an egg stage and shows similar outbreak patterns. Increasing summer temperatures and prolonged growth periods affect the activity and voltinism of boreal bark beetles. The spruce bark beetle (*Ips typographus*) has started to produce two generations during the summer in southern Fennoscandia. Increasing summer temperatures and longer growth periods affect the geographical ranges of boreal forest insects. For example, the nun moth (*Lymantria monacha*) has expanded its range towards the north.

Identifying features of tree-insect interactions prone to major alteration by climate change. Raffa, K. (*University of Wisconsin, USA; raffa@entomology.wisc.edu*).

Changing climate can alter the impacts of forest insects in a variety of ways, but the sheer diversity of processes, herbivore species, and ecosystems poses an enormous challenge to making useful predictions. Changing temperature and precipitation

regimes can affect insect development and survival directly, impair tree defensive capacities and tolerance, and alter multitrophic interactions among herbivores, symbionts, and natural enemies. Further, these processes often interact, such as when increased temperatures allow range expansion into regions with new host species, temperature and drought jointly interfere with tree defense, and physical factors influence the abundance and signaling of community members that exert tritrophic feedbacks. The richly developed and multidisciplinary area of plant-insect interactions can provide some guidance in how to address this complexity. Frameworks such as processes of coadaptation, patterns of resource allocation, mechanisms of plant defense, and phenological synchrony provide particularly useful focus areas for empirical studies. We present results from several feeding guilds and biomes to illustrate how some of these processes can be influenced by a changing climate. These examples likewise illustrate how our knowledge of plant-insect interactions can help inform our basic understanding of how climate influences insect population dynamics, and management approaches in a rapidly changing environment.

Increasing damage due to the pine processionary moth in Europe: role of climate and landscape changes. Rousselet, J., Robinet, C. (*National Institute for Agricultural Research (INRA), France; jerome.rousselet@orleans.inra.fr; christelle.robinet@orleans.inra.fr*), Battisti, A. (*University of Padova, Italy; andrea.battisti@unipd.it*), Roques, A., Rossi, J. (*National Institute for Agricultural Research (INRA), France; alain.roques@orleans.inra.fr; rossi@supagro.inra.fr*).

As highlighted in the Intergovernmental Panel on Climate Change (IPCC) report, disentangling the effects of climate and landscape changes is a challenging issue to assess the role of global warming as a driver of contemporary population dynamics and distribution shifts. We review the case of the winter pine processionary moth, *Thaumetopoea pityocampa*, (PPM) that is a serious and increasing economic and public-health concern in Europe. The problems due to the PPM result from three main causes: 1) the northward and upward expansion due to climate warming, 2) the increasing use of its hosts as ornamental trees, and 3) accidental transportations outside its range with ornamental trees. It has been shown that the distribution changes observed during the last 2 decades and the concomitant forest damage are primarily due to milder winters favouring larval survival. Even if host tree availability is not a limiting factor for the expansion, recent results from landscape analyses in France nevertheless indicate that forest health might largely depend on trees outside forests and permeability of non-forest areas to the moth. Thus modifying ornamental practices may contribute to mitigate the consequences of climate warming on forest health.

Living on the edge: outbreaks of a bark beetle at its range margins, life-history, associated fungi, and host defenses. Villari, C. (*Ohio State University, USA; villari.2@osu.edu*), Colombari, F., Faccoli, M. (*University of Padova, Italy; fernanda.colombari@unipd.it; massimo.faccoli@unipd.it*), Bonello, P. (*Ohio State University, USA; bonello.2@osu.edu*), Marini, L., Battisti, A. (*University of Padova, Italy; lorenzo.marini@unipd.it; andrea.battisti@unipd.it*).

Ips acuminatus is a bark beetle infesting Scots pine throughout Europe, recently causing severe damage in the southern Alps, at its range edge. Climate change may be a driver of these outbreaks as it likely affects forest ecosystems by modifying the relationships among organisms, especially under marginal conditions. We have characterized the beetle's life-history, attack dynamics, its associated fungal community, and its interactions with host plant defenses in these areas. Results suggest that populations of the southern Alps may benefit from climate warming through earlier spring emergence and modified hibernation behavior, which allow the beetle to survive in larger numbers and achieve critical population thresholds that cause more frequent tree mortality. Moreover, both pathogenic and nutritional associated fungi, systematically associated with the beetle, seem to participate in exhausting host plant defenses, indirectly assisting in beetle establishment processes. Finally, an expanded analysis of host plant defensive strategies showed that Scots pine utilizes a varied defense chemistry in which only part of its constitutive metabolism is influenced by tree growth, while no overall trade-offs between different defensive metabolites were found. Global warming will likely increase the outbreak frequency of *I. acuminatus*, causing a rarefaction of Scots pine at its southern range edge.

G-08 Consequences of changing trophic interactions on forest insect population dynamics

Organizers: Aaron S. Weed, Carissa F. Aoki & Nina K. Lany (Dartmouth College, USA)

Population dynamics under climate change: modeling the interactions between predator and prey. Ammunét, T. (*Swedish University of Agricultural Sciences, Sweden; tea.ammunet@slu.se*), Ayres, M. (*Dartmouth College, USA; matt.ayres@dartmouth.edu*), Bjorkman, C., Klapwijk, M. (*Swedish University of Agricultural Sciences, Sweden; christer.bjorkman@slu.se; maartje.klapwijk@slu.se*).

Insects as ectotherms are directly affected by changes in temperature. The direct responses to climate change may in turn have an effect on the population dynamics of species. In particular, increases in reproductive rates, directly influenced by temperature, may lead to larger fluctuations in insect pest population densities and therefore have an effect on the risk to forests. On the other hand, many pest insect populations are influenced or driven by endogenous processes and trophic interactions. Natural enemies influencing these interactions and endogenous processes in pest insect populations are themselves also subjected to a changing environment. Detecting the effects of climate change on trophic interactions and consequent effects on coupled predator-prey populations is, however, often difficult and laborious. Furthermore, continuous changes in temperatures may create a continuous change in the factors affecting the population dynamics of both the predator and the prey. We approached the problem by modeling the change in parameters affecting population dynamics. We assumed a continuous increase in population parameters of both predator and prey reflecting the increases in temperature and explored the resulting long term population dynamics between predator and prey. In addition, the effects on population dynamical stability were explored.

On how to study the effects of climate change on trophic interactions: a holistic approach. Bjorkman, C., Torp, M., Weih, M. (*Swedish University of Agricultural Sciences, Sweden; christer.bjorkman@slu.se; mikaela.torp@slu.se; martin.weih@slu.se*).

One obvious consequence of climate change is increased temperatures. Species respond individually, but not independently, to such changes in the environment. Insects are expected to be particularly responsive to temperature increases. Since insects are responsible for a large proportion of the damage plants experience, a relevant question is whether plants will suffer more insect herbivore damage in the future. A challenge is to quantify and compare species responses among trophic levels because not only the herbivores but also their host plants and their natural enemies are affected by climate change. Here we use results from a lab experiment on willows, herbivorous leaf beetles, and predatory bugs to suggest a framework to allow comparisons of the responses of species from three different trophic levels to the same increase in temperature. A key element in our framework is to use a stepwise holistic approach that connects, at first sight incompatible, vital organism traits at different trophic levels. Our results indicate that environmental conditions, such as temperature, significantly affect trophic interactions, herbivore pressure, and thereby net growth of the targeted plants. We provide suggestions of experimental designs for further exploring effects of climate change on trophic interactions.

Impacts of insect host diversity, tree species, and temperature on parasitism of the eucalyptus snout beetle (*Gonipterus* spp.) by *Anaphes nitens*. Garnas, J., Greyling, I., Hurley, B., Wingfield, M., Slippers, B. (*FABI, University of Pretoria, South Africa; jeff.garnas@fabi.up.ac.za; izette.greyling@fabi.up.ac.za; brett.hurley@up.ac.za; mike.wingfield@fabi.up.ac.za; Bernard.Slippers@fabi.up.ac.za*).

Weevil species in the genus *Gonipterus* are among the most widespread and devastating pests of plantation-grown eucalyptus worldwide. The pest was initially designated as *G. scutellatus,* but has recently been recognized as comprising a complex of species. Understanding the effects of this newly identified diversity on control by the egg-parasitic myrmarid wasp, *Anaphes nitens,* along with host tree and climate, is critical to developing and improving management tools. Populations of the pest and parasitoid have been monitored monthly at 16 sites along an elevational gradient in eastern South Africa since early 2010. Preliminary analyses have shown that parasitism rates are negatively correlated with high summer temperatures and relatively insensitive to low winter temperatures. There were clear differences in infestation and parasitism rates on different host species and clones, but elevation had no major effect. Larvae collected during this survey and identified using COI mtDNA barcode sequences will reveal the role of *Gonipterus* spp. identity on population dynamics of the pest and parasitoid. Results will be used to parameterize a model to predict population abundance and rates of parasitism across South Africa wherever eucalyptus is grown.

Positive direct effects of increased temperature on forest Lepidoptera are outweighed by negative indirect effects of predators and food quality. Lany, N., Ayres, M. (*Dartmouth College, USA; Nina.K.Lany.GR@dartmouth.edu; matt.ayres@dartmouth.edu*).

Temperature directly affects the physiology of all organisms, especially poikilotherms. The direct effects of temperature on herbivorous insects are generally positive; temperature increases growth rates and reduces development time. However, higher temperatures can increase movement and attack rates of predators, and can reduce leaf quality for herbivores. Here, we explored whether the positive direct effects of warmer temperatures can outweigh the expected negative indirect effects propagated through increased predator attack rates and through reduced food quality for two species of forest Lepidoptera: *Orthosia rubescens* (ruby quaker, Noctuidae), and *Heterocampa guttivitta* (saddled prominent, Notodontidae). Warmer temperatures reduced host plant foliar nitrogen in all cases, and the negative effects of this reduced food quality on caterpillar growth rates and final size balanced the effect of higher temperatures on growth rate. Predator attack rates increased with temperature in some, but not all, years. When present, small increases in predator attack rate outweighed large decreases in the time spent as vulnerable larvae. Indirect effects mediated through top-down and bottom-up processes have the ability to alter the population dynamics of these insect defoliators.

Effect of forest fragmentation on parasitism of forest tent caterpillar through a full population cycle. Roland, J. (*University of Alberta, Canada; jroland@ualberta.ca*).

Rates of parasitism by the community of parasitoids attacking forest tent caterpillar were evaluated from 109 sites ranging in degree of forest fragmentation. Estimates of parasitism of larvae and pupae were estimated through more than a full population cycle from 1993 through 2009. Results indicated which parts of the population cycle (and which component of the parasitoid community) were affected most by forest fragmentation. Results are discussed in light of patterns of increased duration of caterpillar outbreaks in more fragmented forests.

Changing climate associated with homogenization of forest assemblages of boreal ground beetles (Coleoptera: Carabidae). Spence, J. (*University of Alberta, Canada; jspence@ualberta.ca*), Bourassa, S. (*Canadian Forest Service, Canada; sb22@ualberta.ca*).

We studied carabid assemblages during 1981–1982 and 2009–2010 using pitfall traps on the same grids in five habitats in central Alberta, Canada. Average catch rate was 39.2% lower in the later period than during 1981–1982. Carabid activity was much reduced in lakeside forest (LS) and meadow (ME) habitats, but higher in spruce forest (SF). Shannon-Weiner diversity (H′) fell between the two study periods, as did overall species numbers. The 1981–1982 catch included 32 species not subsequently collected; 21 species were rare, but many had been common earlier, including *Pelophila rudis, Elaphrus clairvillei*, and *Platynus mannerheimii*. Ten species captured during 2009–2010 had not been detected earlier, including *Synuchus impuctatus, Metabletus americanus* and the invasive exotic species, *Pterostichus melanarius*. Multiple regression tree analysis explained 84.4% of variation in the assemblages and identified differences between ME and the four forest habitats, the two sampling periods, and LS versus the other forest types as explaining most variation in the assemblages. Forest carabid assemblages became more homogeneous across habitats in the later years. Climate has become warmer and drier during the study period and our data support the hypothesis that climate effects are associated with changes in this local carabid fauna.

G-09 Ecology and management of invasive wood boring pests in a changing world

Organizers: Juan Carlos Corley (CONICET- INTA, Argentina), Massimo Faccoli (DAFNAE-Agripolis, Italy), Michael Smith (USDA-ARS, USA) & Brett Hurley (University of Pretoria, South Africa)

Patch size for *Sirex noctilo* in fragmented landscapes. Corley, J., Villacide, J., Lantschner, M. (*National Agricultural Technology Institute (INTA), Argentina; elmallin@gmail.com; josevillacide@gmail.com; vlantschner@gmail.com*).

Many pine plantations in the southern hemisphere are established as a mosaic of patches in non-pine habitat. For invasive pests, such fragmentation may hinder natural spread rates or ultimately, establish barriers that could lead to different populations, each with its own dynamics. For *Sirex noctilio*, a most significant pest of pines worldwide, it has been shown through flight mill assays, that females are capable of long distance flights of up to 50 km. Such distances could imply a degree of continuity in the afforested landscape. Here we ask whether females are actually capable of leaving plantations and flying into non-habitat landscapes. We quantified the distribution of dispersal distances into a non-pine habitat for adult females, using intercept baited traps. Females were caught at traps located outside plantations, at up to 4 000 m from the edge, suggesting a long dispersal ability even during endemic population levels (below 3–5% attack rates). We discuss the contribution of the natural dispersal in determining patch size and spread rates of *Sirex noctilio* in fragmented habitats.

Toward the eradication of the Asian longhorned beetle, *Anoplophora glabripennis*, from northeast Italy. Faccoli, M., Battisti, A. (*University of Padova, Italy; massimo.faccoli@unipd.it; andrea.battisti@unipd.it*), Gilardi, P. (*National Plant Protection Organization, Veneto Region, Italy; paolo.gilardi@regione.veneto.it*), Narduzzo, G., Alfonsi, L., Dal Cin, I. (*Regional Forest Service, Veneto Region, Italy; giovanni.narduzzo@regione.veneto.it; luigi.alfonsi@regione.veneto.it; ingrid.dalcin@regione.veneto.it*), Vettorazzo, M., Zanini, G. (*National Plant Protection Organization, Veneto Region, Italy; marco.vettorazzo@regione.veneto.it; giovanni.zanini@regione.veneto.it*), Favaro, R. (*University of Padova, Italy; jumptorich@gmail.com*).

In 2009 the Asian longhorn beetle (*Anoplophora glabripennis*, Coleoptera: Cerambycidae, ALB), a quarantine species from China and Korea largely polyphagous on broadleaves, was detected in the municipality of Cornuda (northeast Italy). An eradication plan was immediately activated in a joint project among the University of Padova, the National Plant Protection Organization, and the Regional Forest Service. All trees belonging to the ALB host genera growing within 2 km of each infested tree were visually inspected. Large trees or trees showing unclear symptoms were checked by tree-climbers. The plan also required tree nurseries to spray against ALB adults, and prohibited the transplantation, sale, and transportation of any susceptible tree species out of the infested area. Citizens were invited to report to the authorities any sighting of adult ALB and infested trees. About 30 000 trees growing over an area of about 7 000 ha were each checked annually. Trees found to be infested by ALB were about 1 200 (4% of those checked), mainly elms, maples, birches, and willows. All the infested trees were cut and chipped. The number of infested trees has progressively decreased by about 50%, indicating a positive effect of the eradication efforts. No infested trees were found in the forests growing in the infested area.

Invasive longhorned beetles (Cerambycidae) in North America: who, where, and what is being done? Haack, R. (*U.S. Forest Service, USA; rhaack@fs.fed.us*).

Exotic forest insects and diseases threaten forest biodiversity and sustainability worldwide. In North America (continental USA and Canada), numerous exotic bark and wood-infesting insects have become established, including at least 14 species of longhorned beetles (Cerambycidae). Wood packaging material used in international trade is an important pathway by which borers can be spread, as well as in logs, lumber, wood handicrafts, and live plants. Information will be presented on arrival rates of these exotic borers in North America, the states and provinces where they were first discovered and their subsequent spread, the likely means of their arrival, likely countries of origin, tree species at risk, current pest status, regulatory actions taken to control their spread, and eradication efforts. Case studies will be presented on the Asian longhorned beetle (*Anoplophora glabripennis*), brown spruce longhorned beetle (*Tetropium fuscum*), eucalyptus longhorned borer (*Phoracantha semipunctata*), and others. International efforts to reduce live pests in wood packing materials, such as the International Standards for Phytosanitary Measures No. 15 (ISPM-15), will be discussed. In addition, because firewood poses a risk for human-assisted movement of exotic borers in North America, information will be provided on North American efforts to regulate firewood movement and treatment.

Invasive and endemic *Sirex/Amylostereum* associations. Hajek, A., Kroll, S., Castrillo, L., Nielsen, C. (*Cornell University, USA; aeh4@cornell.edu; stef.a.kroll@gmail.com; l.castrillo@cornell.edu; cln@dst.dk*).

Each *Sirex* sp. has historically been assumed to be associated with only one species of the symbiotic fungus *Amylostereum*. Our studies have shown otherwise, demonstrating that two northeastern United States native *Sirex* spp. as well as two European *Urocerus* spp. can be associated with either of two *Amylostereum* spp. However, it seems that *Sirex* spp. can show preferences for fungal species. The presence of a fungal species already in a tree can affect the extent that invasive *Sirex noctilio* or native *Sirex nigricornis* will oviposit in that tree. Different siricids can occur within the same trees and adoption of a fungal symbiont being carried by another woodwasp species has been documented. We will discuss the impact that the fungi associated with woodwasps could potentially have on *Deladenus* nematodes parasitizing them and, in particular, on efficacy of *Deladenus siricidicola* for biological control.

Can acoustic technologies be used to protect trees from insects? Hofstetter, R., Aflitto, N., Potter, K. (*Northern Arizona University, USA; rich.hofstetter@nau.edu; na279@nau.edu; kristen.potter@nau.edu*), Dunn, D. (*Art and Science Laboratory, USA; artscilab@gmail.com*), McGuire, R. (*Northern Arizona University, USA; reagan.mcguire50@gmail.com*).

One of the side effects of globalization is the increase in invasive wood-infesting insects and their negative effects on forest health and larger ecological and climate issues. Wood-infesting insects account for billions of dollars annually in losses due to

tree mortality, reductions in tree growth and health, increased demands for management, and decline in property values. A potential mechanism to reduce tree morality and mitigate infestation of wood materials by insects is the use of acoustic technologies. We describe acoustic methods to protect tree and wood materials from wood-infesting insects, and describe the practicality of this technology for use at different spatial scales. Wood-infesting insects produce a variety of acoustic signals that play critical roles in mate choice, species recognition, communication, territoriality, predator escape, and prey selection. We discuss a bioacoustic approach to reducing wood-infesting insects within wood tissues. Playback of modified biological sounds affected insect behavior and, in some instances, reduced insect reproduction and adult survival. The targeted use of biologically relevant sounds could be a species-specific, environmentally friendly method of insect control.

Intercontinental ecological comparisons as a global tactic for managing invasives. Krivak-Tetley, F., Ayres, M. (*Dartmouth College, USA; fkt.gr@dartmouth.edu; matt.ayres@dartmouth.edu*), Corley, J. (*National Agricultural Technology Institute (INTA), Argentina; elmallin@gmail.com*), Slippers, B., Hurley, B. (*FABI, University of Pretoria, South Africa; Bernard.Slippers@fabi.up.ac.za; brett.hurley@up.ac.za*), Liebhold, A. (*U.S. Forest Service, USA; aliebhold@fs.fed.us*), Garnas, J., Wingfield, M. (*FABI, University of Pretoria, South Africa; jeff.garnas@fabi.up.ac.za; mike.wingfield@fabi.up.ac.za*), Lombardero, M. (*University of Santiago de Compostela, Spain; mariajosefa.lombardero@usc.es*).

The European woodwasp, *Sirex noctilio* Fabricius (Hymenoptera:Siricidae), is considered a secondary pest in its native range (Europe, Asia, northern Africa), but has become a serious pest of pine forests in regions of the southern hemisphere where it has been accidentally introduced. *S. noctilio* was trapped for the first time in the United States in September 2004 in Oswego Country, northern New York, and has since spread to several other counties in New York as well as regions of Pennsylvania, Michigan, Vermont, and Ontario, Canada. This exotic insect has not caused extensive damage across its current North American range, but has the potential to pose a substantial threat to pine stands in the southern and Lake states as its range increases. Here, we outline initial results of a comparative study of *S. noctilio* in North America with populations in Africa and South America (invasive) and Spain (native). Our primary objectives were 1) to develop an understanding of the factors controlling *S. noctilio* range expansion elsewhere such that we can predict future spread in North America; and 2) to examine patterns of abundance and growth to determine why this insect is more or less of a pest in different environments.

***Sirex noctilio* flight: patterns in vertical distribution.** Martinez von Ellrichshausen, A., Fernandez Ajo, A., Corley, J., Villacide, J. (*National Agricultural Technology Institute (INTA), Argentina; andmarv77@gmail.com; afernandezajo@gmail.com; elmallin@gmail.com; josevillacide@gmail.com*).

Many insects search for food and oviposition substrates through flight. Understanding a species vertical flight distribution is important from a behavioral viewpoint and from an applied perspective. For example, this type of information could guide optimal trap placement heights in monitoring programs in addition to patterns that could be used in tailoring specific control strategies. The woodwasp, *Sirex noctilio*, is an invasive insect and constitutes a major threat to pine forests throughout the world. We studied the vertical flight behavior of males and females through unbaited sticky traps placed in three pine plantations in Patagonia, Argentina. Data indicated clear behavioral differences between males and females; males were captured at higher altitudes (males $n = 10$, median = 410 m, 25% quartile = 307.5 and 75% quartile = 482.5; females $n = 184$, median = 250 m, 25% quartile = 150 and 75% quartile = 350), indicating a higher and vertical flight trajectory (i.e., upwards) for males. Additionally, data suggested that females were attracted to traps containing males, with five times more females found in male-containing traps than in male-free traps ($\chi^2 = 14.2$, $P < 0.001$, df = 1), possibly driven by a male-produced volatile attractant compound. The implications of these results are discussed in an applied context.

***Sirex noctilio* woodwasp in Australia: a little further north each year.** Nahrung, H., Griffiths, M. (*University of the Sunshine Coast, Australia; hnahrung@usc.edu.au; manon.griffiths@daff.qld.gov.au*), Ramsden, M. (*HQPlantations, Australia; michael.ramsden@hqplantations.com.au*).

With annual damage estimated at up to $78 million, the exotic woodwasp, *Sirex noctilio* Fabricius (Hymenoptera: Siricidae), poses a very serious threat to commercial pine plantations throughout Australia. It has gradually increased its northward range since becoming established in mainland Australia around 1960. Previously restricted to temperate areas, where its host relationships are understood, and where effective management and control strategies were developed, it recently reached southern Queensland, close to valuable subtropical pine estates. While climate modelling predicts these regions as suitable for *Sirex* establishment, subtropical pines represent unstudied hosts, and biocontrol success may be compromised in these conditions; there is an urgent need to determine *Sirex* host and biocontrol relationships in the subtropics to prepare intervention strategies for its inevitable arrival. We have developed novel surrogate experimental techniques to enable assessments in the absence of the wasp, and we present the results of these trials here. We also discuss results from the ongoing nematode inoculation biological control program in place in Queensland, and woodwasp phenology in this newly invaded region.

G-10 Multiple risk management in planted forests

Organizers: Hervé Jactel (National Institute for Environmental and Agricultural Science and Research, France), Christophe Orazio (European Forest Institute, Finland) & John Moore (Scion, New Zealand),

Storm fellings and pine-weevil-caused seedling damage. Bylund, H. (*Swedish University of Agricultural Sciences, Sweden; helena.bylund@slu.se*).

How does a storm felling affect forthcoming pine weevil population densities and seedling damage risk at local and regional levels? In January 2005, a severe storm struck southern Sweden and felled or damaged coniferous trees in an area of 270 000 ha, which is at least five times the forest area that normally would have been cut during a year in that region. We followed the

immigration and development of pine weevil populations and levels of seedling damage at 10 clearcuts in the storm-struck region and 10 clearcuts in a neighboring unaffected region during 4 years. The results are discussed in a landscape context where the amount of available breeding material is the most important factor from the pine weevil's perspective. Will future disturbance regimes and forest management adapted to a warming climate affect the significance of pine weevil damage in future forest regenerations?

Belowground herbivory in red pine stands initiates a cascade that increases abundance of Lyme disease vectors. Coyle, D. (*University of Georgia, USA; drcoyle@uga.edu*), Murphy, M. (*Centers for Disease Control, USA; mwmurphy@cdc.gov*), Paskewitz, S., Orrock, J., Lee, X., Murphy, R. (*University of Wisconsin, USA; paskewit@entomology.wisc.edu; jorrock@wisc.edu; xlee1@wisc.edu; romurmill@hotmail.com*), McGeehin, M. (*Centers for Disease Control, USA; mcgeehin@cdc.gov*), Raffa, K. (*University of Wisconsin, USA; raffa@entomology.wisc.edu*).

Plantation growth of trees has substantial advantages for some aspects of productivity and operational efficiency, but can also favor certain pests both directly and through complex interactions. In red pine plantations in the Great Lakes region of North America, feeding by rhizophagous insects triggers a cascade that ultimately results in higher densities of blacklegged ticks, *Ixodes scapularis*, which are the primary vector of the Lyme disease pathogen *Borrelia burgdorferi*. We sampled 31 plantations in Wisconsin, USA, that were diseased or asymptomatic for a previously described tree mortality syndrome that originates with root infestation. Understory vegetation was greater in diseased stands, and belowground herbivory had little measurable impact on soil microbiota. The proportion of samples containing ticks and the number of ticks per sample were greater in diseased stands. Infection rates with *B. burgdorferi* were consistent between treatments, but showed considerable regional differences. Tick densities were identical between declining and healthy portions of symptomatic stands, suggesting stand-level factors were responsible, consistent with mammal movement. These results suggest that forest management practices that affect the dynamics of belowground food webs may have implications for human health.

Facing multiple risks with limited knowledge. Deuffic, P. (*National Research Institute of Science and Technology for Environment and Agriculture, France; philippe.deuffic@irstea.fr*).

Forest owners have to integrate multiple risks in order to improve the resilience of planted forests to many biotic and abiotic threats. How do they identify and assess these risks? Which criteria are the most important to base decisions on, in a context of uncertainty about the impacts of multiple risks? An 8-year qualitative survey of French forest owners (Aquitaine region) showed that they often think of one specific risk and more rarely in terms of a combination of natural hazards. However, when faced with multiple sources of risks, they combine different sources of experience and knowledge to make their decisions. They build strategies based on 1) traditional knowledge and scientific advances when these exist, 2) solutions that do not adversely affect the economic profitability (due to a high level of financial losses or insurance costs), and 3) a combination of forestry models that are the most resilient to the combination of risks (short and long rotation, diversification, introduction of mixed species). Despite these adaptive strategies, they expect more certain knowledge in the field of ecological functioning and economic evaluation.

Management of planted forests can mitigate the risk from multiple hazards. Gardiner, B. (*National Institute for Agricultural Research, France; barry.gardiner@bordeaux.inra.fr*), Régolini, M. (*European Forest Institute (EFIATLANTIC), France; margot.regolini@efi.int*), Jactel, H., Kamimura, K., Meredieu, C. (*National Institute for Agricultural Research (INRA), France; herve.jactel@pierroton.inra.fr; kana.kamimura@pierroton.inr.fr; celine.Meredieu@pierroton.inra.fr*), Orazio, C. (*European Forest Institute, France; christophe.orazio@efi.int*).

Planted forests are suffering increased levels of damage and are under increasing risk from a range of hazards due to the changing climate and the increase in their value. For such forests to continue providing the range of ecosystem services that society demands, it will be necessary to adapt forest management at the stand, forest, and landscape levels in order to increase their resilience. In this paper we will show how changes in management practice can modify the impact of forest damage from a range of abiotic and biotic hazards. We investigated changes to the rotation lengths and thinning regimes of stands, and the increased use of broadleaves in the predominantly maritime pine (*Pinus pinaster*) forests of southwest France. Our investigation calculated the growth and risk to multiple individual forest stands within the landscape over many rotations, by linking stand growth and risk models and introducing disturbance from storms, pine processionary moth (*Thaumetopoea pityocampa*) and annosum root rot (*Heterobasidion annosum*) in a stochastic manner. These simulations allow the implications of the different management options on potential timber revenues, management costs, and losses from disturbance to be predicted and compared.

Modeling the dynamics of root rot, European spruce bark beetle, and wind damage in even-aged Norway spruce dominated forests. Honkaniemi, J. (*Finnish Forest Research Institute, Finland; juha.honkaniemi@metla.fi*), Peltola, H. (*University of Eastern Finland, Finland; heli.peltola@uef.fi*), Piri, T. (*Finnish Forest Research Institute, Finland; tuula.piri@metla.fi*), Heliövaara, K., Kasanen, R. (*University of Helsinki, Finland; kari.heliovaara@helsinki.fi; risto.kasanen@helsinki.fi*), Ojansuu, R. (*Finnish Forest Research Institute, Finland; risto.ojansuu@metla.fi*).

The root rot (*Heterobasidion annosum* sensu lato) and the European spruce bark beetle (*Ips typographus*) are the most important biotic damage factors in the Norway spruce (*Picea abies*) dominated forests in northern Europe. In recent years, increasing wind damage has created favorable conditions for bark beetle reproduction, and outbreaks have been reported widely in the Nordic countries. Root-rot-infested spruce stands, where the supporting force of the root system has been decreased due to the wood decay, are sensitive to wind damage. In such areas, the economic losses can be significant. However, silvicultural choices can affect the damage agent dynamics; therefore, suitable forest management practices are of great importance. The purpose of this research was to develop a platform for simulating the dynamics and development of root rot associated with wind and bark beetle damage. Three separate mechanistic models, each representing single damage factor dynamics, were put together and included in the MOTTI tree stand growth simulator. Existing research data were used in the parameterization of the models. The new platform was designed to be a future tool for researchers and experts managing the multiple risks of Norway spruce forests.

Interactions between biotic and abiotic disturbances on host and range expansion of mountain pine beetle in novel host jack pine forests. Klutsch, J., Erbilgin, N. (*University of Alberta, Canada; klutsch@ualberta.ca; erbilgin@ualberta.ca*).

With recent range expansions of species due to climate change, it is important to understand the impact of abiotic and endemic biotic disturbances on exotic species. Mountain pine beetle (*Dendroctonus ponderosae*) is expanding into the novel host jack pine (*Pinus banksiana*), which is an ecologically and economically important tree across most of Canada. The beetle will interact with a new community of jack-pine-infesting organisms such as the widespread and damaging pathogen dwarf mistletoe (*Arceuthobium americanum*). This research compared the induction of host defense chemicals due to drought and mistletoe infection and examined the impact on the performance of mountain pine beetle and its associated fungal diseases. To understand how endemic biotic and abiotic disturbances in jack pine impact mountain pine beetle, we identified the defense chemical induction due to drought and mistletoe in a combination of seedling and mature trees. Furthermore, we examined how mistletoe-induced changes to tree physical characteristics and defense chemical induction leads to impacts on mountain pine beetle-associated fungi and the subcortical insect community. We will discuss implications of plant-insect interactions that can identify forests susceptible to mountain pine beetle and develop preemptive management strategies prior to mountain pine beetle arrival in the boreal forest.

Interacting threats to forest plantations in the Douglas-fir region, USA. Shaw, D. (*Oregon State University, USA; dave.shaw@oregonstate.edu*).

Interactions of forest health threats to plantations in the Douglas-fir region of Oregon and Washington, USA, have not been quantified, but the biology of the organisms involved is well known. Swiss needle cast is causing growth losses across approximately 2 million ha along the coast, but affected trees are not attractive to the Douglas-fir beetle. Wind-throw is known to initiate flare-ups of the Douglas-fir beetle. Laminated root rot, which influences >5% of the landscape, maintains widespread declining trees so the beetle always has susceptible hosts during endemic phases and is poised to respond to wind-throw events. Active forest management can initiate black stain root disease in young plantations due to wounding and thinning. Stumps are attractive to vectors of the disease. If managers don't take note of the disease, losses can be significant locally. Synergy among all these various factors in the Douglas-fir region is not a deterrent to plantation management at this time, although alternatives to Douglas-fir are recommended in high severity foliage disease sites and root disease centers. Climate change may influence future interactions as new threats emerge.

Do prescribed fires cause mountain pine beetle outbreaks? Tabacaru, C., Erbilgin, N. (*University of Alberta, Canada; tabacaru@ualberta.ca; erbilgin@ualberta.ca*).

Prescribed fires are used in Alberta to remove lodgepole pine, hosts of mountain pine beetles (MPB), but live, partly burned (and therefore stressed) trees may be more susceptible to MPB. Such trees may contribute to MPB population growth and allow the beetles to overwhelm otherwise healthy adjacent trees. We investigated how post-burn landscapes influence MPB populations over time and whether prescribed fires contribute to beetle outbreaks. Preliminary results indicate that moderately burned trees were attacked more often by MPB than lightly burned and unburned trees, but that the frequency of MPB colonization in the burned areas decreased over time. We discuss potential explanations for these responses, such as competition and resource depletion.

G-11 Societal impacts of invasive forest pathogen and pests

Organizers: Matteo Garbelotto (University of California at Berkeley, USA), Giles Hardy (Murdoch University, Australia) & Paolo Gonthier (University of Turin, Italy)

Developing wilt-resistant *Acacia koa* for restoration and reforestation in Hawaii. Dudley, N. (*Hawaii Agriculture Research Center, USA; ndudley@harc-hspa.com*), Cannon, P. (*U.S. Forest Service, USA; pcannon@fs.fed.us*), Jones, T. (*Hawaii Agriculture Research Center, USA; tylercjones@gmail.com*), Sniezko, R. (*U.S. Forest Service, USA; rsniezko@fs.fed.us*), James, R. (*Plant Disease Consulting Northwest, USA; pdcn1008@gmail.com*).

Koa (*Acacia koa* Gray) is an endemic tree species of cultural, ecological, and economic importance. As Hawaii's premiere timber species, the annual value of koa products is estimated to be $25 million. Koa is used in furniture, decorative items, musical instruments, jewelry, and is preferred for construction of Hawaiian voyaging canoes. It is culturally significant, as a symbol of strength and bravery. Koa contributes to forest fertility and watershed health while providing habitat for wildlife and plants. There is increased awareness of the importance of koa and in protecting the remaining resource and replanting koa across its native range. Koa wilt disease, caused by *Fusarium oxysporum* f. sp *koae* (FOXY), prevents restoration and reforestation with koa in many Hawaiian environments. The Hawaii Agriculture Research Center operates a program to identify populations that are genetically resistant to FOXY. Results are encouraging, as families with a high frequency of resistance (>85% survival) were identified in greenhouse inoculation trials. The program utilizes local watershed cooperatives, restoration groups, and landowners to provide seed sources for wilt screening. Wilt resistant seeds orchards are being established on public and private land to provide locally adapted, wilt resistant seed to the Hawaiian forestry community.

In spite of different perceptions and responses to sudden oak death, involvement of the public is key to large-scale management of the disease. Garbelotto, M. (*University of California--Berkeley, USA; matteog@berkeley.edu*), Frankel, S. (*U.S. Forest Service, USA; sfrankel@fs.fed.us*).

A single emergent plant disease per generation captures the broad interest of people, government, and industry at a scale unmatched by others. In this talk, we describe how inexplicable sudden mortality of tanoaks (*Notholithocarpus densiflorus*) and of California coast live oaks (*Quercus agrifolia*), i.e., sudden oak death (SOD), swept both rural and urban areas of northern California. The role played by the widespread concern among constituents, fueled by an impressive, albeit often sensationalistic, coverage by the media, was key initially in securing funding to deal with important research needs. In the aftermath of the initial

hectic history of SOD, with both funding and media attention dwindling, the disease is no longer a universal concern, but remains so for forest managers and owners, for environmental groups, and for native communities with a long history of coexistence with the magnificent trees that SOD kills. These concerned groups have stepped up and have provided a base of citizen scientists to survey the disease and to collect acorns for resistance studies. Their efforts surpass those of all government and university researchers combined, and have provided the databases necessary to generate innovative smartphone applications for the identification of risk of oak infection at any given location.

Invasive pathogens and pests may threaten a multipurpose tree species: the European chestnut as a case study. Gonthier, P., Ferracini, C. (*University of Torino, Italy; paolo.gonthier@unito.it; chiara.ferracini@unito.it*).

The European chestnut (*Castanea sativa*) is a multipurpose tree species valued for nuts, timber, tannins, hydrogeological protection, and landscape. It has long served as a substitute for cereals and as a main source of carbohydrates and firewood (fuel) for people living in mountain areas of southern Europe. In this paper we show how invasive pathogens and pests of chestnut accidentally introduced or of unknown origin have significantly impacted the rural economy. We propose that tree decline currently observed in several coppices and orchards may be the result of interactions among invasive pathogens and pests, possibly within the frame of changing socioeconomic and climatic conditions. Ink disease caused by the oomycetes *Phytophthora* spp. and chestnut blight due to the fungal pathogen *Cryphonectria parasitica* spread epidemically since the mid-1800s and first half of the 1900s, respectively, threatening the survival of the European chestnut. The recent introduction and invasion of the oriental chestnut gall wasp *Dryocosmus kuriphilus* and the newly described nut rot caused by the fungus *Gnomoniopsis castanea*, which may locally decrease nut production by 80%, are regarded as two important additional factors leading to the abandonment of chestnut stands. Actual social consequences under an economic, cultural, and political perspective will be discussed.

Impact of invasive *Phytophthora* species on wildland plant communities in western Australia and society responses to their management. Hardy, G., Burgess, T., Crone, M., Paap, T., Dunstan, W. (*Murdoch University, Australia; g.hardy@murdoch.edu.au; t.burgess@murdoch.edu.au; m.crone@murdoch.edu.au; t.paap@murdoch.edu.au; w.dunstan@murdoch.edu.au*).

Introduced *Phytophthora* pathogens in the southwest of western Australia are having a devastating impact on native plant communities. More than 41% of the 5,710 described plant species are susceptible to *P. cinnamomi* with *P. multivora, P. elongate*, and *P. constricta* and a number of other newly described *Phytophthora* spp. having similar and extended host ranges. Research is emphasizing understanding the biology and pathology of these pathogens and understanding their potential impact in a changing climate. Recently, *P. cinnamomi* was shown to survive asymptomatically as an endophyte or biotroph in annual and herbaceous perennials, allowing it to survive indefinitely in infested areas. Due to widespread society concern about the loss of plant species and communities and subsequent impacts on ecosystem function and health, there is significant and active society engagement with regards to management, friends groups, accurate disease mapping, prioritization of areas protectable for 50–100 years, phosphite applications and in the case of industry, attempts at eradication. We will highlight new findings with regards to the biology of these *Phytophthora* spp. and discuss types of community engagement on-the-ground and at the policy level aimed to stop further spread and impact of these *Phytophthora* pathogens into pristine but susceptible plant communities.

Invasion of *Miconia calvescens* in Pacific island ecosystems: impacts and responses. Osmundson, T. (*University of Wisconsin--La Crosse, USA; tosmundson@uwlax.edu), Garbelotto, M. (University of California--Berkeley, USA; matteog@berkeley.edu*).

As a result of insular evolution, island ecosystems exhibit high vulnerability to biological invasions, and invasions may have high impact. Native to Central and South America, *Miconia calvescens* was introduced to Tahiti, French Polynesia, in 1937 as an ornamental plant. It has since invaded to cover more than two-thirds of Tahiti, and has subsequently colonized other islands in French Polynesia, the Hawaiian Islands, and northeastern Australia. Major impacts of *M. calvescens* include ecological disruption, including the threat of extinction of endemic species, and damage to infrastructure. Dense monodominant *M. calvescens* stands cause soil destabilization on steep slopes, resulting in soil erosion, landslides, and increased siltation in freshwater and marine habitats. Control costs to-date total more than $750 000. The severity of the invasion in Tahiti has elicited a number of responses in the research community, including development of biocontrol programs and predictive modeling of disease spread in areas likely to be invaded. However, little public involvement in response to the invasion is evident, and *M. calvescens* continues to be sold as an ornamental plant in some tropical regions. Therefore, the case of *M. calvescens* also highlights the potential for conflict between invasion control measures and other objectives, including economics and aesthetics.

Risk management in response to threat of tree disease: social and economic barriers. Quine, C., Marzano, M. (*Forest Research, UK; chris.quine@forestry.gsi.gov.uk; mariella.marzano@forestry.gsi.gov.uk*).

The health of Britain's trees is being challenged by a number of pests and pathogens. Some of these are new arrivals, but others have been present for some time and only now are beginning to cause alarm by spreading in range and across tree species. Dothistroma needle blight is one such threat and is particularly damaging to a number of pine species, including our native Scots pine. Eradication of this disease is no longer possible but there are a number of measures that can lessen the impact of the disease. Some of these options may require a change in practice by managers, may be costly for owners, or may involve collateral damage to other values held by those who have an interest in trees. While risk management needs to be underpinned with detailed knowledge of the biology of the disease, there is also a need for a greater understanding of the knowledge, values, and beliefs of stakeholders, together with the costs and benefits of the proposed measures. We report the results of an interdisciplinary project examining the social and economic barriers to adoption of disease management and how this improved understanding can be incorporated into strategic and operational risk management.

Emerging diseases and insect pest problems affecting plantation forestry in Colombia. Rodas, C. (*Smurfit Kappa Cartón de Colombia, Colombia; carlos.rodas@smurfitkappa.com.co*).

Colombia has established approximately 500 000 ha of plantations of native tree species as well as those of non-native *Pinus* and *Eucalyptus.* These plantations are seriously threatened by pathogens and insects, including those native to the country and others

that have been, or will most likely be, introduced from elsewhere in the world. Emerging diseases caused by *Diplodia sapinea, Dothistroma septosporum, Fusarium circinatum*, and *Calonectria* spp. represent serious threats to *Pinus* spp. In *Eucalyptus*, damage due to *Puccinia psidii* has increased dramatically in recent years. In addition, the appearance of pests such as *Glycaspis brimblecombei, Pineus boerneri*, and *Monalonion velezangeli* are having a negative impact. These diseases and pests have become a matter of national concern because they threaten the economic viability and long-term sustainability of the forestry industry as well as environmental and social stability. As consequence, the government has restructured the forestry sector, including a vision for preventing new outbreaks and to implement control measures. This is mainly focused on breeding and selection of tolerant planting stock, and integrated pest management. Prospects for future management include strong surveillance measures and the implementation of policies to reduce the introduction of pathogens and pests that threaten plantation forestry in Colombia.

Wider consequences of introduced forest pathogens to society in the UK. Webber, J. (*Forest Research, UK; joan.webber@forestry.gsi.gov.uk*).

Since their emergence over the last decade, several highly invasive pathogens threaten the survival and productivity of UK trees and forests. Arguably the two best known, *Phytophthora ramorum* and *Chalara fraxinea*, arrived via plant trade and now pose distinct challenges dictated by their contrasting quarantine status, behavior, and host range. First impacts of *P. ramorum* occurred on ornamental plants in nurseries, then valuable heritage plants and broadleaf trees in gardens; then in 2009, it spread unexpectedly to commercially grown larch causing extensive mortality. Apart from the environmental damage due to the sudden loss of millions of trees, plant health requirements to destroy or fell *ramorum*-affected plants and trees at owners' cost have become a significant economic and political issue. *Chalara fraxinea*, however, is not an EU-quarantine organism and affects only ash, but the predicted loss of native ash from most woodland has aroused widespread concern and debate about EU plant health regulations. Both diseases have also heighted public awareness of the ecosystem destruction that can result from introduced non-native organisms, generating citizen science initiatives for the early detection or tracking of new pests and pathogens as well as for identifying host resistance in trees under threat from established pathogens.

G-12 The co-evolution of insects and fungi that form symbiotic relationships and kill forest trees

Organizers: Mee-Sook Kim (Kookmin University, Republic of Korea) & Philip Cannon (U.S. Forest Service)

Fungal associates of the pine-infesting bark beetle *Dendroctonus approximatus* in Mexico and Central America. Bauman, T., Eckhardt, L. (*Auburn University, USA; tab0032@auburn.edu; eckhalg@auburn.edu*), Menard, R. (*U.S. Forest Service, USA; rmenard@fs.fed.us*), de Beer, W. (*FABI, University of Pretoria, South Africa; wilhelm.debeer@fabi.up.ac.za*), Sediles, A. (*National Agrarian University, Nicaragua; albertosediles@yahoo.com*), Wingfield, M. (*FABI, University of Pretoria, South Africa; Mike.Wingfield@up.ac.za*).

Dendroctonus approximatus is a bark beetle infesting several pine species over a large geographical range, stretching from the southwestern United States, throughout Mexico and Central America. The beetle is considered a secondary pest attacking dead and dying trees. It has glandular pronotal sac mycangia in which it carries basidiomycete fungi. However, as little is known about the ophiostomatoid fungi vectored by the beetle, the purpose of this study was to identify the ophiostomatoid fungi associated with the beetle in Central America and Mexico. Beetles were collected from the root systems of infested *Pinus oocarpa* in Guatemala, Honduras, Nicaragua, and Mexico and fungi were isolated from both the beetles and their galleries. DNA sequences of three gene regions were employed to tentatively identify the fungi. At least three species of *Ophiostoma* and six of *Leptographium* sensu lato were obtained, including five species that might be new to science. The role of these fungi in bark beetle ecology and their pathogenicity to pines remains unknown, and will be explored further in future studies.

Fungi and insect diversity associated with *Pinus radiata* in pitch-canker-affected stands. Diez-Casero, J., Martínez-Álvarez, P., Bezos, D., Fernandez, M. (*University of Valladolid, Spain; jdcasero@pvs.uva.es; pmtnez@pvs.uva.es; dianabezos@yahoo.es; mffernan@agro.uva.es*), Sanz, A. (*Castilla y León Government, Spain; tra-sanzrozan@jcyl.es*).

Fusarium circinatum is the causal agent of pitch canker disease (PCD) on pines. Several bark beetle species have been implicated as important vectors spreading this pathogenic fungus in northern Spain and in California. These insects are also well known for their association with other endophytic or pathogenic fungi. We hypothesized that the roles of the different bark beetle species did not have the same importance in the spread of the disease in our forests due to differences in their bioecology. *Hylastes attenuatus, H. ater, H. angustatus*, and *Ips sexdentatus* were the species found most abundantly in logs, whereas *H. ater* and *Xyleborinus saxeseni* were the more abundant species collected in ethanol and α-pinene traps. Furthermore, several endophytic species that commonly appear in pines were isolated from both insects and tissues. *Fusarium circinatum* was isolated from 1.05% of the *Pityophthorus pubescens* specimens and from the 3.5% of the shoots with *T. piniperda* feeding gallery. These results showed the important role of *T. piniperda* in the transmission of *F. circinatum* compared with other bark beetles in our study area.

Fusarium dieback and its ambrosia beetle (Coleoptera: Scolitinae) vector: a generalist disease-pest complex threatening agricultural and natural landscapes in California. Eskalen, A., Stouthamer, R., Paine, T. (*University of California--Riverside, USA; Akif.Eskalen@ucr.edu; richard.stotuthamer@ucr.edu; timothy.paine@ucr.edu*).

The polyphagous shot hole borer (PSHB) is an invasive ambrosia beetle that forms a symbiosis with *Fusarium euwallaceae* and *Graphium* sp. Together they cause fusarium dieback (FD), a pathogen-insect complex that affects trees in agriculture, ornamental landscapes, and native forests in California. To determine plant host range of the beetle-fungus complex, two botanical gardens in southern California were surveyed for presence of beetle-fungal combination. The relative abundance of fungal species associated

with PSHB in different hosts was determined by counting colony-forming units of each fungal species identified within the head, abdomen, and larvae of 10 beetles each from eight different hosts. Of the 335 tree species observed, 207 (62%) representing 58 plant families, showed signs and symptoms consistent with attack by PSHB; 19 functioned as reproductive hosts for PSHB. *F. euwallaceae* was recovered from 54% of the plant species attacked by PSHB. Trees attacked by PSHB included 11 species of California natives, 13 agriculturally important species, and many common street trees. Both fungi were recovered from different parts of the beetle at different frequencies. These data suggest the beetle carries more than one fungal species, and this beetle-disease complex potentially may establish in a variety of plant communities locally and worldwide.

The tree-killing ambrosia symbiosis illuminated with modern methods: sometimes stable, sometimes promiscuous, and increasingly more predictable. Hulcr, J. (*University of Florida, USA; hulcr@ufl.edu*).

The scolytine beetle-fungus symbiosis is capable of significant tree mortality that is often considered unpredictable. This is partly because the symbiosis is more species-rich, more ecologically dynamic, and more evolutionarily promiscuous than any other insect-fungus symbiosis. However, most previous analyses have been done on single species, with traditional culturing methods, and without any phylogenetic context. To describe the real diversity of the fungal symbiotic communities, to quantify the fidelity between beetles and fungi, and to test hypotheses about functioning of the symbiosis in different beetle clades, we employed a combination of new approaches: high-throughput marker gene sequencing, quantitative culturing, beetle anatomy, phylogenetics, and simulated inoculations into host trees. We show that some beetles are dominated by a single fungal symbiont, some species have two stable symbionts, some beetle clades host promiscuous symbiotic communities, and several beetle clades lost their symbionts. These levels of fidelity are phylogenetically conserved. Our results suggest that there is not one, but many ambrosia symbioses, and that each may be subject to different ecological and evolutionary processes. This has important applied implications: predicting future pests can be done, but only within comparable clades, and different clades of beetles have different probabilities of carrying tree pathogens.

Factors influencing the percentage of tree mortality by the Japanese oak wilt. Kamata, N. (*University of Tokyo, Japan; kamatan@uf.a.u-tokyo.ac.jp*).

In Japan, Japanese oak wilt (JOW), caused by an ascomycetous fungus (*Raffaelea quercivora*) carried by an ambrosia beetle (*Platypus quercivorus)*, has been prevalent for >2 decades. Host trees are widely found in the family Fagaceae with the exception of the genus *Fagus*. However, great variations in mortality were reported among tree species and also among local populations of each species. Approximate percentage of mortality is 60% for *Quercus crispula*, 5–30% for *Quercus serrata*, and 10% for *Lithocarpus edulis*. Generally, evergreen species show mortality lower than 10–15%. This paper summarizes factors influencing tree mortality by the JOW. Tree susceptibility to the pathogen was lower in evergreen species than in deciduous oaks. Sap defense against colonization from boring insects was weaker in *Quercus crispula* than in *Quercus serrata*. *Quercus crispula* had low sapwood proportion, which is a likely cause of high mortality. However, percent mortality of *Castanea crenata* was low, despite having the smallest sapwood proportion, and was probably related to the high concentration of tannin in sapwood. Not only tree susceptibility to the pathogen but also many other factors such as sapwood proportion, tannin concentration in sapwood, and sap exudation are related to tree mortality by the JOW.

Overview and origin of oak mortality caused by an ambrosia beetle-fungus complex in South Korea. Park, J. (*Korea Forest Research Institute, Republic of Korea; jhpark110@gmail.com*), Kim, M. (*Kookmin University, Republic of Korea; mkim@kookmin.ac.kr*), Lee, S., Seo, S., Kim, K. (*Korea Forest Research Institute, Republic of Korea; lskyou0425@gmail.com; stseo@forest.go.kr; kyung624@forest.go.kr*).

Severe mortality of Mongolian oak (*Quercus mongolica*) and other oak species has been reported in South Korea since 2004. The recent epidemic of oak mortality involves a synergistic interaction of an ambrosia beetle, *Platypus koryoensis*, and its symbiotic fungus, *Raffaelea quercus-mongolicae*. Dying trees exhibited moderate to heavy infestation by the beetle with extensive sapwood discoloration resulting from fungal infection. Multiple microorganisms are associated with the beetle. But, *R. quercus-mongolicae* is likely the primary colonizer of its insect and tree hosts based on its higher frequency of isolation and molecular detection from the beetles and infected wood tissues. Although the beetle and fungus were initially found on most oak species growing in Korea, the extent of infestation and colonization and mortality varied by species. The origin of *R. quercus-mongolicae* is still unknown. Its close association with *P. koryoensis*, the existence of early records, the wide geographic distribution of the beetle, and the presence of some relatively resistant trees may suggest that the fungus is perhaps native to Korea. In contrast, ongoing molecular studies provide preliminary evidence that this fungus may have been introduced into South Korea. The current research is focused on developing more efficient disease prediction and integrated management.

Chemical ecology of the walnut twig beetle, a pest of significance to the international cultivation of walnut for nut and timber production. Seybold, S., Nelson, L. (*U.S. Forest Service, USA; sseybold@fs.fed.us; lnelson@fs.fed.us*), Dallara, P. (*University of California--Davis, USA; twigdoc@gmail.com*), Graves, A. (*U.S. Forest Service, USA; adgraves@fs.fed.us*), Bostock, R. (*University of California--Davis, USA; rmbostock@ucdavis.edu*), Gries, R. (*Simon Fraser University, Canada; mgries@sfu.edu*), Francke, W. (*University of Hamburg, Germany; francke@chemie.uni-hamburg.de*).

The walnut twig beetle, *Pityophthorus juglandis* Blackman (WTB), colonizes the phloem of the branches and stem of all species of walnut (*Juglans*) and wingnut (*Pterocarya*). This invasive pest originated from the southwestern United States and Mexico, but has dramatically expanded its range in the United States through long-range dispersal facilitated largely by transport in raw (barked) walnut wood products. The male-produced aggregation pheromone (3-methyl-2-buten-1-ol) is the principal factor that guides the colonization of host material; an unidentified female-produced pheromone component also appears to be involved. Host (primary) attractants may contribute to WTB aggregation behavior, and their significance is under evaluation. Several host- and beetle-derived semiochemicals (e.g., chalcogran, conophthorin, limonene, 3-methyl-2-butenal) significantly reduce the flight response of WTB to its pheromone. Some of these interruptive behavioral chemicals are also associated with volatiles from the

fungus, *Geosmithia morbida*, which is a pathogen of *Juglans* phloem and vectored by WTB. The impact of this beetle-fungal complex (thousand cankers disease of walnut) has caused considerable tree mortality throughout the United States, and should be considered a threat to the health of walnut trees worldwide.

Coevolution of the siricid-*Amylostereum* mutualism on conifers. Slippers, B., Garnas, J., Hurley, B., Wingfield, M., Fitza, K., Wooding, A. (*FABI, University of Pretoria, South Africa; Bernard.Slippers@fabi.up.ac.za; jeff.garnas@fabi.up.ac.za; brett.hurley@fabi.up.ac.za; mike.wingfield@fabi.up.ac.za; Katrin.Fitza@fabi.up.ac.za; amy.wooding@fabi.up.ac.za*), Masanobu, T. (*Forestry and Forest Products Research Institute, Japan; butter@ffpri.affrc.go.jp*), Yek, S. (*FABI, University of Pretoria, South Africa; Sze_huei.yek@fabi.up.ac.za*), Boissin, E. (*Forestry and Agricultural Biotechnology Institute, France; eboissin@gmail.com*).

All woodwasps in the sub-family Siricinae infest conifers and have an obligate mutualism with species of the fungus *Amylostereum*, which suggests a long history of coevolution. In their native range these insects generally infest only dead or dying trees, causing minimal damage to forests. However, one species, *Sirex noctilio,* along with its fungal mutualist *A. areolatum*, has become one of the most successful global invaders and a very serious pest of *Pinus* plantations and forests. Here we consider phylogenetic and population genetic data from representatives of dominant genera of the Siricinae, as well as their associated *Amylostereum* spp., in order to understand their coevolution and global distribution. Emerging data suggest that the fidelity of this relationship is lower than previously realised. This has consequences in terms of understanding the impact of invasions in regions where other Siricids are native, and where the invasive populations can evidently exchange fungal symbionts with local populations. The data also suggest that this lack of fidelity at the species level is ancient, and not only the consequence of human-assisted introductions. Furthermore, the influence on global diversity patterns by other species than *S. noctilio* that have been introduced around the world should also be considered.

Posters

Life history of the walnut twig beetle, *Pityophthorus juglandis*, in California and Utah. Dallara, P. (*University of California--Davis, USA; twigdoc@gmail.com*), Reboletti, D., Munson, S. (*U.S. Forest Service, USA; dreboletti@fs.fed.us; smunson@fs.fed.us*), Flint, M. (*University of California--Davis, USA; mlflint@ucdavis.edu*), Seybold, S. (*U.S. Forest Service, USA; sseybold@fs.fed.us*.

The incidence of thousand cankers disease of walnut (TCD) in California is associated with increased activity of the walnut twig beetle (WTB), *Pityophthorus juglandis* Blackman, vector of the fungal causal agent, *Geosmithia morbida*. From 2010 to 2013, we used pheromone-baited cut branches of northern California black walnut, *Juglans hindsii*, placed on the ground to investigate the timing of WTB colonization, parental reemergence, larval development, and brood emergence in a native stand of *J. hindsii* in Alameda County, California, and in adventive plantings of eastern black walnut, *J. nigra*, at various sites in northern Utah. Emergence data from laboratory rearing of WTB-infested *J. hindsii* branches as well as data from dissection of periodically collected infested branches were used to model WTB reproductive behavior. A technique for pretreatment of host material by freezing was developed and demonstrated to eliminate confounding pre-existing populations of WTB and allow precise timing of WTB initial colonization. Timing of development of WTB associates is also described.

Taxonomy and population biology of *Grosmannia huntii* sensu lato. Eckhardt, L. (*Auburn University, USA; eckhalg@auburn.edu*), Duong, T., de Beer, W., Wingfield, B., Wingfield, M. (*FABI, University of Pretoria, South Africa; Tuan.Duong@fabi.up.ac.za; wilhelm.debeer@fabi.up.ac.za; Brenda.Wingfield@up.ac.za; mike.wingfield@fabi.up.ac.za*).

Grosmannia huntii (asexual morph also known as *Leptographium huntii*) is an ascomycete often associated with beetles infesting conifer hosts. This species is well known to cause blue stain in timber. However, recent inoculation studies have shown that it is capable of causing significant lesions in inoculated *Pinus* seedlings and young established trees. Since its first description from pine in Canada in 1964, isolates of *G. huntii* have subsequently been reported from various parts of the world including the United States, England, New Zealand, Chile, Portugal, and Australia. The aim of this study was to consider the identity of so-called *G. huntii* isolates from above-mentioned sources using multiple gene phylogenies. Phylogenetic analyses using sequence data from ITS2-LSU, beta-tubulin, and elongation factor-1 alpha regions revealed that the isolates represent two distinct species. One species, including the *G. huntii* ex-type isolate, represents isolates from Canada and the United States. The second species is an undescribed taxon including isolates from the United States, England, New Zealand, Chile, Portugal, and Australia. Considering the global distribution of the latter species, recently developed microsatellite and mating type makers will be applied to provide insight into the global movement and population biology of this species.

Variation in resistance of *Pinus taeda* families against root-infecting fungi. Eckhardt, L. (*Auburn University, USA; eckhalg@auburn.edu*), Singh, A. (*University of Nebraska, USA; amritpal.singh@huskers.unl.edu*), Bauman, T. (*Auburn University, USA; tab0032@auburn.edu*).

Pine decline is a serious threat to forest production sustainability in the southern United States and involves complex interactions of biotic and abiotic factors. *Leptographium* and *Grosmannia* spp. are the major contributing factors. This study was conducted to determine the variability in resistance of *Pinus taeda* families against these blue-stain fungi. Bare root seedlings from 23 *P. taeda* families were screened for resistance using an artificial inoculation method. Seedling responses (seedling survival, lesion presence, lesion length, and occlusion of vascular tissues) were measured 12 weeks after inoculations. Stems exhibited dark brown lesions and resinous occluded tissues. Within each family, different *Leptographium* and *Grosmannia* spp. showed similar responses and there were no family by fungal treatment interactions. Therefore, fungal treatments were pooled and families were categorized according to their level of resistance. Families L-5, L-20, L-8, and L-13 developed consistently smaller lesions, while families L-1, L-2, L-3, and L-4 were found to have larger lesions overall for each fungus. This study shows that family differences exist and that specific families may perform better in high risk sites.

Thinning and fertilization effects on populations of *Hylastes* species and associated ophiostomatoid fungal species in *Pinus taeda* stands. Eckhardt, L., Zanzot, J., Zeng, Y. (*Auburn University, USA; eckhalg@auburn.edu; zanzojw@auburn.edu; yzz0015@auburn.edu*), Kidd, K. (*Virginia Polytechnic Institute and State University, USA; kathryn2@vt.edu*), Bauman, T. (*Auburn University, USA; tab0032@auburn.edu*).

Ophiostomatoid fungi such as *Grosmannia* spp. and *Leptographium* spp. are known as contributing factors to southern pine decline in the southeastern United States. This study was developed to quantify fluctuations in *Hylastes* root-feeding bark beetles and their ophiostomatoid fungal incidence as a response to thinning and fertilization in *Pinus taeda* stands in central Alabama, Louisiana, and Georgia. Thirty-two forest health monitoring research plots were established on three industrial *P. taeda* timberlands (one per state). There were four thinning treatments (500, 300, 200, and 100 trees/acre) and two fertilization treatments (fertilized and not fertilized). Insects were trapped pre- and post- treatment. Roots were excavated and assayed for insect galleries and ophiostomatoid fungal infection. Tree vigor was assessed through crown rating and resin production. Statistical analysis indicated that there were higher insect population in the 100 and 200 trees/acre plots and that fertilized plots in all thinning treatments had higher overall insect populations. The dominant isolated fungal species were *Leptographium procerum*, *L. terebrantis*, *G. alarcris*, *G. huntii*, and *Ophiostoma ips*.

Interactions between *Matsucoccus macrocicatrices*, fungal pathogens, and eastern white pine dieback in the southern Appalachians. Gandhi, K. (*University of Georgia, USA; kjgandhi@uga.edu*), Asaro, C. (*Virginia Department of Forestry, USA; chris.asaro@dof.virginia.gov*), Coyle, D. (*University of Georgia, USA; drcoyle@uga.edu*), Cram, M. (*U.S. Forest Service, USA; mcram@fs.fed.us*), Mech, A., Schulz, A. (*University of Georgia, USA; angmech@gmail.com; anschulz@uga.edu*).

Since 2006, eastern white pine health issues including dieback and mortality have been reported from the southeastern United States. *Matsucoccus macrocicatrices* was found embedded in cankers on symptomatic white pines, and opportunistic fungal pathogens have also been isolated from these cankers. Our discovery of *M. macrocicatrices* in the southeastern United States is novel because this scale insect is a northeastern species; we found the insect persisting outside of epiphytic fungal mats of *Septobasidium pinicola* with which it is considered symbiotic; and the scale insect has historically never been associated with pine dieback. We established plots in Georgia, West Virginia, and Virginia to monitor the extent and severity of white pine health issues. Preliminary results indicate that 100% of the white pines are symptomatic with approximately 40% mortality in our plots. Majority of the mortality was observed on trees with a diameter <30 cm, indicating that seedlings and saplings are particularly affected in the region. In 89% of the plots, white pine dieback increased over 2 years. We plan to extend our sampling efforts across the southeastern region, to better understand the invasion dynamics and effects of *M. macrocicatrices* on an ecologically important pine species in the Appalachians.

Role of phoretic mites in the transmission of tree pathogens. Hofstetter, R. (*Northern Arizona University, USA; rich.hofstetter@nau.edu*), Moser, J. (*U.S. Forest Service, USA; john.moser@fs.fed.us*).

Interactions between insects, mites, and fungi are diverse and complex, but poorly understood in most cases. Many mites and insects rely on fungi as nutrient sources, and fungi benefit from them with regard to spore dispersal, habitat provision, or nutrient resources. We use case studies of bark beetle-*Ophiostoma* and -*Ceratocystis* systems as well other insect taxa to elucidate the effects of mites on the transmission of tree pathogens. We describe mutualistic and antagonistic effects of mites on insect-fungal associations and explore the processes that underpin ecological and evolutionary patterns of these multipartite communities. Mites have important impacts on community dynamics, ecosystem processes, and biodiversity within many tree-insect-fungal systems. Given how understudied but highly abundant mites are, they likely have bigger, more important and widespread impacts in forest health.

Genetic diversity and population structure of an ambrosia-beetle-vectored fungus (*Raffaelea quercus-mongolicae*) associated with oak mortality in Korea. Kim, M. (*Kookmin University, Republic of Korea; mkim@kookmin.ac.kr*), Hohenlohe, P. (*University of Idaho, USA; hohenlohe@uidaho.edu*), Kim, K., Seo, S. (*Korea Forest Research Institute, Republic of Korea; kyung624@forest.go.kr; stseo@forest.go.kr*), Klopfenstein, N. (*U.S. Forest Service, USA; nklopfenstein@fs.fed.us*).

In South Korea, oak mortality is associated with *Raffaelea quercus-mongolicae* and its ambrosia-beetle vector, *Platypus koryoensis*. The resulting disease has continued to spread southwards from its center in Seoul and Gyeonggi Province, and has significantly impacted forest ecosystems in Korea. Thus far, the fungus has only been found in Korea and its origin is unknown. This study was conducted to assess genetic diversity and population structure of the fungus using restriction-site-associated-DNA sequencing (RAD-seq). Fifty-four isolates of *R. quercus-mongolicae* were collected from several regions (populations) of Korea for generating RAD-tag libraries and DNA sequencing. Sequencing the RAD-tag libraries generated 143 696 855 reads using Illumina HiSeq. In total, 179 single nucleotide polymorphisms (SNPs) were identified among 2 639 RAD loci across the nuclear genome of the 54 *R. quercus-mongolicae* isolates (0.00080 SNPs per base pair) with overall low expected heterozygosity and no apparent population structure. The low genetic diversity and no apparent population structure among South Korean populations of this ambrosia-beetle-vectored fungus raises a critical issue about whether this fungal pathogen was introduced to South Korea. Continued studies are needed to confirm whether *R. quercus-mongolicae* was introduced to South Korea and determine its evolutionary origin.

Complementary roles of bark beetles and associated fungi in overwhelming conifer defenses. Krokene, P. (*Norwegian Forest and Landscape Institute, Norway; krp@skogoglandskap.no*).

The spruce bark beetle, *Ips typographus*, is an important tree killer of Norway spruce, *Picea abies*, forests in Europe and Asia. During outbreaks it can kill relatively healthy trees through pheromone-mediated mass-attacks involving hundreds of beetles. The beetles' fungal associates in the genera *Ceratocystis*, *Ophiostoma*, and *Grosmannia* are thought to aid in overcoming tree defenses by increasing the impact of each beetle attack. The most virulent of these fungi can colonize the bark and sapwood of attacked trees far beyond the beetle galleries in the bark. Recent research has demonstrated that the fungal associates of *I. typographus* and

other tree-killing bark beetles can metabolize secondary host metabolites such as terpenoids and phenolics. This is evidence for a mutualistic relationship between the beetles and the fungi and suggests that the beetle-fungus complex acts synergistically to overwhelm tree defenses. The beetles and the fungi challenge different components of the tree's multi-faceted defenses and thus probably complement each other in overwhelming tree resistance.

Xylem dysfunction caused by Japanese oak wilt pathogen *Raffaelea quercivora* and its hyphal distribution. Takahashi, Y., Fukuda, K. (*University of Tokyo, Japan; ytakah@gmail.com; fukuda@k.u-tokyo.ac.jp*).

Mass mortality of Fagaceae trees due to Japanese oak wilt has been tremendous in Japan since the late 1980s. The causal fungus *Raffaelea quercivora* is vectored by an ambrosia beetle, *Platypus quercivorus*, which reiterates local invasion and explosion. The fungus introduced into the gallery by the beetle causes dysfunction of water conduction of vessels. We investigated detailed distribution of water in vessels in the xylem by cryo-SEM and the dye injection method and distribution of *R. quercivora* hyphae in the same specimen by F-WGA staining, and examined their spatial relationships in *Quercus crispula* saplings. Results show that current-year vessels were filled with water, and the previous-year vessels were vacant in both inoculated and control saplings. Although the previous-year vessels were vacant, vasicentric tracheids around those vessels were filled with water in both inoculated and control saplings. Tyloses were distributed in vessels outside the areas invaded by the hyphae; that means there was no water conduction in the vasicentric tracheids around the vessels. Water conduction was lost in the xylem area around the hyphal invasion; however, tracheids were filled with water. Therefore, the dysfunction of water conduction in these seedlings could not be attributed to cavitation in vessels.

Hyphal growth of *Raffaelea quercivora* within inoculated living and gamma-ray-sterilized seedlings of two Japanese and three American oak species. Torii, M., Ito, S., Matsuda, Y. (*Mie University, Japan; masa10torii@gmail.com; ito-s@bio.mie-u.ac.jp; m-yosuke@bio.mie-u.ac.jp*).

Mass mortality of Fagacean trees caused by *Raffaelea quercivora* has occurred widely in Japan. Because conidia or other propagules of the pathogen have not been found in infected trees, pathogen spread is assumed to occur primarily by hyphae. To clarify the relationship between hyphal growth of the pathogen within trees and their vessel arrangements, we examined two native Japanese oaks, *Quercus crispula* and *Q. glauca*, and three exotic American oaks, *Q. coccinea*, *Q. palustris*, and *Q. rubra*. *Quercus glauca* is a radial-porous species, whereas the other four species have a ring-porous wood structure. Hyphal growth within inoculated living seedlings and sterilized stem segments of these species was examined microscopically. Water conductance in the seedlings was examined. The proportion of nonconductive sapwood in *Q. crispula*, *Q. coccinea*, and *Q. palustris* differed between inoculation and control treatment, being much higher in inoculated seedlings. The proportions were positively correlated with the hyphal growth. In sterilized segments, the hyphal growth varied among the foreign species. It is hypothesized that the hyphal growth of *R. quercivora* reflects the extent of nonconductive sapwood irrespective of tree species, but is little affected by vessel arrangements.

Pathogenicity of three *Raffaelea* spp. isolates collected in northern Thailand against *Quercus crispula* seedlings. Torii, M., Ito, S., Matsuda, Y. (*Mie University, Japan; masa10torii@gmail.com; ito-s@bio.mie-u.ac.jp; m-yosuke@bio.mie-u.ac.jp*), Buranapanichpan, S. (*Chiang Mai University, Thailand; sawai.b@cmu.ac.th*).

In Japan, mortality of Fagacea trees caused by *Raffaelea quercivora*, which is transmitted by *Platypus quercivorus*, has been obvious since the late 1980s. Although origins of the pathogen and the vector are under discussion, they are assumed to be introduced from Asian countries. Recently, three unknown *Raffaelea* isolates were obtained from logged Fagacea trees infected by wood-boring beetles in northern Thailand. To evaluate the potential pathogenicity of the unknown *Raffaelea* fungi, the three isolates and one *R. quercivora* isolate were applied to multiple inoculations against Japanese *Quercus crispula* seedlings, which are susceptible to *R. quercivora*. At 45 d after inoculation, mortality rate ranged from 25 to 40% for Thai isolates, and was 82% for *R. quercivora*. The rates in inoculation treatments of one Thai isolate and a *R. quercivora* isolate were significantly higher than those in the control treatment. Irrespective of isolates, conductive sapwood of most inoculated seedlings was not observed in upper positions higher than inoculation sites. These results suggest that the *Raffaelea* fungus is pathogenic to *Q. crispula* is present in northern Thailand.

G-13 Modeling as a tool for improving the knowledge on forest vulnerability and risk exposure in a changing world

Organizers: Alessandra De Marco (ENEA, Italy) & Salim Belyazid (Lund University, Sweden)

Can modeled and measured data interact to evaluate forest health condition? Anav, A. (*University of Exeter, UK; A.Anav@exeter.ac.uk*), Proietti, C. (*Sapienza University of Rome, Italy; chiaraproietti84@uniroma1.it*), Sicard, P. (*ACRI-ST, France; pierre.sicard@acri-st.fr*), Vitale, M. (*Sapienza University of Rome, Italy; marcello.vitale@uniroma1.it*), Paoletti, E. (*National Research Council, Italy; e.paoletti@ipp.cnr.it*), Cionni, I., De Marco, A. (*National Agency for New Technologies (ENEA), Italy; irene.cionni@enea.it; alessandra.demarco@enea.it*).

Increasing atmospheric CO_2 concentration leads to a higher amount of carbon stored in the world's forests. However, the enhanced assimilation could be counterbalanced by the negative effect of air pollutants in the lower troposphere. Among common air pollutants, O_3 is probably the most damaging to forests, frequently reaching high concentrations over large regions of the world. Several studies suggest that ozone might reduce gross primary production by about 15–20% and the crop yield from 0 to 30%, leading to relevant consequences for both surface climate and food supply. Although huge areas of the globe are exposed to high O_3 levels, which are expected to increase in the near future, the impact of ozone on vegetation is largely under-investigated,

or studied with old, accumulated exposure thresholds rather than with instantaneous fluxes. Here we studied the potential effects of O_3 on defoliation of forest canopies. We used different atmospheric chemistry models (WRF/CHEM 3.5, CHIMERE, and RegCM4-CHEM) to produce ozone fields over Europe at high spatial resolution. Then we validated simulated O_3data with measurement station data. Finally, we evaluated the contribution of ozone to defoliation, comparing the effect of this pollutant on nitrogen pools and other relevant climatic variables for plant growth.

Combining large-scale simulation with economic models to investigate impacts of climate change on forests. Hanewinkel, M. (*Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland; marc.hanewinkel@wsl.ch*).

Based on a general framework to assess economic impacts on forests, the paper describes how model chains should be designed to assess economic impacts of climate change on forest ecosystems. An ideal model should, based on models for future climate scenarios, consist of models depicting ecological scenarios from dynamic global vegetation, or similar models that are able to translate ecological results into growth and disturbance effects for forest ecosystems. These models have then to be completed by models that are able to reflect economic impacts in terms of prices, timber production, and welfare effects and should include scenarios for future economic and population growth. In order to project realistic developments into the future, feedback loops between management, ecological impacts, and market interactions have to be implemented in the model chain. The paper shows an example of a model chain consisting of a species distribution model, a large-scale scenario model, and a classical (Faustmann-based) forest economics model that was used to project changes in the land expectation value of European forests. Uncertainties and future research challenges to improve the presented modeling approach are discussed.

Impact of climate and site conditions on the growth-mortality relationship in European tree species. Hülsmann, L. (*Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland; lisa.huelsmann@wsl.ch*), Bugmann, H. (*ETH Zurich, Switzerland; harald.bugmann@env.ethz.ch*), Brang, P. (*Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland; peter.brang@wsl.ch*).

Tree death is a key process in the development of forest ecosystems, particularly under changing environmental conditions. Despite an increasing number of empirical tree mortality models, mortality remains one of the least understood processes, thus leading to large uncertainties in the simulation of future forest dynamics. Principally this is because long-term datasets for mortality prediction are scarce. In this context, large inventory datasets from forest reserves are of particular importance, as regular mortality is higher in the absence of forest management. Based on such datasets from Germany and Switzerland, tree mortality models are derived for a broad range of species and site conditions focusing on models that predict regular mortality in individual trees and consider tree size and growth as a measure for vigor. Particular emphasis is placed on the drivers of spatial variation in mortality by considering environmental influences such as soil properties and climate. Mortality is modeled using mixed-effects logistic regression accounting for the hierarchical structure of inventory data and for unmeasured effects not captured by site covariates. The resulting models enhance our understanding of spatial patterns in the process of tree death. Implemented into models of forest dynamics, improved predictions of future tree mortality are expected.

Uncertainty and sensitivity analyses: can model structure be improved? The case of the wind-risk model ForestGALES. Locatelli, T. (*University of Edinburgh, UK; t.locatelli@sms.ed.ac.uk*), Gardiner, B. (*National Institute for Agricultural Research (INRA), France; barry.gardiner@bordeaux.inra.fr*), Nicoll, B. (*Forestry Commission, UK; bruce.nicoll@forestry.gsi.gov.uk*), Patenaude, G. (*University of Edinburgh, UK; Genevieve.Patenaude@ed.ac.uk*), Tarantola, S. (*Joint Research Centre of the European Commission, Italy; stefano.tarantola@jrc.ec.europa.eu*).

Uncertainty analysis and sensitivity analysis are important tools available to modellers to investigate the validity of model predictions and the robustness of model structure. Analyses of sensitivity of model outputs to the contribution of input variables are often performed with local methods, by taking the partial derivatives of an output variable in respect to the inputs fixed to a nominal value. These approaches, however, cannot explore the entire space of the inputs and neglect second- and higher-order interactions between input variables. When models are known to be nonlinear, or when the structure of a model is still at a developmental stage, this can be a perilous practice. Methods for global sensitivity analysis (GSA) that explore the entire input space, and can account for total effects of variable interactions to the output, are therefore preferred. Moreover, these methods are model-free, in the sense that they do not rely on assumptions of model linearity, additivity, or monotonicity. We present the results of a GSA applied to ForestGALES, a wind-risk model of forest vulnerability, and show that by identifying the input variables that drive most of the variance in the outputs, a more economical model in terms of input requirements can be built.

Predicting the spore infection relationship with climate to model *Heterobasidion annosum* dynamics in an even-aged *Pinus pinaster* stand. Meredieu, C., Lung-Escarmant, B., Labbe, T., Bert, D., Segura, R, Capdevielle, X. (*National Institute for Agricultural Research (INRA), France; celine.Meredieu@pierroton.inra.fr; lung@bordeaux.inra.fr; Thierry.Labbe@pierroton.inra.fr; Didier.Bert@pierroton.inra.fr; Raphael.Segura@pierroton.inra.fr; Xavier.Capdevielle@pierroton.inra.fr*).

Over the past 30 years, in the Landes de Gascogne forest (maritime pine; 1 million ha), *Heterobasidion* root disease has increased its distribution. A previous study showed that it occurred more frequently in well-drained sites than in humid and dry, sandy soils. Understanding how the forecasted increase in warm, dry summers and wet winters along the Atlantic coast of France will change the incidence of the pathogen is crucial for integrating the losses and managements costs against this disease. To investigate the intra-annual climate variability, a 3-year experiment was carried out on air-borne infection. *H. annosum* spore deposition was monitored on freshly cut wood discs exposed for 24 h. Another key point concerned growth losses in trees depending on annual and individual growth rate. Diameter growth loss was investigated by analyzing annual growth increment of pairs of healthy trees versus infected trees during a few years. After implementation of these results into a model, simulations were carried out with different levels of infected stumps. The model provides a means of incorporating the impact of root disease into the future forest planning.

Modeling spruce beetle and fire disturbance under climate change and adaptive management in subalpine forests of northern Colorado, USA. Temperli, C., Hart, S., Veblen, T. (*University of Colorado, USA; christian.temperli@colorado.edu; sarah.hart@colorado.edu; thomas.veblen@colorado.edu*).

While there is ample quantitative evidence of the effects of climate variation on forest development and individual disturbances, projecting the interactions of these effects and their long-term consequences for forest development and adaptive management remains a challenge. We synthesized our current understanding of the interactions among climate, spruce bark beetles (*Dendroctonus rufipennis*), and forest development to parameterize the pathogen module of a dynamic forest landscape model (LandClim) that additionally accounts for climate-wildfire-forest interactions as well as forest management. Applying LandClim in spruce- and fir-dominated subalpine case studies in northern Colorado, United States, we examined the mechanisms and feedbacks that may lead to shifts in forest state and beetle and fire disturbance under a range of climate change and forest treatment scenarios. Simulation results indicate that projected warming and drought increasingly favors beetle and fire disturbance. However, recurring disturbances may decrease forest susceptibility and disturbance frequency and severity in the long term by promoting younger, less dense forests as well as deciduous aspen. Treatments that emulate these long-term climate and disturbance effects were shown to effectively reduce fire disturbance locally, but may not be feasible at the landscape scale, which has important implications for forest management resource allocation.

G-14 Impact and monitoring of forest pests and pathogens in a changing world

Organizers: Maartje J. Klapwijk, Johanna Boberg, (Swedish University of Agricultural Sciences) & Jolanda Roux (FABI/University of Pretoria, South Africa)

Challenges and prospects of forest health monitoring in smallholder community plantations in Ghana. Bosu, P., Apetorgbor, M., Nkrumah, E., Bandoh, K. (*Forestry Research Institute of Ghana; paul_bosu@yahoo.com; mapetorgbor57@gmail.com; enkrumah@csir-forig.org.gh; pbandoh@csir-forig.org.gh*).

A non-conventional forest health monitoring approach was used to monitor pests and disease conditions in smallholder community forest plantations in Ghana. We used a combination of interviews, focus group discussions, exhibition or display of pictures, and samples of potential key pests as well as pictures of symptomatic trees to elicit community perception of forest health condition. This was followed by targeted intensive field surveys and assessment in collaboration with the concerned community members. Twenty-three communities and >20 ha of taungya-type plantations that included two exotic species *Tectona grandis* (teak) and *Cedrela odorata* (cedar), and two indigenous species *Terminalia superba* (ofram) and *Ceiba pentandra* (ceiba) were surveyed. A wide range of tree health conditions involving both biotic and abiotic stresses were identified in at least 15% of the total plantation area. We observed that the approach used was not only effective in identifying forest health conditions in the plantations, but it also offered the opportunity to increase community awareness on a wide range of forest management issues.

Tipping points and transformation in forest pest ecology: the challenge of rising uncertainties under climate change catastrophe theory. Cooke, B. (*Canadian Forest Service, Canada; bcooke@nrcan.gc.ca*).

Réné Thom, the 1970s founder of catastrophe theory, once said that catastrophe theory died a death of its own success, as a paradigm that predicted the unpredictability of those events that were most desperately in need of prediction. Forest pest systems are complex adaptive systems that exhibit both nonlinear dependencies on temperature and nonlinear process interactions of high dimension, and are precisely the sort of systems that Holling showed were predisposed to generating catastrophic, spontaneous ecosystem change. Climate warming, as an agent of continuous change in nonlinear forest insect systems, serves to exacerbate the ordinary uncertainty problem in forest pest management, for which there is currently an adaptive capacity deficit, turning it into an extraordinary challenge in global ecosystem risk management. Using a process-based model of forest insect pest dynamics (bark beetles and budworms) I show that a new paradigm is required to adapt to the unprecedented levels of uncertainty that are likely to prevail under transformative climate-driven ecosystem change.

454 pyrosequencing reveals important *Eucalyptus* pathogens on seed and seed-capsules. Jimu, L., Kemler, M., Wingfield, M. (*FABI, University of Pretoria, South Africa; Luke.Jimu@fabi.up.ac.za; Martin.Kemler@fabi.up.ac.za; Mike.Wingfield@up.ac.za*), Mwenje, E. (*Bindura University of Science Education, Zimbabwe; edmwenje@gmail.com*), Roux, J. (*FABI, University of Pretoria, South Africa; jolanda.roux@fabi.up.ac.za*).

The global spread of *Eucalyptus* pathogens has been attributed to the increased movement of people, germplasm, and timber products. It has been hypothesised that *Eucalyptus* germplasm, especially seed, could play an important role in the movement of pathogens across international boundaries, but little attention has been paid to this question. The aim of this study was to consider whether important groups of *Eucalyptus* fungal pathogens could be seed borne. Seed and seed-capsules were collected from *Eucalyptus grandis* in South Africa. DNA was extracted and the internal transcribed spacer (ITS) locus was amplified using fungal specific primers. Data were analysed using the basic local alignment search tool (BLAST) and phylogenetic reconstructions. A total of 7 313 sequences were recovered from seed (3 378) and capsules (3 935). The majority of the fungal sequences were those of Ascomycota (69.6%). Basidiomycota represented only 5% of the total reads. Results of this study showed a dominance of fungi belonging to Botryosphaeriaceae, Mycosphaerellaceae, and Teratosphaeriaceae. These groups accommodate major pathogens of *Eucalyptus* including important genera such as *Botryosphaeria*, *Mycosphaerella*, *Neofusicoccum*, and *Teratosphaeria* The latter genus includes the devastating stem canker pathogen *T. zuluensis*. These findings present the first concrete evidence of important *Eucalyptus* pathogens being carried on seeds and reinforce the need to manage the global exchange of this form of germplasm.

Contrasting geographical variation in invasibility to non-native forest pests with their impacts. Liebhold, A. (*U.S. Forest Service, USA; aliebhold@fs.fed.us*).

The invasion by non-native forest insect and diseases is a serious problem that threatens the sustainability of forest ecosystems worldwide. Continental scale heterogeneity in the number of non-native forest pest species can be attributed in part to geographical variation in propagule pressure, but is also strongly affected by invasibility, the habitat susceptibility of local ecosystems to the establishment of new species. Empirical evidence indicates that the diversity of forest tree species promotes invisibility by creating more windows of opportunity for the establishment of host-specific pest species. Conversely, tree diversity may also make forests more resilient to the impacts of invasions because more diverse forests can more readily compensate for the loss of tree species. These tradeoffs are discussed as well as implications to forest management.

Monitoring population densities of *Ips typographus* L. using pheromone traps and trapping trees. Lyytikäinen, M., Kantola, T., Lyytikäinen-Saarenmaa, P., Holopainen, M. (*University of Helsinki, Finland; minna.lyytikainen@helsinki.fi; tuula.kantola@helsinki.fi; paivi.lyytikainen-saarenmaa@helsinki.fi; markus.holopainen@helsinki.fi*).

The European spruce bark beetle (*Ips typographus* L.) has become a major threat to Finnish forests. During the past 3 years, thousands of hectares of mature spruce stands have been killed by *I. typographus* in southern and southeastern Finland. The goal of this study was to estimate population density of *I. typographus* with pheromone traps and trapping trees. The target areas were located in the vicinity of Lahti (60°59′N, 25°37′E). Altogether, 42 trap groups (178 pheromone traps) were monitored weekly between May and September 2012. In addition, 29 trapping tree piles were monitored in late June after a trapping period of 6 weeks. The average number of male *I. typographus* in late May was approximately 2 400 individuals per pheromone trap and maximum number was more than 5 800 individuals per trap. For trapping tree piles, average density of *I. typographus* males was 73/m^2. The result showed that population density of *I. typographus* was extraordinary high in the target areas. These high population densities were often connected with even-aged, mature Norway spruce stands, growing on higher elevation. Therefore, it is very important to continue monitoring population densities to promote forest health on adjacent stands and relate these results to forest management planning and risk assessment.

Invasions of forest insects and diseases and their impacts on regional forest dynamics in North America. Morin, R., Liebhold, A. (*U.S. Forest Service, USA; rsmorin@fs.fed.us; aliebhold@fs.fed.us*).

Over the last century, North America has been inundated by a steady stream of non-native forest insect and disease invasions. While most of these species remain sparse and their effects on forests remain unnoticed, a few of these species have caused widespread dieback and mortality of forest tree species. Forests in eastern North America are already in a strong successional flux as a result of extensive land clearing that was carried out >100 years ago, followed by widespread agricultural abandonment. We report here on several analyses that we have conducted attempting to characterize the large scale changes in forest composition and structure associated with invasions by the gypsy moth (*Lymantria dispar*), hemlock woolly adelgid (*Adelges tsugae*), and beech scale, (*Cryptococcus fagisuga*) on a regional scale across the eastern United States. These analyses were conducted by comparing the historical invasion ranges of these pest species with forest inventory data collected at thousands of points over time. The impacts of these species can be clearly seen in the accumulation of dead trees as a result of these invasions; however, to some extent, this mortality is compensated for by increased growth in non-host tree species. As a result, these invasions have altered the direction of ongoing forest succession across large areas resulting in forest species mixtures that would not exist without pest invasions.

Reconstructing the routes of invasion and genetic diversity of *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae) using microsatellite markers. Mutitu, E. (*Kenya Forestry Research Institute, Kenya; estonmutitu@gmail.com*), Garnas, J., Hurley, B., Slippers, B., Wingfield, M., Hoareau, T. (*FABI, University of Pretoria, South Africa; jeff.garnas@fabi.up.ac.za; brett.hurley@fabi.up.ac.za; Bernard.Slippers@fabi.up.ac.za; mike.wingfield@fabi.up.ac.za; thoareau@gmail.com*).

Thaumastocoris peregrinus is a pest of *Eucalyptus* that has recently invaded many parts of the world where this tree is grown commercially. There are currently no control programs in place for this insect and these are urgently needed. Knowledge of the genetic diversity and structure of invasive and native populations of *T. peregrinus* would clarify the sources and routes of invasion, which is important for the development of potential management strategies, such as biological control. Historical records of first reports of the insect and microsatellites analysis (using nine loci) in native and invaded populations were employed to obtain this information. As expected, substantially higher genetic diversity was observed in the native populations compared to invasive populations. The data show that two independent introductions have occurred to form the distinct African and South American population groups. The sub-structure observed in the South African and Kenyan populations revealed a complex colonisation history of African populations. Population genetic structure analysis has shown that the source population of the invading genotypes is mostly likely Sydney (Australia). This information reinforces the complexity of invasion routes of pests, and will provide impetus to a focused search for and identification of potential natural enemies.

Myrtle rust: current and future impacts on myrtaceous diversity in Australia. Pegg, G. (*Queensland Department of Agriculture, Fisheries and Forestry, Australia; geoff.pegg@daff.qld.gov.au*), Carnegie, A., Giblin, F. (*University of the Sunshine Coast, Australia; angus.carnegie@fcnsw.com.au; fgiblin@usc.edu.au*).

Puccinia psidii has long been considered a significant threat to Australian plant industries and ecosystems. In 2010, *P. psidii* was detected for the first time on the central coast of New South Wales, spreading rapidly to become widespread on the east coast of Australia. Our studies aimed to determine the host range and impact of *P. psidii* on species of environmental significance. The host range of *P. psidii* in Australia has increased rapidly, with field surveys identifying more than 220 host species from 51 different genera of Myrtaceae. *Puccinia psidii* has now been identified from many different native Australian forest ecosystems including coastal heath, coastal and river wetlands, sand islands, and littoral, montane, subtropical and tropical rainforests. The impact of *P. psidii* on individual trees and shrubs has ranged from minor leaf spots to dieback and reduced fecundity. Tree death as a result of repeated infection has also been recorded for some species, with regenerating seedlings becoming infected and killed by *P. psidii. Puccinia psidii* infection has been recorded on flower buds, flowers, and fruits of 28 host species. The full impact of this disease in Australia may not be realised for some years.

Global climate change and gall rust disease epidemic on *Falcataria moluccana* in Indonesia and Malaysia. Rahayu, S. (*Gadjah Mada University, Indonesia; tatarahayu@yahoo.com*), Lee, S. (*Forest Research Institute of Malaysia; leess@frim.gov.my*).

Gall rust disease caused by *Uromycladium tepperianum* is one of the most destructive diseases on *Falcataria moluccana* plantations in parts of the Southeast Asia region. The disease causes severe damage to all developmental stages of the plant from the nursery to mature trees in the field, including development of chocolate brown, cauliflower- or whip-like galls on stem, branch, petiole, shoot, and pod. The objectives of this study were to determine the status of gall rust disease, estimate the relationship between incidence of gall rust disease and environmental factors that may influence those phenomena in the estate, and predict the origin of gall rust spore sources. The sampling intensity was 10% of the total area at each site. More open-site forest, flat topography, absence of fog, more age, and lower altitude were significant local site conditions that reduced gall rust disease incidence and severity. High relative humidity and slower wind speed promoted gall rust disease development. The wind blew predominantly from the northeast at Brumas Estate, possibly spreading gall rust spores from the north, probably from the Philippines to Tawau.

Population genetic studies reveal complex patterns of global movement of pests and pathogens in *Pinus* and *Eucalyptus* plantations. Slippers, B. Kemler, M., Garnas, J., Hurley, B., Wingfield, B., Wingfield, M. (*FABI, University of Pretoria, South Africa; Bernard.Slippers@fabi.up.ac.za; Martin.Kemler@fabi.up.ac.za; jeff.garnas@fabi.up.ac.za; brett.hurley@fabi.up.ac.za; Brenda.Wingfield@up.ac.za; mike.wingfield@fabi.up.ac.za*).

The threat from invasive pests and pathogens to the sustainability of the extensive *Pinus* and *Eucalyptus* plantations is well recognized. In recent years increasingly powerful molecular genetics and genomics tools have allowed for the fine scale dissection of the routes and extent of these introductions. These studies are revealing that the introductions are often large, and/or recurring, thus leading to complex and genetically diverse invasive pest and pathogen populations. These patterns increase the chances for adaptation and invasion success of the alien pests and pathogens, and they complicate control programs based on breeding and biological control. This situation raises serious questions regarding the efficiency of quarantine approaches to mitigate the treat of new introductions. A change in focus to managing pathways of introduction rather than individual pests and pathogens has frequently been proposed, and seems overdue. Yet, based on previous experiences it seems unrealistic to expect that there would be sufficient control to stem the continued introduction of new pests and pathogens. Substantially increased capacity is therefore also required to develop monitoring and control programs to ensure an ability to respond more rapidly to the inevitable and continued increase in globally distributed pests and pathogens of plantation-grown trees.

Sentinel nurseries: an early warning system to prevent alien forest pathogens invasion. Vettraino, A. (*University of Tuscia, Italy; vettrain@unitus.it*), Li, H., Eschen, R., Kenis, M. (*CABI, China; h.li@cabi.org; R.Eschen@cabi.org; m.kenis@cabi.org*), Yart, A., Roques, A. (*National Institute for Agricultural Research (INRA), France; Annie.Yart@orleans.inra.fr; alain.roques@orleans.inra.fr*), Vannini, A. (*University of Tuscia, Italy; vannini@unitus.it*).

Recent rapid expansion of alien invasive pathogens into European forest ecosystems has posed a serious threat to their sustainability with relevant environmental and economic impacts. Most of the alien pathogens recently introduced into Europe were not included in any quarantine list, thus they were not subjected to phytosanitary inspections. The identification and description of alien fungi potentially pathogenic to native European flora before their introduction in Europe, is a paramount need in order to limit the risk of invasion and the impact to forest ecosystems. Within the European Union's project ISEFOR and the COST Action PERMIT, the sentinel trees strategy has been used to identify Asian fungi pathogenic to European trees and to those Asiatic species most frequently imported into Europe. A first plot has been established in Fujian, China, using healthy seedlings of the European broadleaved species *Quercus petreae*, *Q. suber*, *Q. ilex*, *Fagus sylvatica*, and *Carpinus betulus*, and two conifers, *Abies alba* and *Cupressus sempervirens*. A second plot was established in Beijing with seedlings of the Asiatic species *Fraxinus chinensis*, *Ilex cornuta*, *Buxus microphylla*, *Acer palmatum*, and *Zelkova schneideriana*. The fungal assemblage associated with specific symptoms was studied using isolation on synthetic media and the tag-encoded 454 pyrosequencing of the nuclear ribosomal internal transcribed spacer-1 (ITS 1). The results will be reported.

Developing national biosecurity charters: safeguarding forest and agro-ecosystems for cultural and functional integrity. Williams, S. (*University of Wyoming, USA; sewms@uwyo.edu*), Bellgard, S. (*Landcare Research, Ltd., New Zealand; BellgardS@landcareresearch.co.nz*), Aronis, J. (*Malcolm V. Leeke & Co., Australia; john@leeke.com.au*), Boldgiv, B. (*National University of Mongolia; boldgiv@num.edu.mn*).

Disease is expressed when environmental conditions favour pathogens and insect pests and tree hosts are stressed. Kauri forests of New Zealand are being compromised by a novel *Phytophthora* pathogen, and pine forests of the western United States by mountain pine bark beetles. Coastal forests on Fraser Island, a World Heritage sand island off northeastern Australia, are subject to the effects of strip-mining and water pollution stressors from recreational activities. Mongolian ecosystems seem relatively unstressed, but high altitude and latitude exacerbate impacts of global climate change. Already, there is recognised demise of Mongolian beech forests. All of these systems are subject to the effects of global climate change, environmental pollutants (e.g., SO_x, NO_x), with global plant trade, mineral exploration, and development providing avenues for exotic incursions. The focus of the study is to preemptively identify legal, cultural, social, and economic impediments which prevent timely implementation of scientific research to develop incursion response procedures. The role of research (i.e., quantitative, qualitative, pragmatic, and participatory) is to navigate through constraints to achieve consensus among stakeholders and allow delivery of best practice solutions. These guide the sustainable development of natural and mineral resources, and biosecurity responses to maintain functional, cultural, ecological, and economic values of forest resources.

Why does a species become a pest? Comparison of three *Physokermes* species. Winde, I., Jönsson, A. (*Lund University, Sweden; inis.winde@biol.lu.se; anna_maria.jonsson@nateko.lu.se*), Gertsson, C. (*Consultant, Sweden; carlaxel.gertsson@gmail.com*), Isacsson, G. (*Swedish Forest Agency, Sweden; gunnar.isacsson@skogsstyrelsen.se*), Anderbrant, O. (*Lund University, Sweden; Olle.Anderbrant@biol.lu.se*).

The Hungarian spruce scale, *Physokermes inopinatus,* was detected for the first time in Sweden in 2010, when it infested 1 000 ha of Norway spruce. Why did this happen and why have its native close relatives, *P. piceae* and *P. hemicryphus*, never caused comparable damages? Insects are known to react to climate change, e.g., with respect to phenology, number of generations per year, mobility, or dispersal range. Changes like these can increase the damage caused by known pests. Also insects without any former pest record could develop abilities to colonize, even seriously infest, new areas at long distances from earlier records. We have focused on clarifying possible differences in the life cycle and habitat requirements of the three *Physokermes* spp., to provide answers to the questions above. Due to their hidden and discrete life style they have been studied to a very limited extent before our investigations. We here report results from studies on their morphology, life cycle, and host preferences, which will give insights into their adaptation abilities. Thereby, we will be able to evaluate the actual pest value of the species as well as supply information for a general, species comprehensive, management of invasive or new pests.

Posters

Monitoring air-, water-, and insect-borne invasive forest pathogens in Sweden. Boberg, J., Stenlid, J., Oliva, J. (*Swedish University of Agricultural Sciences, Sweden; johanna.boberg@slu.se; jan.stenlid@slu.se; Jonas.Oliva@slu.se*).

An efficient detection of invasive forest pathogens can be achieved by targeting their main dispersal pathways. Forest pathogens typically disperse by air or water, or they are vectored by insects. Currently in Sweden, we are testing whether different types of trapping systems can be used in monitoring schemes. Airborne pathogens disperse by spores that can be captured by passive or active traps. Water filters can be used to concentrate and separate propagules in river water. Detection of insect-vectored pathogens requires capturing the vector with pheromone traps and then identifying the pathogen within the vector. In all pathways we intend to identify the species by using unspecific high through-put DNA sequencing techniques. To validate this monitoring approach, we will use already established invaders such as *Chalara fraxinea*, *Phytophthora alni*, *Ophiostoma novo-ulmi*, and *Sphaeropsis sapinea*. Spore catchments will be used to study the relationship between conductive weather conditions and propagule production to understand which seasons capture the highest variation. Some of the potentially threatening invaders for Sweden are not yet present, or have not been detected, but occur in southern European forests. Some of the trapping schemes have been replicated in Spain to validate the monitoring scheme to be used as an early detection tool for known invaders.

Neonectria canker on true fir in western USA. Chastagner, G. (*Washington State University, USA; chastag@wsu.edu*), Talgø, V. (*Norwegian Institute for Agricultural and Environmental Research, Norway; venche.talgo@bioforsk.no*), Riley, K. (*Washington State University, USA; klriley@wsu.edu*).

Neonectria neomacrospora causes severe damage to fir (*Abies* spp.) in Scandinavia. In August 2013, a survey was carried out in Washington, Idaho, and Oregon to determine if this pathogen is also damaging firs in the Pacific Northwest (PNW), USA. Typical symptoms were canker wounds, resin flow, and branch dieback. Characteristic red fruiting bodies (perithecia) of *Neonectria* were found on 16 hosts in Washington and Oregon: *A. alba* (European silver fir), *A. amabilis* (Pacific silver fir), *A. balsamea* (balsam fir), *A. balsamea* var. *phanerolepis* (Canaan fir), *A. bornmuelleriana* (Turkish fir), *A. cephalonica* (Greek fir), *A. concolor* (white fir), *A. fraseri* (Fraser fir), *A. grandis* (grand fir), *A. koreana* (Korean fir), *A. lasiocarpa* (subalpine fir), *A. magnifica* var. *shastensis* (Shasta red fir), *A. nordmanniana* (Nordmann fir), *A. numidica* (Algerian fir), *A. pinsapo* (Spanish fir), and *A. procera* (noble fir). The diseased trees were found in Christmas tree and landscape plantings. Morphological identification of *N. neomacrospora* was confirmed by internal transcribed spacer (ITS) sequencing and inoculation tests proved pathogenicity on selected hosts. Since *N. neomacrospora* is seed borne, the pathogen may have been introduced to Europe via seeds, but thus far the pathogen has not been found in areas where cones are harvested in the PNW.

Monitoring bark and ambrosia beetles in commercial forestry in Uruguay. Gómez, D., Martinez, G. (*National Agricultural Research Institute, Uruguay; dgomez@tb.inia.org.uy; gmartinez@tb.inia.org.uy*).

Bark and ambrosia beetles are part of the common fauna occurring in pine and eucalyptus plantations in Uruguay. In the last decades, these groups have been associated with sanitary problems in Uruguayan commercial forestry. In December 2009, following a long drought, a large infestation of bark beetles occurred on several *Pinus* spp. in Uruguay. Tree losses up to 80% were recorded in the southern part of the country, particularly on *P. pinaster*. Three insect species were the responsible for this outbreak: *Hylurgus ligniperda*, previously reported in 1967, *Cyrtogenius luteus*, and *Orthotomicus erosus*, the latter two being first records for the country. Six monitoring stations were established in pine plantations throughout the country in a cooperative effort between research institutes, forest companies, and the national government. A set of three interception traps were placed at each station to assess flight seasonality of these three species. In 2012, extensive surveys using ethanol-baited Lindgren traps in several eucalyptus plantations were added to the monitoring scheme, after ambrosia beetles species were collected from dead trees. These efforts constitute a necessary first step towards the understanding of the bark and ambrosia beetle fauna associated with commercial forestry in Uruguay.

Dead stands from Space: experiences with synergized multi-date medium-resolution imagery to describe damages caused by European bark beetle. Latifi, H. (*University of Wuerzburg, Germany; hooman.latifi@uni-wuerzburg.de*), Fassnacht, F. (*University of Freiburg, Germany; Fabian.fassnacht@felis.uni-freiburg.de*), Kautz, M. (*Munich University of Technology, Germany; kautz@wzw.tum.de*), Dech, S. (*German Aerospace Center (DLR), Germany; Stefan.dech@dlr.de*), Schumann, B. (*University of Wuerzburg, Germany; bastian.schumann@freenet.de*).

Insect infestations have been reported to account for 60% of all sanitary forest damage in Europe. Following bark beetle attacks, an accurate spatiotemporal characterization of the affected area alleviates rapid post-attack management. Associating forest mortality and remotely sensed data has long been a main research focus. In contrary to North America, the tendency in Europe has often been towards applying high resolution data, since the majority of damage is spatially small to medium scale. We, however, believe that there are advantages in applying medium-resolution imagery whose multi-date availability is growing via

the launch of new and upcoming satellite programs. We focused on a combined use of multi-date Landsat and SPOT imagery across a 10-year time span in which various epidemic/non-epidemic infestations occurred within the Bavarian Forest National Park in Germany. Along with separating infested from non-infested stands, efforts were made to separate the temporally adjacent mortality classes using object- and pixel-oriented paradigms. Whereas the main mortality classes were able to be precisely separated from non-attacked stands, the classification of temporally transitional classes was still challenging. The results suggest that the applied datasets may be advantageous for mapping forest mortality, provided that properly acquired reference data are available.

Detection and epidemiology of invasive fungal pathogens by real time quantitative PCR. Luchi, N., Ghelardini, L., Pepori, A., Migliorini, D., Santini, A. (*National Research Council, Italy; n.luchi@ipp.cnr.it; l.ghelardini@ipp.cnr.it; a.pepori@ipp.cnr.it; nowanda2@gmail.com; a.santini@ipp.cnr.it*).

Early detection of invasive plant pathogens, which represent a major threat to both forest ecosystems and planting of trees in cities, is fundamental to prevent their epidemic spread and avoid extensive damage. This paper evaluates the application of molecular tools based on real-time quantitative polymerase chain reaction assays (qPCR) to detect potentially invasive pathogens at an early stage of colonization. To this purpose, different qPCR assays were developed, in natural and artificial environments, to specifically detect various invasive pathogens, such as for instance *Phytophthora* spp. in nurseries and *Ceratocystis platani* from airborne samples. The sensitivity and specificity of qPCR enable detection of small quantities of DNA of pathogens in soil and in plant tissues even before occurrence of symptoms. Therefore, qPCR is particularly useful at a global scale to check health conditions of symptomless plants along commercial pathways between different countries. The qPCR technique proved to be reliable to study the epidemiology and ecology of airborne pathogens, insect-vectored pathogens, and also of newly formed insect-fungus associations that may enhance the spread of invasive species. This technique represents a promising tool for diagnosis and management of invasive fungal species, and it may help preventing new introductions in anthropic and natural ecosystems.

Monitoring of *Sesia apiformis* infestations in poplar plantations at different spatial scales. Martín-García, J. (*University of Valladolid, Spain; jorgemg@pvs.uva.es*), Jactel, H. (*National Institute for Agricultural Research (INRA), France; herve.jactel@pierroton.inra.fr*), Diez-Casero, J. (*University of Valladolid, Spain; jdcasero@pvs.uva.es*).

Poplar plantations are expanding worldwide but little is known about *Sesia apiformis*, a wood borer which is one of their most severe pests. Thirty-two poplar plantations of I-214 clone were sampled in Spain, according to a factorial design combining stand age, site condition, and understorey management. In each plantation, one pheromone trap was activated throughout the flight season to test the correlation between captures and percentage of attacked trees. The proportion of other poplar forests in surrounding landscapes was used as a covariate in predictive models of trap catches. There was no significant effect of site quality and tree vitality on the rate of infestation between attacked and unattacked trees within each stand, suggesting that *S. apiformis* could behave as primary pest. We observed a positive correlation between trap capture and percentage of attacked trees in a radius of 100 m around the trap. The regression was improved when the area of other poplar plantations within a distance of 600 m was incorporated in the model. This suggests that surrounding poplar stands may act as sources of immigrating moths in monitored stands. Our findings confirm that *S. apiformis* should be considered as a primary pest threatening poplar plantations and that pheromone trapping provides a suitable tool for monitoring local populations.

***Mycosphaerella* leaf disease and its impact on *Eucalyptus* plantations in Uruguay.** Pérez, C. (*University of the Republic, Uruguay; caperez@fagro.edu.uy*), Wingfield, M. (*FABI, University of Pretoria, South Africa; Mike.Wingfield@up.ac.za*), Blanchette, R. (*University of Minnesota, USA; robertb@umn.edu*), Palladino, M., Grignola, P. (*University of the Republic, Uruguay; cintiapalladino@fagro.edu.uy; piagrignola@gmail.com*), Torres-Dini, D., Simeto, S. (*National Agricultural Research Institute, Uruguay; dtorres@tb.inia.org.uy; ssimeto@tb.inia.org.uy*), Perez, G. (*Polo de Desarrollo Universitario Forestal Tacuarembó, Uruguay; guillermoiufro2011@gmail.com*), Balmelli, G. (*National Agricultural Research Institute, Uruguay; gbalmelli@tb.inia.org.uy*).

Mycosphaerella leaf disease (MLD) is one of the most important diseases affecting *Eucalyptus* plantations worldwide. A relatively large number of species from *Mycosphaerellaceae* and *Teratosphaereaceae* are found on *Eucalyptus* in plantation in Uruguay. Since 2008 plantations of *Eucalyptus* spp. have been surveyed annually to quantify crown damage index (CDI) and to identify pathogens present. Results showed a great diversity of species associated with MLD. On *E. globulus, T. nubilosa* was predominant, whereas on *E. dunnii* the most prevalent species were *Mycosphaerella scytalidii* and *Pseudocercospora norchiensis*. For those *E. globulus* plantations monitored over the first 24 months, the CDI increased over time between 6 months (CDI = 12) and 24 months (CDI = 75) as an overall average for 84 stands monitored. These results emphasize the impact of this disease on *E. globulus* and illustrate why the forestry industry has virtually abandoned this species in Uruguay. Surprisingly, even where the overall CDI on *E. dunnii* was low, there were some stands with CDI of 55 at 18 months. This suggests that this disease can be as serious on *E. dunnii* as it is on *E. globulus* where susceptible genotypes are planted and when environmental conditions favor infection.

The Swiss needle cast foliage disease epidemic on the northwestern coast of the United States. Ritokova, G., (*Oregon State University, USA; gabriela.ritokova@oregonstate.edu*), Kanaskie, A., (*Oregon Department of Forestry, USA; alan.kanaskie@state.or.us*), Shaw, D. (*Oregon State University, USA; dave.shaw@oregonstate.edu*).

Swiss needle cast (SNC) foliage disease of Douglas-fir (*Pseudotsuga menziesii*) is caused by the fungal pathogen *Phaeocryptopus gaeumannii* and was first observed causing visible symptoms in plantations in Oregon and Washington in the mid-1980s. A decade later, the disease began to cause widespread concern among tree growers and landowners, and a research cooperative was formed to investigate the epidemiology and management of the disease. In 1996, an aerial survey detected 53 048 ha of stands with SNC-symptomatic chlorotic foliage. Since then, the area with visible symptoms has increased and in 2013, 215 450 ha of symptomatic stands were detected. A combination of factors is responsible for the increase in disease incidence, including

1) species shift from *Picea sitchensis*, *Tsuga heterophylla*, *Thuja plicata*, and *Alnus rubra* to *P. menziesii*; 2) naturally high nitrogen concentration within coastal soils, which has been linked to accelerated development of fruiting bodies; and 3) changes in regional climate, including increases in winter temperature and spring wetness during spore dispersal period (May-July).

***Physokermes inopinatus*: a new forest pest due to changing climate?** Winde, I., Anderbrant, O., Olsson, P., Eklundh, L., Jönsson, A. (*Lund University, Sweden; inis.winde@biol.lu.se; Olle.Anderbrant@biol.lu.se; Per-Ola.Olsson@nateko.lu.se; lars.eklundh@nateko.lu.se; anna_maria.jonsson@nateko.lu.se*).

Severe damage to >1 000 ha of Norway spruce in 2010 was caused by the Hungarian spruce scale, *Physokermes inopinatus,* a species until then unknown in Sweden. How and when the insect came to Sweden is unknown. The following fungal infestation reduced the needle photosynthetic capacity, thereby increasing the risk of secondary bark beetle attacks. This event clearly shows that risk assessment and development of early warning systems are needed. To study the ecological context of *P. inopinatus*, we investigated its life cycle, habitat requirements, and natural enemies. To evaluate the impact of the Hungarian spruce scale on its host tree, we also studied the symptoms of an infestation on the host tree and tree recovery, as well as environmental factors, which make trees more vulnerable to an attack. The combined data will be used to model the development of *P. inopinatus* to assess the potential hazard this species poses to boreal spruce forests. A diagnostic tool to determine the range of an outbreak using satellite based remote sensing has already been developed. This case study will contribute to the development of guidelines for long-term planning for sustainable forestry including aspects of climate change impact on ecosystem interaction.

G-15 Monitoring emerging threats to forest health in North America across regional to national scales

Organizers: Borys Tkacz (U.S. Forest Service) & Kevin Potter (North Carolina State University, USA)

From local to national: mining and transformation of local urban forest inventory data for use in national-scale monitoring and assessments. Ambrose, M. (*U.S. Forest Service, USA; mambrose@fs.fed.us*).

Urban forests are an important but often poorly understood resource. Data sources such as the U.S. Forest Service's Forest Inventory and Analysis plots provide a solid foundation for monitoring the health of natural forests, but urban forest inventories are a less reliable data source; relatively few communities have surveyed their forests, and surveys have often been restricted to street trees or a subset of community lands. However, it is possible to compile data from local urban forest inventories, combining them for analyses at larger scales. Combining such data requires making crucial assumptions about the comparability of sampled populations. Also, because of the variety of inventory scales and protocols used, data usually must be relativized or put on a per area basis to obtain comparability. We compiled urban forest inventory data from approximately 500 communities across the United States and Canada. The composite dataset was then analyzed using PC-ORD to determine which cities' forests were most similar (using cluster analysis) and how species composition related to large-scale environmental variables (using non-metric multi-dimensional scaling). The data were also used to model the abundance of key tree species groups (oaks, maples, and ashes) that serve as hosts to invasive pests and pathogens of concern.

Mechanisms of rapid synchronization in gypsy moth populations. Johnson, D., Dattelbaum, K. (*Virginia Commonwealth University, USA; dmjohnson@vcu.edu; kdattelbaum@vcu.edu*), Tobin, P. (*U.S. Forest Service, USA; ptobin@fs.fed.us*).

Forest insect outbreaks are most damaging when synchronized over large areas because they exacerbate ecological impacts, challenge land managers' ability to suppress populations and mitigate the effects, and concentrate economic hardship into discrete years. Thus, understanding synchronizing mechanisms of forest pests is critical to effective management and mitigation. The gypsy moth is an invasive forest defoliator in North America with periodic outbreaks that are synchronous at distances up to several hundred kilometers. At the invasion front, gypsy moth outbreaks rapidly synchronize within 10 years after colonization. In contrast, theoretical analysis predicts that populations with periodic dynamics akin to the gypsy moth will require up to 30 years to synchronize. In this study, we explored low density dynamics with theoretical and empirical analyses to understand the mechanisms of rapid synchronization in the gypsy moth. We used pheromone-baited trap data to estimate rate of synchronization and correlate it with geographic variation in weather and Allee effects. We tested the hypothesis that rapid synchronization is facilitated by a lack of periodic drivers in unstable low density populations of gypsy moth. Our work shows how small amounts of environmental change can interact with population dynamics to create regime shifts in forest ecosystems.

The influence of climate gradients and climate change on nitrogen-sensitive lichen species across forests of Oregon, Washington, and California. Jovan, S., Monleon, V., Fenn, M., Root, H., Geiser, L. (*U.S. Forest Service, USA; sjovan@fs.fed.us; vjmonleon@fs.fed.us; mfenn@fs.fed.us; htroot@fs.fed.us; lgeiser@fs.fed.us*).

Lichens lack roots and are unable to store water, which closely links lichen health to both pollutant deposition processes and ambient climate. Researchers commonly use abundance of N-sensitive oligotrophs and N-loving eutrophs to map N deposition in forests and define critical loads for policymakers. Climate influences are poorly understood, although it is generally known that oligotrophs are naturally low in hot, dry forests. We developed geospatial linear models using lichen surveys collected from 2 119 sites and predicted lichen abundance across clean sites (N deposition <2.5 kg N/ha/year) using precipitation and climate as covariates. Climate was highly influential; in clean, dry forests oligotroph abundance was negligible while at clean, wet sites oligotrophs were twice as abundant as other species. Affinity for high moisture is probably partly physiological and partly because precipitation leaches N from the lichen thallus, decreasing exposure. Large-scale N mapping should consider natural variability in lichens across climate gradients to prevent systematic bias. Climate change may also skew N estimates and presents a conservation challenge because increasing drought or warming are expected to accelerate the loss of N-sensitive lichen species.

Data, data everywhere: detecting spatial and temporal patterns in fine-scale forest health information collected across a continent. Potter, K. (*North Carolina State University, USA; kpotter@ncsu.edu*).

For more than a decade, U.S. government agencies have collected standardized fine-scale forest health data that span the width and breadth of the country. These data sets include the Forest Inventory and Analysis system of approximately 120 000 plots, daily MODIS satellite detections of fire occurrences, and aerial surveys of forest insect and disease damage. Making this information useful for forest health monitoring efforts poses a challenge, however. Here, I describe methods that detect spatial and temporal patterns within fine-scale data sets collected nationally, and I provide examples. One approach aggregates data within ecoregions, which are defined based on environmental characteristics. It then quantifies the degree of deficit or excess of a phenomenon (fire occurrences per area of forest, for example) within the ecoregion in a given year relative to previous years. Another approach identifies statistically significant geographic hot spots of a phenomenon. It divides the country into hexagonal cells of approximately 2 500 km^2, within which data are aggregated. It then identifies clusters of cells within which values exceed those expected by chance. Such analyses have become standard components of recent annual U.S. Forest Service, Forest Health Monitoring Program reports on the status and trends of forest health across the nation.

Using vascular plant inventory data to derive indicators of forest health. Schulz, B. (*U.S. Forest Service, USA; bschulz@fs.fed.us*).

Detailed species composition and structural arrangement data from a subset of forest inventory plots provide measurements from which meaningful indicators can be derived. A wide variety of species traits, such as nativity or origin, contributions to or regulation of nutrient cycling, forage or fuel qualities, or sensitivity to pollutants, can be assessed in a straightforward manner when data collection includes a full species census. For example, species composition has been assessed in terms of percentage of introduced species and their relative abundance over large regions of the United States using the U.S. Forest Service's Vegetation Diversity and Structure (VEG) indicator. However, when resources are limited, can less detailed measurements, such as cover by growth habit or most abundant species, be used to monitor forest health conditions as they relate to emerging threats? This presentation will highlight the trade-offs between more detailed data from a subset of plots and less detailed data collected over a higher proportion of plots as a part of a national forest inventory. Lessons learned from a decade of implementation and pathways forward will be discussed, addressing the questions: Can affordable be meaningful? Can meaningful be made affordable?

Is the western United States running out of trees? Shaw, J. (*U.S. Forest Service, USA; jdshaw@fs.fed.us*), Long, J. (*Utah State University, USA; james.long@usu.edu*).

During the past 2 decades, the forests of the Interior West of the United States have been impacted by drought, insects, disease, and fire. When considered over periods of 5–10 years, many forest types have experienced periods of negative net growth, meaning that mortality exceeded gross growth at the population scale. While many of these changes have been attributed almost solely to climate change, the factors contributing to widespread mortality, and their interactions, are much more complex. For example, the dominant forest age class distribution, in which a high percentage of acreage is in the 80- to 120-year age class, is largely the result of Euro-American settlement of the area in the late 1800s. This history, coupled with aggressive fire suppression during the past century, has resulted in disproportionate areas of forest being in a highly susceptible condition. For example, most of the lodgepole pine population is at high risk from mountain pine beetle attack, and much of the aspen population is becoming senescent and increasingly susceptible to succession by conifer species. In this presentation, we analyze the status and trends of Interior West forests, and highlight some of the important, and in some cases unexpected, changes.

Comparison of tree mortality rates on reserved vs non-reserved land the Interior West using Forest Inventory and Analysis annual inventory. Thompson, M. (*U.S. Forest Service, USA; mtthompson@fs.fed.us*).

The objective of this study was to evaluate differences in tree mortality on forest land in the Interior West (IW) by reserved status using annual inventory data from the IW Forest Inventory and Analysis (IW-FIA) program. In many IW regions, recent estimates of tree mortality have greatly exceeded those reported by IW-FIA in the past. Mortality currently exceeds net growth for most of the major species and species groups in the IW. Contributing factors include recent episodes of insect infestations such as bark beetle epidemics. However, very significant differences in tree mortality estimates have been recorded between reserved and non-reserved forest land. Mortality is significantly higher and is increasing at a much larger rate on reserved land. Using IW-FIA's annual inventory data that began in 2000, differences in mortality rates by reserved status will be presented. Reasons that explain these differences will also be presented such as analysis of stand structure, age, species composition, and management regimes on reserved and non-reserved lands.

Overview of the U.S. Forest Service, Forest Health Monitoring Program. Tkacz, B. (*U.S. Forest Service, USA; btkacz@fs.fed.us*).

The Forest Health Monitoring Program (FHM) of the United States (US) was initiated >2 decades ago in response to increasing concerns about health of the nation's forests. Since its inception in 1990, the program has provided holistic assessments of the major factors affecting the health and sustainability of forested ecosystems across all ownerships. The conceptual approach to FHM is multi-tiered. The initial component, detection monitoring, consists of aerial and ground monitoring to detect changes in a suite of forest health indicators. This is followed by evaluation monitoring projects which determine extent, causes, and impacts of forest health concerns detected through the first component. The third component of FHM, intensive site monitoring, consists of long-term research studies to determine forest health processes at a more detailed level. All of these components are supported by research on monitoring techniques, analysis, and reporting. This paper presents the development of the FHM program through the last 2 decades and highlights some of the most significant findings regarding the health of US forests.

Primary drivers of forest regeneration dynamics in the eastern United States. Woodall, C., Domke, G., Walters, B. (*U.S. Forest Service, USA; cwoodall@fs.fed.us; gmdomke@fs.fed.us; bfwalters@fs.fed.us*), D'Amato, A. (*University of Minnesota, USA; damato@umn.edu*).

The influence of various drivers of tree regeneration (e.g., stand stocking, coarse woody debris, or herbivory) have only been evaluated at small scales in a limited number of forest ecosystems. To more fully evaluate the potential influence of numerous drivers of tree regeneration across large scales, a remeasured forest inventory (including standing live/dead trees, seedlings, and down woody debris) across the eastern United States was used to estimate changes in seedling abundance in the context of stand attributes including detritus and herbivory. Initial results suggest that stand attributes such as coarse woody debris or deer browse pressure may be a stronger controlling factor of tree regeneration than stand live tree stocking or recent mortality. Future research is suggested to refine the regeneration metrics of detritus and herbivory within the context of potential tree range dynamics and fragmentation due to global change.

G-16 Forest health in changing landscapes: the roles of landscape patterns

Organizers: Kurt Riitters (U.S. Forest Service) & Peter Vogt (European Commission Joint Research Centre, Institute for Environment and Sustainability, Italy)

Abiotic and biotic factors influencing pine health in Georgia and Alabama. Coyle, D. (*University of Georgia, USA; drcoyle@uga.edu*), Klepzig, K., Nowak, J., Smith, W., Koch, F., Otrosina, W. (*U.S. Forest Service, USA; kklepzig@fs.fed.us; jnowak@fs.fed.us; bdsmith@fs.fed.us; fhkoch@fs.fed.us; wotrosina@fs.fed.us*), Bates, C., Cameron, S. (*Georgia Forestry Commission, USA; cbates@gfc.state.ga.us; rscameron@prodigy.net*), Gandhi, K. (*University of Georgia, USA; kjgandhi@uga.edu*).

Recent studies have suggested that various pine trees in the Southeast are experiencing mortality that may be linked to the incidence of root weevils and their associated fungi. We are investigating pine health issues in Georgia and Alabama, with a focus on both abiotic and biotic factors. Our goal is to determine if variables such as poor soils, short- and long-term drought, south- and west-facing aspects, and high slopes are acting as predisposing and inciting factors leading to increasing pine health issues. We are also examining the prevalence of above- and belowground herbivores in healthy and unhealthy pine stands. Preliminary analyses of Forest Inventory and Analysis data did not indicate any relationships between slope and aspect and rates of pine mortality, and there was a lack of clear patterns in terms of pine mortality. This suggests that if there are areas of declining pine health, these areas are small and locally distributed, and that multiple agents may be operating on the landscape. We suggest areas of future research that may help elucidate the nature, extent, severity, and associated insects and diseases related to pine health issues in the Southeast.

Mapping spatial and temporal pattern of hemlock woolly adelgid-induced hemlock mortality in the southern Appalachians. Kantola, T. (*University of Helsinki, USA; tuula.kantola@helsinki.fi*), Tchakerian, M. (*Texas A&M University, USA; mtchakerian@tamu.edu*), Lyytikäinen-Saarenmaa, P. (*University of Helsinki, Finland; paivi.lyytikainen-saarenmaa@helsinki.fi*), Coulson, R. (*Texas A&M University, USA; r-coulson@tamu.edu*), Holopainen, M. (*University of Helsinki, Finland; markus.holopainen@helsinki.fi*), Streett, D. (*U.S. Forest Service, USA; dastreett@fs.fed.us*).

Hemlock woolly adelgid (*Adelges tsugae* Annand, HWA) outbreaks pose the biggest threat to eastern hemlock (*Tsuga canadensis* L. Carr.) and Carolina hemlock (*Tsuga caroliniana* Engelm.) in the eastern United States. These hemlock species play an important role in forest ecosystems, e.g., cooling mountain streams and providing habitat for many species. No controlling agents against HWA populations have proved to be effective. Furthermore, there are no other tree species having a similar ecological niche and function. Spatially explicit inventory information on herbivory by HWA at a landscape scale does not exist. The study area of 60 km^2 is located in Linville River area, southern Appalachians, North Carolina (35°56′N, 81°55′W), where both eastern and Carolina hemlocks serve as foundation species. The study objectives were to 1) detect dead hemlock patches via remote sensing change detection procedures from multi-temporal high resolution aerial imageries, between years 2006, 2008, 2010, and 2012; and 2) study the spatiotemporal spreading pattern of hemlock mortality at a broad scale. These results are important findings that could be used to project future distribution and extent of HWA infestations and to study potential establishment of invasive plant species in future forest canopy gaps, created after hemlock elimination.

Natural forest fragmentation evaluation at Campos Gerais Region, southern Brazil. Moro, R., Milan, E. (*Ponta Grossa State University, Brazil; moro.uepg@gmail.com; elisana_milan@hotmail.com*).

In the Campos Gerais region the Araucaria forest, fragmentation resulted mainly from natural dynamics, related to Quaternary climatic fluctuations over edaphic, topographic, and/or geomorphological features. To discriminate the original forest patch patterns from the anthropogenic one, we selected two well-preserved state parks: Vila Velha and Guartelá. By means of SPOT orthoimages (2005) with a 5-m spatial resolution and by ArcGIS 9.3, Envi 4.7, Guidos 1.3, and Fragstats 2.0 software, the landscape structure was analyzed in both areas. It was observed that most of the patches were smaller than 10 ha (90.3% of the total number of patches) and very few were larger than 100 ha (2.7%). The smaller patches had the simplest regular shape, with a no particular extent of edge effect and repeated over the landscape on a fractal dimension. The largest were more complex and irregularly shaped, supporting higher edge effects. The connectivity among all patches could be considered good; they presented an average distance of 50 m between them and had several islets acting as stepping stones. We concluded that the regional forest fragmentation was strongly influenced by geomorphological and hydrological conditions over time, and offer a natural pattern for comparison.

Land-cover changes and future projection in Gambari Forest Reserve, southwestern Nigeria, using Landsat imagery. Olayode, O. (*Ekiti State University, Nigeria; funkefaboy@yahoo.com*), Bada, S. (*University of Ilorin, Nigeria; badasaka@yahoo.com*), Popoola, L. (*University of Ibadan, Nigeria; labopopoola@yahoo.com*).

The issue of deforestation and forest degradation, especially of tropical forests, has become a global concern in recent years. The extent of any forest influences its capacity to provide goods and services. Land-cover changes in Gambari Forest Reserve, Oyo State, Nigeria, were therefore assessed with the use of Landsat imageries of 1984, 2000, and 2006. The imageries were

georeferenced to the same coordinate system using a topographical map of the study area. Bands 2, 4, and 5 suitable for vegetation studies were used. Idrisi32 and ArcGIS were used for the analyses and map production, respectively, while Markov chain was used for future land-cover projection. A supervised classification scheme of natural forest (NF), plantation, and farmland was adopted after reconnaissance survey and field work in the study area. NF occupied 55.7% of the area in 1984, but declined to 3.9% in 2006. Plantation covered 13.7% in 1984 and increased to 59.8% in 2006, while farmland, which occupied 30.6% in 1984, increased to 36.3% in 2006. NF, plantation, and farmland will likely cover 12.7, 38.6, and 48.7%, respectively, by 2016. The implications of the declining NF and other land classification schemes for sustainability of the study area are discussed.

Slash-and-burn agriculture, fragmentation, and landscape dynamics in the lowland rainforest of Madagascar: the case of Manompana, northeast of Madagascar. Rabenilalana, F., Rakoto Ratsimba, H. (*University of Antananarivo, Madagascar; rmihajamanana@yahoo.fr; rrharifidy@moov.mg*), Bogaert, J. (*University of Liège, Belgium; j.bogaert@ulg.ac.be*), Sorg, J. (*Federal Institute of Technology Zurich, Switzerland; jean.pierre.sorg@env.eth.ch*).

Shifting cultivation, or tavy, is a traditional subsistence farming practice, predominant in the Betsimisaraka population in the eastern part of Madagascar. It consists of clearing and burning an area of forest for cultivation. The fire control when burning is precarious; the extent of the tavy generally exceeds the expected area, leading to a progressive loss of forest. This activity shapes the landscape with many significant openings leading to a very heterogeneous structure. This study analyzed the spatial dynamics of tavy, particularly in the toposequence. Based on spatial analysis using two series of SPOT 5 multispectral images and field data, the study showed that the choice of land for shifting cultivation was particularly driven by the slope. Indeed, it was observed that the hillsides having a slope between 25 and 50% are most favorable for this kind of practice because soil erosion risk is still low. These results allow a better understanding of the dynamics of the observed crop rotation and fragmentation processes.

National integration of in-place and remotely sensed forest and landscape pattern inventories to evaluate changes in forest health. Riitters, K. (*U.S. Forest Service, USA; kriitters@fs.fed.us*).

In-place forest inventory measurements are ideal for tracking changes in forest characteristics over time, while remotely sensed information is more suitable for tracking changes in landscapes which contain forestland. As a result, it is necessary to integrate in-place and remotely sensed information in order to analyze how landscape-level land use patterns may be managed to reduce risks of forest health impacts from changing climate. Such integration at national scale has only recently become practical in the United States. To illustrate current practices, this presentation highlights national analyses prepared for the 2015 Update of the U.S. Forest Service, Resource Planning Act (RPA) Assessment. Changes in forest land-cover fragmentation between 2001 and 2006 were evaluated using national land-cover maps. Spatial integration with approximately 150 000 field plot measurements permitted the interpretation of fragmentation in relation to about 125 different forest types, local versus public forest owners, and other plot-based observations.

Morphological analysis of state and trends of landscape pattern. Vogt, P. (*European Commission Joint Research Centre, Italy; peter.vogt@jrc.ec.europa.eu*).

Pattern, connectivity, and fragmentation can be considered as key elements for a comprehensive quantitative analysis of digital landscape images. Morphological spatial pattern analysis (MSPA) provides an intuitive, repeatable, and scale independent description of image pattern structures, i.e., forest patches. Dedicated additional routines describe and quantify the connectivity network and the spatial fragmentation of the forest landscape. A morphology-based change analysis aims to reliably detect coherent forest change areas by excluding uncertainties due to differences in image quality, ortho-correction, and classification accuracy of the input images. These tools and more are available in the free software GuidosToolbox (http://forest.jrc.ec.europa.eu/download/software/guidos). The principal processing steps are explained and illustrated on synthetic and sample data sets. The reliable assessment of forest pattern and its change over time is a prerequisite for a meaningful understanding and interpretation of forest landscape dynamics. As an additional benefit, it permits measuring progress in biodiversity and landscape planning projects. The provision of tools for monitoring and especially quantifying the impact of human activities on forest landscapes should facilitate the design of efficient and assessable forest resource policies.

G-17 Changes in distributional ranges in a changing world

Organizers: Patrick Tobin (U.S. Forest Service) & Christelle Robinet (National Institute for Environmental and Agricultural Science and Research-URZF, France)

Climate-associated range shifts of mountain pine beetle in western Canada. Aukema, B. (*University of Minnesota, USA; bhaukema@umn.edu*), Sambaraju, K. (*Canadian Forest Service, Canada; kishan.sambaraju@nrcan.gc.ca*), Carroll, A. (*University of British Columbia, Canada; allan.carroll@ubc.ca*).

The ongoing epidemic of mountain pine beetle in western Canada covers approximately 18 million ha of mature pine forest. Improved climatic suitability in recent decades has been invoked as a key reason for the insect's recent range expansion over the historical geoclimatic barrier of the Rocky Mountains into jack pine forests of northern Alberta. Continued range expansion through jack pine to the east threatens to encompass pine species native to eastern North America. Here, we utilize spatiotemporal regression approaches to examine range expansion of this insect north and east, as well as to higher elevations, at different population stages. Temperature affects population growth at endemic and epidemic levels, and subtle warming at the landscape level has helped set the stage for rapid range expansion in the past decade. Shifts of increasing mean annual temperatures of only 2 °C created highly suitable habitat directly west of the invasion zone into northwestern Alberta. Similar temperature changes have had disparate effects on elevational boundaries, however. If new host associations, in concert with warming temperatures, allow the expanding populations to exist at epidemic levels, rapid expansion in a short time frame can be expected.

Consequences of climate change for biotic disturbances in North American forests. Ayres, M., Weed, A. (*Dartmouth College, USA; matt.ayres@dartmouth.edu; aaron.s.weed@dartmouth.edu*), Hicke, J. (*University of Idaho, USA; jhicke@uidaho.edu*), Bentz, B. (*U.S. Forest Service, USA; bbentz@fs.fed.us*).

The properties of forests are a product of disturbance regimes. In North America, a third of which is forested, insects and diseases exceed even wildfires as the dominant source of disturbance. The first U.S. Climate Assessment (2000) predicted consequential changes in forest disturbance because 1) herbivores and pathogens have high physiological sensitivity to temperature, high mobility, short generation times, and high reproductive potential; 2) tree defenses vary with climate; and 3) effects on pests from their enemies, competitors, and mutualists can change with climate. In fact, the appearance of epidemics in new regions has been rapid and dramatic, e.g., spruce beetles in Alaska, mountain pine beetle in high-elevation forests of the Rocky Mountains, and southern pine beetle in the Northeast. Important drivers have been milder winters, longer summers, and changing precipitation. Climatic effects on forest pest outbreaks can produce feedbacks to climate by influencing ecosystem fluxes in carbon, water, and energy, and by influencing human interactions with landscapes. Human adaptation to climate-induced changes in forests will be aided by general practical theories of pest management that can address new vulnerabilities and also by responding to new opportunities (e.g., increases in forest productivity in many areas, and probably decreases in forest disturbance in some areas).

Range expansion of the pine processionary moth in relation to climate warming. Battisti, A. (*University of Padova, Italy; andrea.battisti@unipd.it*), Larsson, S. (*Swedish University of Agricultural Sciences, Sweden; stig.larsson@slu.se*), Roques, A. (*National Institute for Agricultural Research (INRA), France; alain.roques@orleans.inra.fr*).

The geographic range of herbivorous insects can change over years to decades based on climate. There are signs of recent pole-ward geographic range expansion in several insect species, including forest pests. Other species are expanding their outbreak range within their current geographical range. A good example is given by the pine processionary moth (*Thaumetopoea pityocampa*, Lepidoptera Notodontidae) which has recently expanded its latitudinal and elevational range, through both natural and human-aided dispersal. Improved survival during the feeding period in winter contributed to outbreaks in pine forests previously unoccupied. Rapid range expansion seems also to be facilitated by warm summer nights that contribute to long-distance dispersal of female moths, as observed during the record-warm 2003 summer in the Alps. At the southern edge of the range, in northern Africa, mild winters have resulted in an expansion of the outbreak area at high elevations, where previously uninfested native stands of cedar (*Cedrus atlantica*) are now facing large outbreaks. There is no evidence of retraction in the most southern pine forests facing the Sahara desert. All this information is used to predict future patterns of range expansion of this species.

Potential northward expansion of spruce budworm outbreaks under climate change and related impacts on forest ecosystems. Candau, J., Fleming, R. (*Canadian Forest Service, Canada; Jean-Noel.Candau@nrcan.gc.ca; elspeth.fleming@sympatico.ca*).

The spruce budworm (*Choristoneura fumiferana*) is the most important insect disturbance in Canada's boreal forest. During widespread periodic outbreaks, it causes considerable tree mortality of its two principal hosts, balsam fir (*Abies balsamea* L. Mill.) and white spruce (*Picea glauca* Moench Voss). Climate change will likely affect spruce budworm defoliation dynamics both directly through changes in the parameters of the population dynamics and indirectly through feedback and interactions with other species and abiotic factors. We developed process-oriented models that describe the relationships between the spatial distribution of spruce budworm defoliation in eastern Canada, and bioclimatic conditions. In these models, climate appears to play a role in the distribution of both the occurrence and the frequency of defoliation over the landscape. The models were then extended to assess possible future distributions under different climate change scenarios. Projections of the spatial distribution of spruce budworm defoliation during the next anticipated outbreak period suggest an expansion of the area of defoliation northward but a decreasing overall severity as fewer areas experience many years of defoliation. We discuss the potential impacts of a northward shift of spruce budworm outbreaks on forest ecosystems.

Introduced tachinids explain decline of browntail moth in North America. Elkinton, J. (*University of Massachusetts, USA; elkinton@ent.umass.edu*), Parry, D. (*State University of New York, USA; dparry@esf.edu*), Boettner, G. (*University of Massachusetts, USA; boettner@psis.umass.edu*).

The browntail moth, *Euproctis chrysorrhoea,* was introduced from Europe to North America near Boston in 1897. It became an important defoliator of many tree species throughout New England and was also a human-health hazard due to severe skin rashes caused by urticating hairs from the larvae. Beginning around 1915, however, browntail populations receded gradually to coastal enclaves at the tip of Cape Cod and on islands in Casco Bay in Maine, where high densities have persisted. Until now no studies have explained why it declined and why it persists in coastal enclaves. We present evidence that a major cause of the decline was the generalist tachinid parasitoid *Compsilura concinnata,* which was introduced to North America in 1906 to control gypsy moths. Analysis of historical data revealed high levels of parasitism of browntail moth by this species, but low levels in coastal areas. We confirmed this pattern experimentally by creating artificial browntail populations at both inland and coastal locations on Cape Cod. Another introduced tachinid, *Carcelia laxifrons,* causes high mortality to browntail larvae at coastal sites with rich vegetation and helps restrict high browntail densities to dune habitats with sparse vegetation.

Range expansion in insect pests: how important is climate change? Larsson, S. (*Swedish University of Agricultural Sciences, Sweden; stig.larsson@slu.se*), Battisti, A. (*University of Padova, Italy; andrea.battisti@unipd.it*).

The distribution range of insects is generally determined by niche availability, demographic processes, and dispersal capacity (active or passive). The true range is difficult to describe because the occurrence of individuals forming stable populations in a given area is often not known in enough detail. For forest pests, surveillance networks provide useful information about the geographic area where they occur. Climate change has been invoked to explain recent range expansion in a few insect pest species from the temperate region; presumably higher temperatures have resulted in higher winter survival and prompted dispersal over longer distances. This applies, in different ways, to both native and alien species. We analysed literature data on range expansion for a number of pests in forestry and compared results with similar data for agriculture. Appropriate data were

available for 10 alien and 19 native forest pests. Most species showed range expansion as a result of higher temperatures, whereas very few showed retraction at the rear edge of their distribution. The expansion rates varied greatly among species, and seemed to be generally higher for alien species, in both forestry and agriculture. Ecological phenomena behind differences in expansion among insect species are discussed and potential mitigation measures are suggested.

Influence of increasing summer temperatures on range dynamics of an invasive forest pest and its host tree. Mech, A., Gandhi, K. (*University of Georgia, USA; angmech@uga.edu; kjgandhi@uga.edu*), Tobin, P. (*U.S. Forest Service, USA; ptobin@fs.fed.us*), Teskey, R. (*University of Georgia, USA; rteskey@uga.edu*), Rhea, J. (*U.S. Forest Service, USA; rrhea@fs.fed.us*).

Warmer temperatures predicted under current climate change models are expected to have an overall positive effect on the success of invasive forest pests by increasing biological attributes such as survivability, geographic range, and fecundity. These changes in life history factors may then result in negative cascading effects on forested ecosystems. Cold temperatures are an abiotic limiting factor used for predicting forest pest distributions, and consequently in determining the range where host trees will be protected and maintained. However, heat may also be a limiting factor for invasive insects that undergo aestivation, or summer diapause, such as the exotic hemlock woolly adelgid (*Adelges tsugae*, HWA), which is causing widespread mortality of eastern hemlock (*Tsuga canadensis*) in eastern North America. We examined the thermal ecology of HWA in the southernmost limit of the eastern hemlock range by determining HWA survivorship under increasing temperature regimens and heat waves. Results showed a positive correlation between increasing temperatures and duration and HWA mortality. In response to lower HWA densities, hemlock trees exhibited signs of possible tolerance rather than the anticipated rapid dieback and mortality. This study shows the potential of climate change to maintain pockets of eastern hemlock at the southernmost edge of their natural range.

The importance of range dynamics of insects and pathogens in forest ecosystems. Robinet, C. *(National Institute for Agricultural Research (INRA), France; christelle.robinet@orleans.inra.fr*), Tobin, P. (*U.S. Forest Service, USA; ptobin@fs.fed.us*).

Assessing the range dynamics of a forest insect or pathogen species reveals whether the species is declining or not. Based on the status of the species (endangered versus invasive), appropriate measures could be taken to preserve forest health and biodiversity. Despite the differences in the goals between invasion ecology and conservation biology, many of underlying mechanisms that affect range dynamics are similar. For example, factors such as climate suitability, host availability, and presence of natural enemies, competitors or mutualists, could potentially affect the distribution ranges of both invasive and endangered species. Furthermore, at range borders, both endangered and invading populations are often at low densities and subject to stochasticity, loss of individuals to emigration, and Allee effects. In a changing world, the effects of climate change on these range dynamics should be also carefully considered. In this paper, we explore abiotic and biotic factors as individual drivers of the changes in species' distribution ranges, their interaction, and their implications in terms of forest ecosystem functioning in the face of stochasticity and uncertainty.

Modeling spatial spread of pine wilt disease: an individual-based approach. Takasu, F. (*Nara Women's University, Japan; takasu@ics.nara-wu.ac.jp*).

Pine wilt disease is caused by a pinewood nematode with a *Monochamus* beetle as a vector that distributes the nematode to healthy trees. The disease has been expanding worldwide and has brought severe damage to pine trees in some areas in eastern Asia. Considering the beetle life cycle, it is likely that the Allee effect operates for the beetle reproduction and that complete eradication of the beetle is not necessarily essential to stop the disease, i.e., once the beetle local density is lowered less than a threshold, they are doomed to be locally extinct. Previous models of pine wilt disease have shown that the functional form of the beetle dispersal kernel, i.e., how far beetles disperse, critically affects the disease expansion. In this talk, I revisit this problem using individual-based modeling in which mechanistic interactions of beetles and pine trees are explicitly considered and explore how to stop the disease expansion, e.g., by setting a barrier zone where potential healthy trees are removed. Based on individual-based simulations, effective control measures to eradicate the disease will be discussed.

Supraoptimal temperatures restrict and retract the distribution range of the gypsy moth. Tobin, P. (*U.S. Forest Service, USA; pc.tobin@gmail.com*), Gray, D. (*Canadian Forest Service, Canada; David.Gray@nrcan-rncan.gc.ca*), Liebhold, A. (*U.S. Forest Service, USA; aliebhold@fs.fed.us*).

The shifting, expansion, and retraction of species distribution ranges hold critical implications to both invasion ecology and conservation biology. Biotic and abiotic factors are known to influence a species' range, and much recent attention has been given to the role that climate and changes in climate could play in affecting range dynamics. We used a 20-year spatially referenced dataset on gypsy moth, *Lymantria dispar* (L.), invasion dynamics to document range expansion, stasis, and retraction across a fairly narrow latitudinal region in Virginia and West Virginia, USA. Across this region, we also observed significant differences in the amount of exposure above the optimal temperature for *L. dispar* larval and pupal development. Temperature regimes in the coastal plain of Virginia, where the *L. dispar* range has retracted, were significantly warmer than those in the Appalachian mountains of Virginia and West Virginia, where *L. dispar* has expanded its range. Our analyses at a smaller spatial scale confirmed a statistically negative association between exposure time above the optimal temperature for *L. dispar* larvae and pupae, and the rate of *L. dispar* invasion spread over the 20-year period. This work highlights the importance of supraoptimal temperatures on the range dynamics of a non-native invasive insect.

G-18 Research on pathway risk management and phytosanitary policy to prevent invasions of forest insects and pathogens

Organizers: Eckehard Brockerhoff (Scion, New Zealand), Andrew Liebhold (U.S. Forest Service) & Jolanda Roux (FABI/University of Pretoria, South Africa)

Facilitating international trade and preventing forest pest invasions: progress and the challenge ahead. Brockerhoff, E. (*Scion, New Zealand; eckehard.brockerhoff@scionresearch.com*), Liebhold, A. (*U.S. Forest Service, USA; aliebhold@fs.fed.us*), Roux, J. *(FABI, University of Pretoria, South Africa; jolanda.roux@fabi.up.ac.za*).

Globalised trade has contributed to the introduction of numerous forest insect pests and pathogens, often with grave environmental and economic consequences. International trade in nursery stock, the use of untreated wood packaging material, and various other pathways have been implicated. Much effort has been directed at developing phytosanitary policies that make international trade safer, with a reduced risk of facilitating biological invasions. While phytosanitary policies for some pathways (e.g., International Standards for Phytosanitary Measures No. 15, ISPM-15) have been implemented widely, the development and implementation of effective phytosanitary measures for other pathways remain difficult, and trade volumes continue to increase, potentially negating some of the gains that have been made. Phytosanitary measures need to be based on good science, requiring information on pest biology, invasion risks and potential impacts (environmental and economic), trade volumes and transportation pathways, benefits and costs of treatments and policy, and communication with the wide range of interest groups. Furthermore, this is an area where collaboration between scientists, trade organisations, policymakers, and the wider public is critical. These aspects will be summarised and underpinned with relevant examples as an introduction to this multidisciplinary session. Key research questions, progress to date, and remaining challenges will be highlighted.

Probability of pest dissemination in Europe with imported wood products: a focus on pine wood nematode and oak wilt disease. Douma, J., van der Werf, W., Hemerik, L., Mourits, M. (*Wageningen University, Netherlands; bob.douma@wur.nl; wopke.vanderwerf@wur.nl; lia.hemerik@wur.nl; monique.mourits@wur.nl*), Roques, A., Robinet, C. (*National Institute for Agricultural Research (INRA), France; alain.roques@orleans.inra.fr; christelle.robinet@orleans.inra.fr*).

Given the increasing number of biological invasions and their impacts on forest health and biodiversity, assessing the probability of introduction of new pests and identifying the best options to reduce this probability have become important objectives for national authorities. A probabilistic pathway model was developed to keep track of infested wood products entering Europe. This model accounts for the structure of the trade pathway and wood transformation chain. Here, we present 1) the dissemination risk of a major pest on softwood, the pine wood nematode, *Bursaphelenchus xylophilus*, when importing sawn wood of pines; and 2) the dissemination risk of a major pest on hardwood, oak wilt disease caused by *Ceratocystis fagacearum*, when importing roundwood of oaks. These models highlight the Achilles' heel of the wood trade in Europe, but also show alternatives to reduce this risk. The generic probabilistic pathway model was designed to be used by pest risk analysts for any forestry pest.

Designing cost-effective inspection programs and phytosanitary policy for reducing pest risk from live plant imports. Epanchin-Niell, R. (*Resources for the Future, USA; epanchin-niell@rff.org*).

While globalization and international trade provide many benefits, trends of increasing international movement of goods and people also drive increasing environmental risks and damages, including ecological and economic impacts from invasive species introductions. Trade in live plants is a particularly important and growing invasion pathway, as it is the most frequent medium for introduction of non-native forest pests worldwide. Here we examine the cost-effectiveness of phytosanitary policies for reducing pest risk, with particular focus on border inspection policies for live plant imports, including risk-based sampling and allocation of surveillance resources across multiple flows of plant imports. Our findings contribute to informing phytosanitary policy design for protecting forest health.

Effects of ISPM-15 on bark- and wood-infesting insect infestation rates of wood packaging material. Haack, R. (*U.S. Forest Service, USA; rhaack@fs.fed.us*).

Several wood-infesting insects have been moved through international trade, often by means of wood packaging material (WPM) such as crating and pallets. In 2002, the international community recognized that WPM was a high-risk pathway by adopting International Standards for Phytosanitary Measures No. 15 (ISPM-15), which provides treatment standards for WPM used in international trade. The goal of ISPM-15 was to "practically eliminate" the risk of international transport of bark and wood pests in WPM. The United States (US) implemented ISPM-15 in three phases from September 2005 to July 2006. A comparison of pest interception rates during 2003–2009, using the Agriculture Quarantine Inspection Monitoring (AQIM) database of the U.S. Department of Agriculture, indicated that infestation rates of WPM declined by 36–52% following implementation of ISPM-15, but the reductions varied in statistical significance and magnitude depending on the start date selected for implementation and the exporting countries included in the analysis. Factors that could limit the apparent impact of ISPM-15 on reducing WPM infestation levels will be discussed. Few other datasets are available worldwide to allow similar analyses. The international community should design sampling programs to be conducted before and after implementation of major phytosanitary policies to allow assessment of their effectiveness.

International plant trade associated risks: laissez-faire or novel solutions? Hantula, J., Müller, M., Uusivuori, J. (*Finnish Forest Research Institute, Finland; jarkko.hantula@metla.fi; michael.mueller@metla.fi; jussi.uusivuori@metla.fi*).

The trade of plants and plant products is globally the most important pathway for alien pests and pathogens causing damage to forest health. The introductions of alien pests and pathogens have increased exponentially in Europe, and continued even in Australia, where extreme quarantine efforts are implemented. Therefore it is obvious that the current type of quarantine-list-based legislation alone is not going to solve the problem, but additional mechanisms are needed. In this presentation we note that the commercial actors in international plant trade lack a strong motive to reduce pest and pathogen risks, as the true costs are not internalized in the pricing of the products but footed to taxpayers and landowners. Therefore, a shared responsibility of international plant traders is suggested to complement the current legislative restrictions in controlling exotic pests and pathogens.

Plant smuggling: a pathway for invasions by damaging non-native forest insects and pathogens. Liebhold, A. (*U.S. Forest Service, USA; aliebhold@fs.fed.us*).

Throughout all portions of the world, non-native forest insects and pathogens are accidentally being introduced and many of these species have severe economic and ecological impacts on forest ecosystems. While most of these invasions are believed to be the result of inadvertent transport of species associated with legal trade, a significant number of invading species most likely are associated with live plants that are imported illegally. Some of these illegal plant imports are intended for food consumption or

for medicinal or decorative (e.g., floral arrangements) purposes. In other cases, plants are sometimes transported by private individuals intending to propagate plants merely for hobby interests. However, some fraction of plant smuggling is conducted by commercial enterprises intending to utilize plants for commercial propagative purposes. Most smuggled plants enter either in passenger baggage, mail, or as undeclared items in other imported cargo. We describe here several damaging forest insects and pathogens that entered the United States via illegal plant imports. Although the U.S. Department of Agriculture currently has programs designed to intercept illegal plant imports, it is likely that a large volume of plants continues to enter unnoticed and this represents a serious risk to both forestry and agriculture.

Posters

***Megastigmus* parasitism of North American Cupressaceae.** Candau, J. (*Canadian Forest Service, Canada; Jean-Noel.Candau@nrcan.gc.ca*).

Seed-feeding *Megastigmus* spp. (Chalcidoidae: Torymidae) are generally host specific, at least at the genus level, but significant host-switching has been observed when exotic hosts or parasites were introduced in new areas. This apparent level of plasticity, combined with a cryptic larval stage and extended diapause, confer these insects a significant potential for invasion. Worldwide, 16 species of *Megastigmus* are known to infest Cupressaceae seeds. The vast majority of these species are native to the Palearctic, and only one species is reported as native of the Nearctic although 25% of Cupressaceae species originate from this region. At least two Palearctic species of *Megastigmus* are reported to attack a number of Nearctic Cupressaceae species introduced in Europe thus implying that if these insect species were introduced to North America they could establish successfully. Our objective was to assess the presence of native and introduced *Megastigmus* spp. on Cupressaceae in North America. Cones and berries of more than 30 native and introduced species of Cupressaceae were sampled in 35 geographic locations around North America. We present the results of this sampling campaign and discuss the potential for the introduction of exotic *Megastigmus* spp. on Nearctic Cupressaceae.

Allee effects and the establishment of exotic invasive bark beetles. Chase, K. (*University of Canterbury, New Zealand; kdc39@uclive.ac.nz*), Brockerhoff, E. (*Scion, New Zealand; eckehard.brockerhoff@scionresearch.com*), Liebhold, A. (*U.S. Forest Service, USA; aliebhold@fs.fed.us*), Kelly, D. (*University of Canterbury, New Zealand; dave.kelly@canterbury.ac.nz*).

The dynamics of non-native populations during the establishment phase of biological invasions are often not fully understood. The probability of establishment of a founder population is thought to depend upon the initial size of the population, which affects a variety of biological processes including the ability to find mates, satiate predators, or utilize host resources. Such inverse density-dependent interactions are known as Allee effects and they can create thresholds below which a species' population growth is negative, leading to extinction. The objective of this study is to quantify Allee thresholds for founder populations of invasive or potentially invasive bark beetles, using *Hylastes ater* and *Hylurgus ligniperda* in New Zealand and *Ips pini* in the United States as model species. Simulated introductions are being conducted where varying numbers of beetles released at different distances from suitable host material (i.e., pine logs) at locations with no background populations of beetles. We anticipate this information can ultimately be used to create more robust foreign policies regarding international trade of timber and wood packaging materials to mitigate the associated risk of beetle establishment.

Nurseries as pathways for *Phytophthoras* to enter Turkish forests. Dogmus-Lehtijarvi, T. (*Çankırı Karatekin University, Turkey; tugbadogmus@sdu.edu.tr*), Lehtijarvi, A. (*Bursa Technical University, Turkey; asko.lehtijarvi@btu.edu.tr*), Aday Kaya, G., Oskay, F. (*Çankırı Karatekin University, Turkey; guldenaday@sdu.edu.tr; fundaoskay@sdu.edu.tr*).

Phytophthora spp. are important limiting factors in the production of forest seedlings in nurseries. Environmental conditions in nurseries are often ideal for the proliferation of disease-causing *Phytophthoras*. In addition to causing large losses of nursery stock, exotic *Phytophthora* spp. also threaten natural ecosystems, in which they have caused severe damage. In Turkey, 122 state forest nurseries, with an annual capacity of 496 million seedlings of 400 species, are established in 62 cities. Over the last 2 years, our research group in Turkey intensively surveyed local nursery fields for the presence of *Phytophthora* spp. In total, 15 important forest nurseries in the southwestern part of Turkey were sampled. Thirteen nurseries were found to be infested with six *Phytophthora* spp.; *P. cactorum* and *P. citricola* were very common in almost all nurseries. Among surveyed nurseries İzmir-Torbalı and Adapazarı-Hendek, which are large and important seedling sources for plantations, were mainly found to be infected by these two *Phytophthora* spp. We concluded that nursery production facilities with densely grown plants, intensive cropping at the same site, intensive fertilization, drainage problems, movement of nursery stock, and that use recycled irrigation water provided multiple opportunities for infection by *Phytophthora* spp.

The use of EDDMapS to monitor the range extension of two invasive insect species in Hungary. Lakatos, F., Tuba, K., Molnár, M. (*University of West Hungary, Hungary; flakatos@emk.nyme.hu; tubak@emk.nyme.hu; mmiki@emk.nyme.hu*), Douce, K. (*University of Georgia, USA; kdouce@uga.edu*).

The walnut husky fly (*Rhagoletis completa*) is a quarantine species in Europe. Its host tree, the walnut, is widely present all over Europe. The larvae can cause problems in walnut orchards and in forests, and also in urban areas. The box tree pyralid (*Cydalima perspectalis*) is an invasive species in Europe with serious economic and ecological impacts. Box trees are beloved ornamental plants, but in several European countries, the box tree is also a typical member of the forest community. Both insect species have been recorded recently in Hungary; this provided a unique opportunity to investigate their range expansion within the country. These two species were investigated to observe their special spreading characteristics, estimate the speed of their range extensions, and assess the effect of human influence on their spread. In Hungary, the walnut husky fly is spreading in a natural way. Its range expansion was influenced by weather conditions (temperature, wind) and the presence of its host; the role of humans, according to our current knowledge, is minor. In contrast, human effects played an important role in the spread of the box tree pyralid (e.g., trade, lack of information).

GENERAL POSTER SESSIONS

IUFRO Division 1: Silviculture

Linking ecosystem service tradeoffs with perceived benefits from reforestation in human-modified tropical landscapes. Abelleira, O., Tavarez, H., Ramos-Bendaña, Z., Galbraith, S. (*University of Idaho, USA & CATIE, Costa Rico; ojabelleira@gmail.com; tavarez21@gmail.com; zramos@catie.ac.cr; sara.marie.galbraith@gmail.com*), Fremier, A. (*University of Idaho and Washington State University, USA; alex.fremier@wsu.edu*), Gunter, S., Elbakidze, L., Vierling, L., Bosque Pérez, N., Ordoñez, J., DeClerck, F.

Environmental policies such as payments for ecosystem services (PES) assume reforestation increases ecosystem service (ES) provisions and human welfare. In PES schemes, reforestation may include natural or plantation forests, which may result in unknown ES tradeoffs. Since ecological processes modulating ES within forests are studied at plot scale, spatial up-scaling is needed to link ES tradeoffs to economic benefits at scales perceived by residents. We aim to quantify ES tradeoffs and perceived benefits in a seasonally dry region of Costa Rica where extensive reforestation occurred partly due to PES-sponsored plantations of introduced species. We are using plot-scale measurements of water balance and pollinator diversity per forest type to calibrate spatially explicit ES modeling platforms using high resolution forest cover maps. We will examine how water yield and pollination ES link spatially to resident benefits obtained via stated-preference methods. Initial survey results showed ~30% of sampled rural residents suffer water shortages in the dry season, yet the relationship of perceived benefits with changes in forest cover and associated ES tradeoffs remain to be assessed. We expect our results will help clarify social-ecological links between ES provisions and benefits in PES and broaden the application of these methods in human-modified tropical landscapes.

Growth response of *Moringa oleifera* (Lam.) seedlings to organic and inorganic fertilizers on an Alfisol in south-western Nigeria. Adejoh, O., Shodeke, D., Yakubu, F., Igboanugo, A. (*Forestry Research Institute of Nigeria, Nigeria; bumexd@yahoo.com; shofoluwade@yahoo.com; fredyakubu@yahoo.com; aloyigboanugo@yahoo.com).*

The study investigated the effects of poultry manure (PM), spent mushroom substrate (SMS), bark of *Moringa oleifera* pod (BMP), and NPK (15:15:15) fertilizers applied singly and in combination on early growth of uniform-sized *M. oleifera* seedlings in an Alfisol in south- western Nigeria**.** The treatments were: T1=5 t/ha PM, T2=10 t/ha PM, T3=5 t/ha SMS, T4=10 t/ha SMS, T5=5 t/ha BMP, T6=10 t/ha BMP, T7=2.5 t/ha PM + 2.5 t/ha SMS, T8=2.5 t/ha PM + 2.5 t/ha BMP, T9=2.5 t/ha BMP + 2.5 t/ha SMS, T10=100 kg/ha NPK, T11=200 kg/ha NPK, and T12=control. The experiment was laid out in a completely randomized design with four replicates. Data were collected bimonthly for 6 months. The results showed that plants grown under 2.5 t/ha PM + 2.5 t/ha SMS had the highest plant height (90.6 cm) and collar diameter (8.3 mm) whereas those grown in 2.5 t/ha PM + 2.5 t/ha BMP produced significantly greater number of leaves (70.40) and branches (14.6). Thus, it is recommended that a combination of poultry manure with spent mushroom substrate should be used for raising good-sized seedlings of *M. oleifera* for plantation establishment.

Assessment of current woody species and potential candidate for forest exploitation: implication for reforestation system improvement in Benin. Akpona, A. (*Direction Générale des Forêts et des Ressources Naturelles, Benin; akpona@gmail.com*), Gogan, Y. (*Université Catholique de l'Afrique de l'Ouest, Benin; gogyan4@gmail.com*), Houessou, L., Djagoun, C., Akpona, T. (*Laboratory of Applied Ecology, Benin; houeslaur@yahoo.fr; dchabi@gmail.com; ajeandidier@gmail.com.*

Sustainable reforestation in Benin requires a forward-looking vision which predicts succession in the use of tree species for various purposes and includes it in reforestation planning. We documented current and potential candidate woody species involved in forest exploitation, the criteria which determined their choice, and the level of mastery of their production in a nursery. We surveyed 140 persons involved in tree use and performed a correspondence analysis and principal component analysis for perceived frequency citations abundance, threats, and criteria selection of species in order to establish respectively the relationship between the perceptions of abundance, threats, and the woody species as well as the criteria of choice and the woody species. A total of 31 wood species from 15 botanical families are listed as potential candidates, while 24 wood species belonging to 12 families are currently exploited for timber, art, and sculpture purposes. Thirteen criteria determined the choice of species and vary depending on the type of use. Only 40% of current woody species and potential candidates are produced in nurseries, and less than 30% of species are currently involved in reforestation programs. A long-term plan for integrating targeted species into reforestation programs is required and necessitates synergy among stakeholders.

Examining native and exotic *Pinus taeda* plantation spacing, resource availability and varietal effects using crown ideotypes. Albaugh, T., Fox, T. (*Virginia Tech, USA; tim_albaugh@vt.edu; trfox@vt.edu*), Rubilar, R. (*University of Concepción, Chile; rrubilar@ncsfnc.cfr.ncsu.edu*), Alvares, C. (*Institute of Forestry Research and Education, Brazil; clayton@ipef.com*), Stape, J. (*North Carolina State University, USA; stape@ncsfnc.cfr.ncsu.edu*).

To meet demand for forest products, from solid wood to bioenergy, managers must utilize intensive silvicultural practices including site selection, resource management, stocking, and elite genetic material including clones. While our understanding of these factors has improved tremendously in the past 50 years, questions still remain including how to evaluate clonal material and why *P. taeda* planted in the southern hemisphere typically outperforms that in the southeast United States. Our approach to address these questions has been to establish three sites (Virginia: outside native range but in the southeast United States; North Carolina: native range; and Brazil: southern hemisphere) where the same clones, mass control pollinated and open pollinated families with a range in crown ideotype, were planted at three spacings (618, 1 235, 1 853 stems/ha; from wide spacing for solid wood to narrow spacing for bioenergy biomass production), and two levels of resource availability (operational and intensive for maximum growth). We will present growth response data after 3 years to understand if crown ideotype will be useful in identifying the best silvicultural regime for a given genetic entry.

A forest for all: management for multiple uses. Axelsson, E., Strengbom, J., Lundmark, T., Nordin, A. (*Swedish University of Agricultural Sciences, Sweden; petter.axelsson@slu.se; joachim.strengbom@slu.se; Tomas.Lundmark@slu.se; Annika.Nordin@slu.se*).

Implementing multi-use management to account for both commercial and ecosystem values of managed systems is accumulating global recognition. This study explores the influence of forest management practices including thinning, nitrogen fertilization, and unmanaged control on the multi-use potential of pine (*Pinus sylvestris*) dominated forests in Sweden. The results showed that the species diversity of understory vegetation was higher in thinned than in unmanaged forests. Lichen biomass increased three-fold in thinned forests. Fertilization decreased the abundance of lingonberry shrubs (*Vaccinium vitis-idaea*) while thinning in combination with fertilization increased that of bilberry shrubs (*V. myrtillus*). Annual stem volume increment increased with fertilization but decreased with thinning. Due to these divergent effects, tradeoffs among different ecosystem services was common, e.g., thinning increased reindeer fodder potential by 200% while at the same time it decreased annual stem volume increment by 28%. We showed that forest floor vegetation responses depend both on management action and focal ecosystem delivery. Hence, it appears possible to design management actions in accordance with management goals as long as the goals are carefully specified. As tradeoffs were common and nonmonetary deliveries such as biodiversity will need consideration, a key challenge will be to decide on these goals and adjust management actions accordingly.

Introduction of adaptable tree species to arid climate in Iran: case study at Fars Province, Darab. Azhdari, F. (*University of Tehran, Iran; fatemeh_azhdari@ut.ac.ir*).

Because Iran has a dry climate, increasing forest area through plantations is of particular importance. In plantation projects, species from a known origin should be used. Lacking information on the species being planted may be hazardous to the ecosystem. Therefore, the ecological conditions of the natural distribution of the species being planted should match the area where they are being introduced. In this paper, adaptable species were introduced into Fars Province, Darab. The climatological parameters used were mean annual precipitation, mean annual temperature, maximum and minimum absolute temperature, mean relative humidity, and dry season duration. Based on the climatological indexes of De Marti and Amberge, the climate in this area was determined to be arid. Based on these studied parameters, 20 tree species were introduced for this area. Studies like this are necessary in arid area like Zagros. It is hoped that studies on management of forest parks and forestry plantations will be increased due to effective preservation and management.

Improving soil conditions to increase productivity of *Tectona grandis* in northern Costa Rica: established plantations. Briceño-Elizondo, E., Arias, D., Esquivel, E. (*Instituto Tecnologico de Costa Rica, Costa Rica; ebriceno@itcr.ac.cr; darias@itcr.ac.cr; eesquivel@itcr.ac.cr*).

Available land for Teak (*Tectona grandis*) cultivation has specific chemical and physical limitations that require further study and possible solutions. Costa Rica is required to keep reforested areas under the same use. However, as of yet no discussion on second rotation has taken place nor has there been any considerations regarding continuing with the same species or not, nutritional conditions of the site after harvesting, or what technological package will ensure a sustainable production. What is clear is that the land used to grow teak with moderate to high productivity should be maintained for timber production. This research addressed improvements to soil conditions to enhance growth by applying physical and chemical treatments not generally used in reforestation in the tropics. A three-block experimental design was established using eight treatments which included combining the effect of two deep tillage levels and three intensities of tillage implements (using 1, 3, and 5 chisel ploughs), and a fertilized no-till treatment and a control plot. The fertilization program was determined after careful soil analysis. Early treatment responses are being monitored and will help to determine what level of intensity is ideal for this species in areas of low productivity.

The Cuban experience within integrated forest farms: the case of La Aurora, Municipality of San Cristobal, Artemisa Province, Cuba. Calzadilla Zaldivar, E. (*Instituto de Investigacion Forestal, Cuba; calzadilla@forestales.co.cu*).

An integrated forest farm (IFF) is the smallest sustainable forest management unit within the system of Forest Ente. The IFFs are created in areas of forest heritage and are state owned. They constitute forests or deforested areas which are assigned to an individual known as the farm manager with a legal contract signed between the state representative and the estate manager. The objective of the estates is forestry, but as recorded by the contract, the estate manager is entitled to additional production, including the creation of subsistence crops in an area of 1.0 to 2.0 ha, as well as animal husbandry and fruit-growing, from which up to 50% of the revenues can be received by the estate manager. At the end of 2010 there were 1 367 forest estates nationwide, with the addition of 100 new farms yearly. In order to disseminate these original experiences, the IFF La Aurora was selected to represent the achievements of the program locally and nationally, and thereby to promote it to the forestry community in the Caribbean subregion.

European beech trees have developed an adaptive strategy of survival through crown die-back under stress of drought and plant competition. Chakraborty, T., Saha, S., Matzarakis, A., Reif, A. (*University of Freiburg, Germany; tamalika.chakraborty@waldbau.uni-freiburg.de; somidh.saha@waldbau.uni-freiburg.de; andreas.matzarakis@meteo.uni-freiburg.de; albert.reif@waldbau.uni-freiburg.de*).

Frequency and severity of drought will increase in central Europe. The reaction of beech trees to drought could show high plasticity at their distribution limit, especially in dry near-natural forests. Understory beech trees could have a survival strategy by developing a crown-dieback threshold. However, such hypotheses have never been tested. To test these hypotheses, five Downy oak-beech ecotones in near-natural forest stands were selected in Germany and Switzerland. Plots were installed across beech and oak dominated areas representing stand composition and moisture gradients. Crown dieback (CD) was measured as the percentage of dead aboveground biomass (AGB) to represent tree vitality. Biomass equations were formulated from the harvested trees for each stand. Soil and climatic parameters were combined to quantify drought. Crown-based spatially explicit plant competition

indices were calculated for target trees. We found that drought, competition, and slope significantly increased CD in beech trees. We calculated for the first time the survival threshold (58% of dead AGB) of beech trees at their drought limit. Irreversible damage occurred beyond this threshold and led to complete plant die-back. We concluded that plant competition along with drought was acting as a predisposing factor of beech die-back at their distribution limits.

Development and dynamics of young aspen-spruce mixedwood stands in western Canadian Boreal Forests. Comeau, P., Bokalo, M. (*University of Alberta, Canada; phil.comeau@ualberta.ca; mike.bokalo@ualberta.ca*).

The Western Boreal Growth and Yield Association (WESBOGY) is a regional association of industrial, federal, provincial, and university foresters and researchers interested in evaluating the dynamics of boreal forest development and the yield implications of silvicultural practices. The four western provinces and the Northwest Territories are represented among the members. In 1992, WESBOGY began a long-term study to evaluate the effects of aspen and spruce densities on the long-term dynamics of mixedwood stands. Eleven replicate installations of this study have been established in western Canada since that time. This poster describes the study design and presents results from recent analyses showing height, height increment, diameter, and height/diameter ratio responses for spruce and aspen in the different treatments.

Dendroenergetic analyses of *Acacia mearnsii* De Wild. culture. Corte, A.D., Sanquetta, C., Pscheidt, H., Ruza, M., Behling, A. (*Federal University of Paraná, Brazil; anapaulacorte@gmail.com; carlos_sanquetta@hotmail.com; heloisaa_p@yahoo.com.br; marielisabrina93@gmail.com; alexandre.behling@yahoo.com.br*).

The objective of this paper was to analyze the dendroenergetic potential of *Acacia mearnsii* De Wild. (black wattle) culture throughout its growth cycle. The study was conducted on plants ranging in age from 1 to 7 years in two different locations in southern Brazil, where this species is largely cultivated. Biomass was measured by means of compartments and ages. Moreover, the superior calorific power (SCP) of samples was measured. Energetic productivity was calculated by multiplying these variables. Analyses of variance indicated there were significant differences in the assessed SCP by compartment. Leaves, bark, living branches, and wood showed a mean SCP of 5 408, 4 787, 4 692, and 4 572 Kcal/kg. The energetic productivity of biomass tended to increase in older stands, varying from 16.3 Gcal/ha for 1-year-old cultures to 635 Gcal/ha for the 7-years-old plants, with wood contributing the most to this value in all but the 1-year-old plants. To conclude, it was noticed that black wattle's energetic productivity varied according to compartment and stand age, and it has a great potential to supply further energetic demands.

Provenance trial of *Shorea leprosula* Miq. In Palembang, South Sumatra, Indonesia. Dewayani, A. (*Bogor Agricultural University, Indonesia; monica.dorothea@gmail.com*).

This research tested the growth performance of five provenances (designated A, B, C, D and E) of *Shorea leprosula* Miq. to 20 years of age in Palembang, South Sumatera, Indonesia. Parameters examined were diameter at breast height (DBH), total height, and bole height. The data from the three parameter analyzed using Analysis of Variance (Anova test) and also significant analysis with Duncan Test. Results indicated a wide genetic variance among provenances for all parameters measured parameter. Based on Anova test, provenance has a significant influence on DBH, total height, and bole height growth but no differences were apparent among blocks for these parameters. The differences among provenances indicates that there is scope for genetic improvement during the selection phase. Based on these results, the best recommended provenance is provenance E.

Teak (*Tectona grandis* Linn. f.) biomass and carbon stocks in FIO Thong Pha Phum Plantation, Western Thailand. Diloksumpun, S., Wachrinrat, C., Thongfak, C., Chumsangsri, T. (*Kasetsart University, Thailand; sapit.d@ku.ac.th; ffforcrw@ku.ac.th; nitazang@hotmail.com; ffortpc@ku.ac.th*).

Forest Industry Organization (FIO) plays an important role in commercial teak (*Tectona grandis* Linn.) plantations in Thailand where significant amounts of CO_2 are stored in biomass and harvested wood products. The objective of this study was to determine the carbon storage in the Thong Pha Phum teak plantation, one of the largest FIO plantations in Thailand. The sampling plots were established in 12 stands representing the 30-year rotation. Allometric equations for biomass estimation and growth model were developed and the carbon storage was then estimated accordingly. Results indicated that all growth parameters were significantly different among stand ages ($p < 0.01$). Total biomass and carbon stored in the biomass tended to increase with age, but considerably lower biomass and carbon storage were also observed in a few stands due to the thinning schedule and/or poor site quality. In 2009, the Thong Pha Phum plantation, with a 2 213.89 ha teak plantation provided 62 019.56 Mg carbon storage, suggesting that Thong Pha Phum plantation could serve as one of the carbon sinks in Thailand where sustainable forest management is employed.

Silver fir (*Abies alba* Mill.): native or alien tree species in northern Poland. Dobrowolska, D. (*Forest Research Institute, Poland; d.dobrowolska@ibles.waw.pl*).

Silver fir is an important tree particularly in mountain forests because of its lower susceptibility to insect infestation compared to *Picea abies* Karst. The northern limit of fir distribution runs across Poland. However, fir grows outside the boarder of its range. The key objective of this study was to verify the natural distribution of the species. The main goals were: (1) to compare the structure, growth, and regeneration of silver fir inside and outside its range; and (2) to compare the vitality and damage of silver fir stands in and outside its natural range. A total of 48 plots (24 inside and 24 outside the natural range of the species) were established on two site types (fresh mixed deciduous and fresh deciduous) and in three age classes (<100 years; 101–125 years; >126 years). Data were collected on circular plots established randomly in stands containing different proportions of silver fir in the species composition. The vitality and growth of silver fir outside the limit of its natural range have been satisfactory. The results of the study will be useful for foresters and policy makers to change the approach for native and non-native species, especially under the condition of climate change.

The carbon balance in forest fuels from long rotation forestry: the outcome is in the assumptions. Egnell, G. (*Swedish University of Agricultural Sciences, Sweden; Gustaf.Egnell@slu.se*), Berndes, G. (*Chalmers University of Technology, Sweden; goran.berndes@chalmers.se*).

Many recent studies claim that biomass from long-rotation forestry for energy purposes will not contribute much to mitigating climate change. Typically these studies take a single stand approach and/or use the terminology of carbon debt, focusing on the time lag before the CO_2 immediately released when the harvested biomass is combustion is balanced by carbon captured in the subsequent stand. Other studies take a what if approach with an overexploitation of the forest resource, and few studies include the behavior of the forest owner on altering future markets for forest products or risks associated with carbon stored in forest stands. Here we present results from software developed within the Heureka project in Sweden to estimate total carbon sequestration, including soil and stand carbon, over time following different assumptions for (1) markets for forest fuels, pulpwood, and timber; (2) forest owners behavior based on market expectations; and (3) the age structure of the forest. Results are given for a single stand, a forest estate, and for the whole productive forest in Sweden based on national forest inventory data. Since the outcome is in the assumptions, they are also discussed.

Evaluation of natural regeneration of woody plants in a mixed plantation of tree species. Enciso Gomez, M., Leguizamon Aranda, A., Elias Dacosta, L. (*National University of Asuncion, Paraguay; manuelenci@yahoo.com; adanleguiaranda@gmail.com; elidaco28@gmail.com*).

The occurrence of the regeneration of woody plants in a plantation forest is important because it can eventually lead to the formation of a structure and coverage that resembles that of a natural forest. Therefore, the assessment of natural regeneration can produce results that clarify the potential to reconstitute the characteristics of a natural forest through planting. In this study we evaluated the natural regeneration in a 23-year-old mixed plantation with eight native forest species located on the campus of the National University of Asuncion, in the city of San Lorenzo, Paraguay. Sampling areas were systematically established within the plot where individuals were identified and calculations of abundance, frequency, and mixing ratio were completed. We found 20 967 individuals/ha, consisting of 13 families and 25 species. There were no regeneration individuals corresponding to the two planted species. The two species with the highest relative abundance had values of 48.01% and 14.31%, respectively. The two species with higher relative frequency at seedlings stage had values of 15.07% and 12.33%, respectively. While at pole stage, the two species with the highest relative frequency had values of 10.84% and 9.64%, respectively. The mixing ratio of species had a value of 0.04. It was concluded that the mixed planting of native forest species promotes regeneration of a large number of individuals and can be an alternative to restoring vegetation cover having the characteristics of a natural forest.

Sustainable energy from wood plantations benefits Coopetarrazú coffee. Esquivel, E., Molina Quesada, S., Arias, D., Briceño-Elizondo, E. (*Instituto Tecnológico de Costa Rica, Costa Rica; eesquivel@itcr.ac.cr; samolina117@gmail.com; darias@itcr.ac.cr; ebriceno@itcr.ac.cr*), Calvo, M. (*Coopetarrazú, Costa Rica; mcalvo@coopetarrazu.com*).

For the market value price to reflect coffee with a distinction of being produced sustainably, processing requires heat that traditionally has been obtained from burning wood. However, wood supply comes from different sources with various species, age, and heat capacities, creating differences in boilers at the industrial level, thus justifying the need to obtain a source of biomass of a standard quality for the coffee processing industry. Coopetarrazú coffee industry is located within an area where land use for coffee is inadequate and using farmsteads for forestry would be more appropriate. Using high-density plantations, we established a three-block experimental design with six treatments combining two Eucalyptus species (*Eucalyptus tereticornis* and E. *saligna*) at three stockings (5000, 10 000 and 20 000 trees/ha) in 100 m^2 plots. By periodically evaluating soil nutrients, biomass, stage of development, and carbon sequestered in soil and biomass, we have identified suitable densities and species combinations for energy production. This knowledge is of great importance to Coopetarrazú and other coffee companies.

Natural regeneration in Mediterranean pine forests: a conceptual approach under climate change. Fonseca, T.F. (*University of Trás-os-Montes e Alto Douro, Portugal; tfonseca@utad.pt*), Lucas-Borja, M. (*Universidad de Castilla La Mancha, Spain; ManuelEsteban.Lucas@uclm.es*), Rodríguez García, E., Bravo Oviedo, F. (*Universidad de Valladolid, Spain; enkaro@hotmail.com; fbravo@pvs.uva.es*).

Factors restricting natural regeneration success in Mediterranean pine forests at the earlier stages are especially complex, and some of them are not completely understood. They include year-to-year variability in seed production, post-dispersal seed predation, suitable medium for seed germination and seedling survival, diseases, and variable environmental conditions. In addition, factors can vary annually or within a given year and can vary with local conditions and season. From data obtained in *Pinus nigra* and *Pinus pinaster* stands in Spain during the last decade, results showed that the processes linked at the beginning of recruitment do not predict good expectancies in non-masting years. Moreover, seed germination, seedlings survival, and initial seedling growth are influenced by site perturbation (harvest, fire), stand density, shrub and canopy cover, and soil properties. In conclusion, the relationship between natural regeneration and all the factors involved appears to be site specific and additionally mediated by species plasticity. Further research work is needed to determine whether the relationships described above can be generalized.

Growth reaction of a multiple use species (*Tectona grandis* L. F.) to pruning in the State of Rondonia, Brazilian Amazon. Gama, M.B., Vieira, A.H., Rocha, R.B., Locatelli, M. (*EMBRAPA, Brazil; michelliny.bentes-gama@embrapa.br; abadio.vieira@embrapa.br; rodrigo.rocha@embrapa.br; marilia.locatelli@embrapa.br*).

Research on tropical silviculture practices is a key point for generating answers for forest managers and policy-makers. Especially in the Brazilian Amazon where complex biodiversity has experienced rapid degradation and the efforts on adjusting management techniques to encourage reforestation are permanent. Production forests may fit viable strategies to mitigate the negative effects of deforestation, but some driving characteristics for enhancing good wood quality are still needed. This study reported on the

pruning trial in a commercial plantation of teak in the State of Rondonia in northwestern Brazil. Treatments consisted of pruning intensities of 25%, 50%, and 75% and the control treatment with no pruning. Differences among treatments in pruning and age were not significant at 25% and 50% intensities in contrast to the control, but were significant at 75% intensity. In addition, the pruning intensities caused no detrimental effect on the commercial height of trees at the age of 44 months. Current findings indicate that moderate pruning regimes are adequate for pursuing improvements to stem form and wood quality without having a strong effect on tree growth and stand yield in this portion of the Amazon.

Evaluation of the effectiveness of the use of bokashi on seedling quality of *Balfourodendron riedelianum* (Engl.) Engl (Guatambu). Garcia, M., Zorrilla Benítez, S., Enciso Gomez, M., Vera de Ortiz, M. (*Universidad Nacional de Asunción, Paraguay; marialisgarcia@gmail.com; ser-zorro@hotmail.com; manuelenci@yahoo.com; dircif@agr.una.py*).

The growing demand for native tree seedlings requires research related to the use of substrates capable of providing seedlings with high initial growth rates and survival after planting. *Balfourodendron riedelianum* (Engl.) Engl (Guatambú) is a native species of Paraguay whose wood is in high demand both nationally and internationally. This study evaluated the effectiveness of bokashi on the quality of seedlings of Guatambú, with and without fertigation. The applied experimental design was a randomized factorial design with 14 treatments, 5 replicates, and a control. Each experimental unit consisted of four plants, totaling 300 seedlings. Morphological parameters including height, collar diameter, shoot dry weight, root dry weight, root shoot dry weight ratio, slenderness index, and Dickson quality index were evaluated. No significant differences in the levels of fertilization were found. The treatment consisting of soil (70%) + bokashi (30%) + fertigation produced the best results in height. In diameter and shoot root dry weight ratio, the best results were obtained with the substrate composed of soil (80%) + bokashi (20%) + fertigation. For slenderness index and Dickson quality index, the substrate composed of soil (50%) + bokashi (25%) + cow manure (25%) with fertigation produced the greatest value.

Enhancing mine and energy crop soils to promote willow and poplar growth using ash and biosolids: a greenhouse trial. Gilbert, N. (*International Forestry Students Association, Canada; sno_reason@inorbit.com*).

Wood ash from bioenergy production contains a high concentration of nutrients essential for plant growth and can neutralize acidity in soil. The objective of this study was to assess the growth of willow and poplar in soils amended with different amounts of bioenergy ash (0%, 0.5%, 1%, 2%). In two trials divided by soil type (sand and loam), clonal cuttings were grown in a greenhouse for 4 months. Three bioenergy ash differing in chemical properties, such as pH and CEC, and bioenergy system, boiler system versus gasifier, were used for this study. To supplement the nitrogen deficiency common of wood ash, biosolids were mixed into half the treatment samples. The acidic, well-draining, sandy soil produced the greatest yield of new growth in the mixed ash and biosolids combinations. In the neutral loam trial, the plants also responded best to the ash treatments mixed with biosolids. These results suggest a method of fertilization that not only promotes plant growth, but also provides a use for materials otherwise considered to be waste.

Advanced oak seedling development as influenced by shelterwood treatments, competition control, deer fencing, and prescribed fire. Gottschalk, K., Miller, G., Brose, P. (*U.S. Forest Service, USA; kgottschalk@fs.fed.us; gwmiller@fs.fed.us; pbrose@fs.fed.us*).

Advanced northern red oak (*Quercus rubra* L.) seedlings in an 85-year-old forest located in north-central Pennsylvania were observed for 10 years after manipulation of overstory density, herbicide control of interfering plants, exclusion of deer by fencing, and application of a single prescribed fire. A total of 24 treatment combinations including untreated controls were studied on 72 permanent plots. Seedling survival and seedling growth were enhanced by both exclusion of deer by fencing combined with a moderate (12% of basal area) to high (27% of basal area) removal of the overstory. Published dominance probabilities for site index 70 were applied to the average size and number of tagged advanced seedlings in each plot to determine which treatments produced the greatest predicted number of codominant oaks in the next stand after final harvest. Treatments that included exclusion of deer by fencing combined with a moderate (12% of basal area) to high (27% of basal area) removal of the overstory projected new stands with more than 50 percent oak composition. Fencing and no overstory removal, while producing much less growth, also predicted more than 50 percent oak composition. Oak seedling development and suggestions for writing silvicultural prescriptions to prepare for successful oak regeneration are discussed.

Mixed-species plantations of *Eucalyptus* and *Acacia mangium* as an alternative for bioenergy production in tropical regions. Hakamada, R. (*University of São Paulo, Brazil; rodrigo_hakamada@yahoo.com.br*), Bouillet, J. (*CIRAD, France; jean-pierre.bouillet@cirad.fr*), Gonçalves, J. (*University of São Paulo-ESALQ, Brazil; jlmgonca@usp.br*), Voigtlaender, M. (*Institute of Forest Research, Brazil; mvoigtlaender@gmail.com*), Gava, J. (*Suzano, Brazil; jgava@suzano.com.br*), Leite, F, Mareschal, L., Nouvellon, Y., Mazoumbou, J., Koutika, L., Epron, D., Laclau, J. (*CIRAD, France; jean-paul.laclau@cirad.fr*).

Silvicultural practices that increase wood production in forest plantations are required to achieve society's demand for renewable energy sources. Mixed-species plantations of *Eucalyptus* and *Acacia mangium*, a N-fixing species, have been studied as a pathway of ecological intensification, enhancing nitrogen availability and carbon accumulation within the system. Our objective was to compare the potential of bioenergy production in pure and mixed-species plantations. We used calorific values from the literature along with data of wood production measured at five sites in Brazil and Congo with various levels of productivity to calculate the energy produced at the end of stand rotation (on average 6.2 years after planting). We compared pure *Eucalyptus* stands (100E) to mixed-species stands with the same density of *Eucalyptus* trees with 25% *Acacia* trees (100E:25A). At all sites, the mixtures generated energy gains ranging from 0.2 to 36.3% compared to *Eucalyptus* monocultures. These gains were highly correlated (R^2>0.99) with total stemwood production, due to comparable calorific values for both species. This study opens the possibility for using mixed-species plantations of *Eucalyptus* with N-fixing tree species as a renewable source of bioenergy for both domestic and commercial uses.

Sustainability and profitability of a 2 year rotation in *Eucalyptus* for biomass production: case study in Brazil. Hakamada, R. (*University of São Paulo, Brazil; rodrigo_hakamada@yahoo.com.br*), Lemos, C. (*International Paper, Brazil; Cristiane.Lemos@ipaper.com*), Almeida, A. (*International Paper, Brazil; adriano.almeida@ipaper.com*).

Short rotation (SR) harvests of 2 years or less have been discussed in Brazil as a silvicultural system for producing biomass for energy. Although it is a way to grow biomass faster, sustainability and profitability of this system has been questioned. Our objective was to estimate the balance of nutrients and the costs of establishment, harvesting, and transportation of SR wood compared with a traditional system with 7 years rotation in *Eucalytpus*. We used results from Nelder design spacing trials to compare a traditional stocking with 1 545 trees/ha with a tighter planting with 7 150 trees/ha. Simulating a period of 70 years of cultivation, nitrogen, phosphorus, and potassium exportation was 53, 124, and 4% higher in SR. Establishment, harvesting, and transportation wood cost would be 192, 16, and 36% higher in SR. Land expected value, a measure that compares different duration investments, was 303% lower in SR, meaning lower profitability of this system compared with traditional stocking. Results indicated that even though it seems a faster way to acquire wood, in the long term it might be injurious for the soil nutrient balance and may not be profitable. Detailed methods for estimating nutrient exportation and costs will be presented.

Water deficit is a good predictor of maximum stocking in a *Eucalyptus* clonal plantation in Brazil. Hakamada, R. (*University of São Paulo, Brazil; rodrigo_hakamada@yahoo.com.br*), Lemos, C., Almeida, A., Silva, R., Batistuzzo, G. (*International Paper, Brazil; Cristiane.Lemos@ipaper.com; adriano.almeida@ipaper.com; renato.meulman@ipaper.com; guilherme.batistuzzo@ipaper.com*).

The choice of spacing is often made empirically, mainly in regions with no historical data of trees plantations. A wrong decision can cause the total mortality of a stand, and mortality usually is related to water constrains. The objective of this work was to create a tool which relates spacing decision with climate information. To do that, we planted four Nelder design trials with spacing varying from 228 to 7 150 trees/ha in different soil and climate conditions affecting water storage capacity, which permitted a variation in water deficit from 50 to 450 mm, calculated by the Thornthwaite and Mather method. We evaluated the stocking which could support more than 95% of survival in each site. We found a very strong relationship ($R^2 = 0.94$) between the water deficit and maximum stocking supported in each site. For areas with no water deficit, a stocking of more than 2 000 stems/ha was permitted, and this declined to less than 800 in areas with elevated water deficit. An increase of 100 mm of water deficit needs a decrease of 200–300 stems/ha. This tool provides some direction for making spacing decisions and uses information that groups soil and climate conditions.

Bioenergy and fiber use of bamboo biomass from small-scale plantations in Thailand. Haruthaithanasan, M., Darabant, A., Atkla, W., Phudphong, T., Thanavat, E., Haruthaithanasan, K., Wittayakarn, S. (*Kasetsart University, Thailand; aapmwt@gmail.com; darabant@gmail.com; dadida_62@hotmail.com*); *aaptpp@ku.ac.th; fgteak.t@gmail.com; aapksh@ku.ac.th; aapstr@ku.ac.th*).

In Thailand, farmers have recently begun establishing bamboo plantations on marginal land for possible utilization for bioenergy and fiber. This study looked at the potential of bamboo for biomass feedstock. First-year yield data of *Bambusa beecheyana* and *Dendrocalamus membranaceus* indicated vast differences between sites (1 vs. 18 t/ha), which is highly related to soil conditions and annual rainfall, but not between species. In terms of feedstock quality for power plants, high heating values (19.2 to 19.5 MJ/t) did not differ between species, but culm moisture contents did differ between species (51% for *B. beecheyana* vs. 45% for *D. membranaceus*) and between culm sections (38% wet base at top vs. 55% at bottom). This gradient was stronger in *D. membranaceus* which showed significantly higher moisture content in internodes as compared to nodes (46% vs. 43%). Fiber yield extracted from internodes of *D. membranaceus* was higher than that of *B. beecheyana* (alpha-cellulose content 46% vs. 36%), and fiber quality did not differ in spite of higher lignin content of *D. membranaceous* (23% vs. 16%). The chemical-free stem explosion method yielded higher quality fiber (in terms of fiber length, size, strength, and anti-bacterial properties) as compared to acidic and alkaline boiling. Our results provide guidance on increasing the value of bamboo biomass by optimizing the allotment of different species and biomass compartments to different uses (e.g., bioenergy, fibers).

Short rotation forestry in Bavaria (southern Germany): results of a survey of operators. Hauk, S., Wittkopf, S., Knoke, T. (*University of Applied Sciences Weihenstephan-Triesdorf, Germany; s.hauk@wz-straubing.de; stefan.wittkopf@hswt.de; knoke@forst.wzw.tum.de*).

The main focus of short rotation forestry (SRF) science has been basic research concentrating on results from experimental sites. Hence, about 1 200 hectares of SRFs in Bavaria (southern Germany) operated by normal farm practitioners have not yet been investigated, nor have the concerns and suggestions of these practitioners been documented. To fill these knowledge gaps, a standardized questionnaire was mailed to all SRF operators in Bavaria. The survey was designed to gather information about the land ownership and land use characteristics of SRF growers as well as the reasons they chose to cultivate SRF and the obstacles they face. SRF cultivation in Bavaria is practiced in a somewhat different manner than in northern Germany and the rest of Europe. Most SRF operators in Bavaria are part-time farmers cultivating poplar on small fields (on average 1.1 ha). In most cases, SRFs are cultivated in rotation periods of between 5 and 10 years on relatively poor and moist agricultural lands and harvested by chainsaw. Stems are dried in the open air and later used to cover the cultivators' heat demand. This extensive management practice is an interesting option for producing woody biomass on small-scale unfavorable agricultural lands.

Newly transplanted *Larix olgensis* Henry stock with greater root biomass has higher early nitrogen flux rate. He, X., He, X., Wang, W. (*Chinese Academy of Sciences, China; hexingyuan@iga.ac.cn; hexingyuan@neigae.ac.cn; wangwenjie@neigae.ac.cn*).

During wetland afforestation, information is quite limited about the relationship between initial tree stock status before transplanting and early nitrogen (N) flux in root. In this study, we pre-fertilized *Larix olgensis* Henry seedlings with three top-dress applications (NPK, 20-4-10) at rates of 0 (control), 31.58 (E-Low), 200 (E-Medium), and 525.08 (E-High) kg N/ha in a nursery

in Jilin, Northeast China. After being graded into large and medium sizes, overwinter stocks were transplanted into aerated distilled water or nutrient solution to detect early root N efflux or N influx, respectively. In large stocks, N influx tended to increase within 1 month in the E-Medium and E-High treatments where N efflux tended to rise as well. Root biomass in pretransplanted stock was linearly correlated with both N influx and N efflux for both stock sizes, but root N concentration was only correlated with N influx for large stocks. In conclusion, proper nursery fertilization could lead to appropriate seedling N reserves and greater root biomass resulting in a higher N influx rate for larger stocks, but roots would also risk more N efflux in humid, infertile sites shortly after planting.

Carbon storage capacity of monoculture and mixed-species plantations in subtropical China. He, Y. (*Chinese Academy of Forestry, China; hyjun163@163.com*), Qin, L. (*Guanzi University, China; nilniq@gxu.edu.cn*), Li, Z., Liang, X. (*Chinese Academy of Forestry, China; zyli1017@gmail.com*; *ecologystar@gmail.com*).

To evaluate the impacts of tree species compositions on the carbon storage capacity of plantation ecosystems, we measured the above and belowground biomass, as well as the carbon content, in three 27-year old forest plantations of monoculture *Castanopsis hystrix* (CH stand), monoculture *Pinus massoniana* (PM stand), and mixed *C. hystrix* and *P. massoniana* (mixed CH/PM stand) stands. The carbon storage levels of understory, litter, and soil components were also estimated. Results show that the ecosystem carbon storage of the mixed CH/PM stand (327 Mg/ha) was higher than those of the CH (315 Mg/ha) and PM (294 Mg/ha) stands. The majority of carbon storage was found in the soil pool. Almost 40% of soil carbon at a depth of 0–60 cm was stored in the upper 20 cm of the soil pool. Except for the vegetation layer, each layer of the CH and mixed CH/PM stands consisted of a higher amount of carbon than did the layers of the PM stand. These findings suggest that mixed CH/PM plantation stands or valuable indigenous CH plantation stands more substantially improve carbon storage in litter, soil, and ecosystems than do monoculture PM plantation stands.

Effect of nitrogen fertilization on morphological parameters of *Balmasocarpon brevifolium*, *Oxalis gigantean,* and *Balbisia peduncularis*: xerophytic species of importance in arid zones of Chile. Hernandez, J., Silva, S, Leon, P., Leon, M., Espejo, M. (*Instituto de Investigaciones Agropecuarias, Chile; jose.hernandez@inia.cl; sergio.silva@inia.cl; p.leon@inia.cl; mario.leon@inis.cl; mjose.espejocortes@inia.cl*).

Arid and semiarid regions cover approximately 30% of the Earth's surface yet have great importance in biological diversity. An example of this is the native and endemic flora found in northern Chile (29º53′ S 71º15′ W to 18°28′ S 7º21′ W), where we find a large number of species with serious conservation problems. In this context, the lack of existing knowledge about these species is transformed into a difficulty in deciding conservation measures, largely because of a lack of knowledge of the propagation process. Therefore, we studied the effect of nitrogen nutrition on growth of *Balmasocarpon brevifolium*, *Oxalis gigantea*, and *Balbisia peduncularis*. We used seeds collected from different altitudinal levels (m), and seedlings were subjected to different levels of nitrogen (0, 100, 300, and 500 mg/L) with the aim being to determine the effect of nitrogen fertilization on plant growth. To meet the objective, we recorded the height, diameter, and root biomass every 30 ± 1 days. As the nitrogen concentration increased in the growth medium, plant growth increased in *O. gigantea* and *B. peduncularis* ($P < 0.001$), with no effect of nitrogen on locust bean plants ($P > 0.05$).

Short-term responses of saproxylic insects to different types of forest restoration. Hjälten, J. Hägglund, R., Johansson, T., (*Swedish University of Agricultural Sciences, Sweden; joakim.hjalten@slu.se; ruaridh.hagglund@slu.se; therese.johansson@slu.se*), Dynesius, M. (*Umeå University, Sweden; mats.dynesius@emg.umu.se*) Roberge, J. (*Swedish University of Agricultural Sciences, Sweden; Jean-Michel.Roberge@slu.se*).

Intensive forest management has had severe impacts on forest biodiversity in many forest ecosystems. Thus, we have moved past a point where we can rely on passive conservation measures and must start assessing different methods for restoration of hitherto managed forests. The aim with this project was to evaluate ecological effects and cost efficiency of two different ecological restorations methods used in low-quality voluntary forest set-asides (prescribed burning and selective cutting conducted to resemble gap-dynamics), with non-restored stands serving as controls. We evaluated how these two restoration methods (which are currently developed and used in Swedish forestry) influenced a variety of organism groups (e.g., insects, fungi, bryophytes, vascular plants, and small mammals). The project was developed in close collaboration with representatives from the forest company Holmen Skog to ensure a potential rapid application of these restorations measures in various forest habitats if they are found effective. Immediate responses of saproxylic insects following burning and gap-cutting suggest fast responses of pyrophilous and fire favored beetles (e.g., *Melanophila acuminata*, and *Acmaeops pratensis*) to fire restoration. The response of other insect groups and the potential for large scale application of these types of restoration is discussed.

The characteristics of seedlings occurrence by different regeneration methods in a natural *Pinus densiflora* stand of South Korea. Hwang, J., Hyun Seop, K., Lee, K, Lee, S., Seo, K. (*Korea Forest Research Institute, Republic of Korea; jhwang@forest.go.kr; dendron@forest.go.kr; lkj0217@forest.go.kr; lst9953@forest.go.kr; kwseo@forest.go.kr*).

This study was carried out to understand the characteristics of seedling occurrence by regeneration method in a natural *Pinus densiflora* stand. Regeneration methods were divided into mother tree and clear-cutting. Seedling density and age were surveyed every 10 m in four directions (upper, lower, left, right) from the mother tree and in the lower direction of slope from the seed stand near clear-cutting sites. Seedling amounts by crown direction from the mother tree were 35% at lower direction, 25% to left, 22% to right, and 17% at upper direction. The seedling amount by distance from mother tree was 46% at 0 m (below crown) and 7% at 30 m from mother tree's crown. Results showed that seedling amount decreased with distance from the mother tree. The distribution of seedling age was from 2 to 5 years. However, more than 98% of seedlings occurred within 3 years after harvest. The characteristics of seedling occurrence by distance from seed stand in clear-cutting sites were 41% at 10 m, 32% at 20 m, and 12% at 40 m. Also, distribution of seedling age was from 2 to 9 years, and nearly 80% of seedlings appeared within 3 years after clear-cutting. These results will contribute to decisions regarding optimal placement of mother trees and size of regeneration area for secondary growth forest by natural seeding after harvest of *Pinus densiflora*.

The comparison of early growth of *Pinus koraiensis* seedlings in harvested deciduous and evergreen coniferous plantations. Hwang, J., Yang, A., Cho, M., Kim, S. (*Korea Forest Research Institute, Republic of Korea; jhwang@forest.go.kr; ramrami0130@gmail.com; mscho@forest.go.kr*, *ksk5409@forest.go.kr*).

This study was conducted to compare early growth of *Pinus koraiensis* seedlings planted in harvested *Larix kaempferi* (Chuncheon site) and *Pinus rigida* (Inje site) plantations in Gangwon, Korea. Containerized seedlings of *P. koraiensis* (2-2) were planted in both plantations in 2010. Two or three 400 m^2 plots were established in each study site, and 30 seedlings/plot were randomly selected for the measurement of seedling growth. Five soil (0–20 cm soil depth) samples were randomly collected in each plot in 2011 and were analyzed for soil properties. Each October from 2011 to 2013 we measured diameter at root collar and seedling height and then calculated relative growth rate (RGR) and the ratio of diameter at root collar to seedling height. Concentrations of soil total nitrogen, available phosphorus, organic matter, and cation exchange capacity at the Chuncheon site were significantly higher than those at the Inje site. The RGR of diameter at root collar at the Chuncheon site (30.4–37.0%) was higher than that of the Inje site (14.5–30.2%) every year. The RGR of seedling height at the Chuncheon site (48.2%) was significantly different compared to the Inje site (44.3%) in 2013. From these results, it is assumed that *P. koraiensis* seedlings in a harvested *L. kaempferi* plantation might show significantly higher early growth than that in harvested *P. rigida* plantation due to better soil conditions.

Variations in early seedling growth of *Quercus acutissima* in a strip cut *Larix kaempferi* plantation. Hwang, J., Yang, A., Cho, M., Lee, S. (*Korea Forest Research Institute, Republic of Korea; jhwang@forest.go.kr; ramrami0130@gmail.com; mscho@forest.go.kr; sg12612@forest.go.kr*).

This study was conducted to compare the early growth of *Quercus acutissima* seedlings in a strip cut *Larix kaempferi* plantation located in Boeun, Chungcheongbuk province, Korea. Strip cutting was performed using a 30 m width in the direction of contour. Bare-root seedlings of *Q. acutissima* (1-1) were planted at a density of 2 000 trees/ha in a strip cut *L. kaempferi* plantation in 2006. Three 400 m^2 plots were established in the edge and center of planted sites, respectively, and 30 seedlings/plot were randomly selected for the measurement of seedling growth. We measured diameter at root collar and seedling height each October from 2011 to 2013 using a folding scale and digital calipers and then calculated relative growth rate (RGR) and ratio of diameter at root collar to seedling height. The RGR of diameter at root collar in edge plots (16.9%) was significant higher than that in center plots (14.5%) in 2013. The RGR of seedling height in center plots (24.6–37.4%) was significantly higher than that in edge plots (22.6–32.5%) every year. From these results, it is possible to determine the appropriate width for strip cutting and management methods for regeneration in *Larix kaempferi* plantations.

Evaluation of the vegetation and proposal of species for rehabilitation of the Necropolis Cristóbal Colón patrimonial area in the Havana, Cuba. Jiménez Águila, M., Velazquez Viera, D., Sordo Olivera, L. (*Instituto de Investigacion Forestal, Cuba; mjimenez@forestales.co.cu; digna@forestales.co.cu; sordo@forestales.co.cu*).

The Necropolis Cristóbal Colón National Monument was declared due to the exceptional character of its historical and artistic securities. Since 1990, authorities, historians, restorers, and forest investigators have taken charge of veiling, to study and to disclose their patrimonial securities to maintain and to conserve the architectural beauty of monuments, gardeners, and the tree-lined cemetery, harmonizing the specific functions of the place. The objective was to evaluate the existing vegetation and to propose species to rehabilitate the patrimonial area to preserve the cultural memory. The inventory, diagnostic, and evaluation of the arboreal vegetation and shrubs of the area allowed species to be recommended for rehabilitating the green spaces in the main artery and other sections without affecting the monuments, streets, or sidewalks. Charts, pictures, designs and outlines were presented. An arboreal cover of 2 142 physical individuals was observed (trees and bushes). The prevailing species included *Ficus* sp., *Calophyllum antillanum* Britt., *Roystonea regia* (H.B.K.) O.F. Cook, and *Juniperus lucayana* Britt. Suggestions that contribute to elevating the cultural level and act to administer and manage the integral classification of the place and enlarge the interrelation between historical-cultural institutions and environmentalists are recommended for the rehabilitation and conservation of the specialized urban landscape.

Implementation of sustainable agroforestry in Mongolia. Jo, H., Park, H., Kim, J. (*Kangwon National University, Republic of Korea; jhk@kangwon.ac.kr; bhm63@knagwon.ac.kr; kjy84@kangwon.ac.kr*).

There is rising concern about desertification associated with drought, grazing, and deforestation in arid and semiarid regions. This study explored and implemented sustainable community agroforestry to combat desertification and to improve income in Elsentasarhai, Mongolia. Field and questionnaire surveys were conducted to determine growth environments and resident needs. Field surveys included tree planting techniques and growth conditions of the Desertification Research Center in Elsentasarhai and the Korea-Mongolia Greenbelt Project in Runsom. The questionnaire survey included what tree and income species should be planted as well as income level and life satisfaction. The majority of residents recommended *Ulmus pumila* and *Populus sibirica* as tree species to plant for desertification control. They also preferred cultivation of *Hippophae rhamnoides* and potato as income species. This study established a desirable agroforestry plan which was characterized by a combined land use system of tree plantings and crop cultivation. The plan was implemented around the Desertification Research Center in May 2013. The implementation is being monitored including parameters such as windbreak effect, soil moisture, tree vitality, and crop productivity.

Effects of soil amendments on survival rate and growth of *Populus sibirica* and *Ulmus pumila* seedlings in a semi-arid region, Mongolia. Jung, Y., Son, Y., Yoon, T., Han, S. (*Korea University, Republic of Korea; nayejee@gmail.com; yson@korea.ac.kr; bluemirror_@hanmail.net; saerom.han@gmail.com*), Kang, H. (*Dongguk University, Republic of Korea; HDK0225@dongguk.edur*), Yi, M. (*Kangwon National University, Republic of Korea; mjyi@kangwon.ac.kr*).

This study was conducted to investigate adequate soil amendments for a tree planting in a semi-arid region in Mongolia. *Populus sibirica* and *Ulmus pumila* seedlings were planted in alkaline sandy soils and treated with two levels of nitrogen, elemental sulfur, artificial moisture retention, and converted loess. After 4 months, the seedling survival rate of both species decreased as the amount of nitrogen increased. Nitrogen generally increases seedling survival rate and growth, however, the survival rate in this study might have be affected by an excess of nitrogen fertilization or by the microclimate, including the wind. The root collar

diameter (RCD) growth of both species increased significantly when treated with the converted loess, but only RCD growth of *P. sibirica* increased with the artificial moisture retention treatment. Although *P. sibirica* is drought tolerant, its growth depended on the capacity of available water. The elemental sulfur treatment showed no effect on the survival rate or RCD growth for either species due to the low oxidation of sulfur. Further studies are needed to examine the influence of nitrogen fertilization on seedling survival rate and growth for both species, and extended monitoring is also required to elucidate the long-term effects of soil amendments in this semi-arid region.

Effects of repeated whole-tree harvesting on soil properties and tree growth in a Norway spruce (*Picea abies* (L.) Karst.) stand. Kaarakka, L. (*University of Helsinki, Finland; lilli.kaarakka@helsinki.fi*).

Increased demand for forest-derived biomass has resulted in changes in harvest intensities in Finland. The Nordic countries have a long tradition of utilizing their forest resources intensively for both industry and energy purposes, and the use of forest-derived biomass for energy has steadily increased in the region during the past 15 years. Conventional stem-only harvest (SOH) has to some extent been replaced with whole-tree harvest (WTH). The latter involves a greater removal of nutrients from the forest ecosystem, as all the above ground biomass is exported from the site. This has raised concerns that WTH could result in large changes in the nutrient dynamics of a forest stand and could eventually lower its site productivity. The objective of this study was to assess the effects of repeated SOH and WTH on surface soil properties and stand growth in a fertile Norway spruce (*Picea abies* (L) *Karst*.) stand. The studied stand is part of a series of whole-tree thinning experiments established in Southern Finland. The results suggest that although the stand possesses significant pools of nutrients at present, WTH, if continued, could have long-term effects on site productivity.

Why bank on ban on felling for managing mountain forests sustainably? Kant, P. (*Institute of Green Economy, India; promode.kant@gmail.com*).

Himalayan forests hold 41% of India's growing stock, and community institutions in these hills have historically managed their forest resources reasonably well. The Forest Policy of 1988 is aimed at ensuring environmental stability and maintaining an ecological balance. Economic benefits must be subordinate to this principal aim, but increasingly rigid judicial interpretations of this principal have led to a near total harvesting ban in the hills, eroding the people's connection with the forests. Sustainable forest management can be defined as a coherent set of policies and practices under which the sum total forest capital stock of natural forests, manmade forests, and related institutional capital does not corrode over time and the natural forest capital itself does not dip below a critical threshold, even as the forests consistently enhance human welfare. The authors used national inventory data to estimate possible annual sustainable harvesting of 9.5 Mm^3 of timber and 3.8 Mm^3 of biomass-based fuel from these hills. This is almost twice the annual import of timber into India priced at US$ 2.6 billion, a substantial part of which would benefit the communities, generate employment, and increase climate change mitigation benefits. There are challenges to balancing competing ecosystems services, benefit transfer to remote stakeholders, and avoiding conflicts among neighboring communities over claims on forests.

Biodiversity and ecosystem services project in Cambodia. Khun, B. (*Biodiversity Conservation Corridors Cambodia, Cambodia; kbunnath@gmail.com*).

The design of the biodiversity corridors is embedded within a multipurpose, sustainable, biodiversity landscapes approach. The project will cover 22 communes (12 in Mondulkiri and 10 in Koh Kong) located across eight districts with a total population of approximately 68 048 (2008 census) in both provinces and households numbering just over 14 000. The project in both Koh Kong and Mondulkiri provinces is predominantly in mountainous areas covered with protected forests, national parks, and wildlife sanctuaries. An estimated 17 500 households will benefit from the project, of which about 25% are indigenous peoples of Mondulkiri largely from the Phnong group and 50% are women. The project will: (1) provide forest tenurial security to local communities and indigenous groups for collective management of forest resources; (2) restore habitat on degraded forest lands with tree planting of natives species and agroforestry models with improved sources of nontimber forest products; (3) improve livelihoods and income, enhancing small scale infrastructure; and (4) generate over 1 million cash-based labor days through project activities. Delineation and demarcation of these corridors will be in consultation with primary beneficiaries based on a participatory land use planning approach. Biodiversity corridors are geographic areas within or cutting across GMS economic corridors that need to be placed under sustainable management regimes to secure local livelihoods, address habitat fragmentation, and maintain ecosystem services.

The relationship between replanted tree growth and frequency of bush clearing in replanted Sugi (*Cryptomeria japonica*) forests. Kitahara, F. (*Forestry and Forest Products Research Institue, Japan; bunsho@ffpri.affrc.go.jp*).

Recently, it has become important to reconsider low-cost silviculture for effective replanting in Japan. In this study, the relationship between replanted tree growth (tree height and diameter) and frequency of bush clearing in replanted Sugi (*Cryptomeria japonica*) forests was evaluated. The results showed that the amount of weeds affected tree height growth and bush clearing affected tree diameter growth. The reporting and comparison of further experiments of bush clearing and growth surveys is encouraged.

Short-term effects of whole tree and stem-only harvesting on C and N fluxes in two *Picea abies* stands, Norway. Kjønaas, O., Clarke, N., Eldhuset, T., Hanssen, K., Hietala, A., Lange, H., Nordbakken, J., Økland, T., Røsberg, I. (*Norwegian Forest and Landscape Institute, Norway; janne.kjonaas@skogoglandskap.no; nicholas.clarke@skogoglandskap.no; elt@skogoglandskap.no; kjersti.hanssen@skogoglandskap.no; ari.hietala@skogoglandskap.no; holger.lange@skogoglandskap.no; jfn@skogoglandskap.no; tonje.okland@skogoglandskap.no; ingvald.rosberg@skogoglandskap.no*).

As the Norwegian government plans to increase use of bioenergy from harvest residues in order to reduce the need for fossil fuels, we need to know the short- and long-term consequences for the forest ecosystem. In 2008 and 2010, we established field experiments at Gaupen (SE Norway) and Vindberg (SW Norway) to compare the effects of whole-tree (WTH) and stem-only

(SOH) harvesting on tree and ground vegetation litter input and microclimatic factors and their effects on decomposition of new litter and soil organic matter, fungal community structure, and nutrient losses. We weighed selected trees and logging residues, surveyed understory biomass production, quantified soil C and nutrient pools down to 30 cm, and deployed litterbags. Soil water, soil respiration, temperature, and moisture were measured monthly. Fungal sequencing was performed, and organic and mineral horizons were incubated at different temperatures to estimate potential C and N mineralization. Long-term changes in the soil C pool depend on the balance between the decomposition rates of soil organic matter, input of litter from ground vegetation, and the contribution of slash to the buildup of humus. We will present a synthesis of C and N fluxes and discuss differences between the SOH and WTH harvesting.

Phenology observation of *Macaranga tanarius* in four regions in peninsular Malaysia. Koter, R. (*Forest Research Institute Malaysia, Malaysia; rosdi@frim.gov.my*).

Monitoring phenology is important when managing the collection of matured seed. Not many studies focus on phenology of pioneer species such as *Macaranga tanarius*. It is importance to investigate the phenology pattern of the species to better manage seed collection and planting material. The phenology of *M. tanarius* was observed during April 2012 until September 2013 at four regions, namely Central, East Coast, Northern, and Southern. At each region, four trees of *M. tanarius* were selected, and new shoot, flower bud, blooming flower, falling flower, fruiting set, young fruit, mature fruit, and falling fruit were recorded. Two flowering seasons were observed with the first period peaking from February to April and the second peaking from June to September. Most trees flowered at the beginning and fruited at the end of the first peak, but some flowered during the end of the first peak and fruited during the second peak. The most abundant flowers collected determine the specificity of the phase experience by the mother plant. The plants took 2 to 3 weeks to complete the fruiting phase. The seed collection can be made when fruits are fully ripened.

Responses in physiology and growth of minor central European tree species to drought events. Kunz, J., Löffler, G., Räder, A., Bauhus, J. (*University of Freiburg, Germany; joerg.kunz@waldbau.uni-freiburg.de; gemaloe@web.de; annemarie.raeder@web.de; juergen.bauhus@waldbau.uni-freiburg.de*).

To adapt European forests to climate change, it has been suggested to increase tree species diversity and the proportion of drought tolerant species. Regionally, forest area covered by economically important tree species might be further reduced by increasing incidences and severity of droughts. Currently, neglected broadleaved species such as *Sorbus torminalis*, *S. domestica*, *Acer campestre*, and *A. platanoides*, which are being regarded as drought-tolerant, may offer suitable silvicultural alternatives; however there is little reliable information about their responses to drought. Here, we examined the resistance to and recovery from drought of seedlings and mature trees using physiological and dendrochronological approaches. Water was withheld from seedlings of the above tree species and their common associates *Fagus sylvatica* and *Quercus petraea* in greenhouse and outdoors experiments. Measurements of physiological performance of unwatered individuals compared to well-watered individuals showed varying responses to withstand water shortage. *A. campestre* seemed to be best adapted to drought. Additionally, the response of mature trees to drought was examined through tree-ring analyses. While *Q. petraea* appeared to be the most drought-resistant species, *S. domestica* appeared to recover most quickly from drought. Our results indicated that minor broadleave species have the potential to enrich species diversity in forests on drought-prone sites.

Short-rotation forestry with hybrid aspen in hemiboreal Estonia: implications for forest management, science, and society based on 15-year experience. Lutter, R. (*Estonian University of Life Sciences, Estonia; reimo.lutter@emu.ee)*, Tullus, A. (*University of Tartu, Estonia; arvo.tullus@ut.ee*), Tullus, T. (*Estonian University of Life Sciences, Estonia; tea.tullus@emu.ee)*, Kanal, A. (*University of Tartu, Estonia; arno.kanal@ut.ee*), Tullus, H. (*Estonian University of Life Sciences, Estonia; hardi.tullus@emu.ee*).

Short-rotation forestry (SRF) is a new silvicultural concept in hemiboreal Estonia. One of the most promising tree species for SRF in northern Europe is hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.). In Estonia, the first hybrid aspen plantations for the production of pulpwood were established in 1999 on abandoned agricultural land. A network of 80 long-term experimental plots in hybrid aspen, and for comparison also in silver birch (*Betula pendula* Roth) plantations, was created to study ecology and management of SRF with these species. By now the studied hybrid aspen plantations have passed two-thirds of a 25-year rotation period. Growth and productivity of 15-year-old hybrid aspen plantations exceeds most local tree species at this age. Hydrophysical properties, rather than nutrient stocks from past fertilization of abandoned agricultural soils, have been decisive for the growth rate of the trees in young plantations. Economic calculations indicate that SRF with hybrid aspen is an economically profitable use for areas where agricultural land use has ceased. The main damages in young hybrid aspen plantations have been moose browsing and stemwood infestation by poplar longhorn beetles. To conclude, hybrid aspen has proved to be an economically and ecologically suitable tree species for afforestation of abandoned agricultural lands.

Trade-offs between utilizing fine woody debris and minimizing rotation time in hybrid poplar plantations. McCavour, M. (*Concordia University & Université de Québec à Montreal, Canada; mccavour@gmail.com*), Paré, D. (*Canadian Forest Service, Canada; David.Pare@RNCan-NRCan.gc.ca*), Messier, C. (*Université du Québec en Outaouais, Canada; ch.messier@gmail.com*), Thiffault, E. (*Canadian Forest Service, Canada; Evelyne.Thiffault@RNCan-NRCan.gc.ca*), Thiffault, N. (*Ministère des Ressources naturelles du Québec, Canada; nelson.thiffault@mrn.gouv.qc.ca).*

Forest harvest residue (FHR) may be utilized as an alternative energy source. A hidden cost however, is the lengthened rotation time if trees grow more slowly due to reduced nutrient input. Our objectives were to: (1) examine soil nutrition, tree wood volume, and foliar nutrient status of hybrid poplar (*Populus maximowiczii x P. balsamifera*) as a function of proximity to slash pile; and (2) estimate the block-scale poplar yield loss at year 7 if all FHR were removed. Using two 7-year-old poplar plantations on sandy loam in Quebec, we found that poplar relative growth rate was faster nearer to the piles, and semi-log correlations of tree volume and soil and foliar nutrients on distance from pile were significant and inverse, with little effect >10 m. The accrual of wood biomass by pile-propinquous trees more than compensated for loss in planting space. We estimate a block-wide reduction of 20% by age 7 if piles had been removed in year 1. Given that the rotation for hybrid poplar for this site is 20 years,

slash retention will lead to a dramatic shortening of the rotation interval. The tradeoffs for policy and management of retaining some or all FHR within the block are discussed.

Growth, biomass accumulation, and functionality of *Gmelina arborea* (L.) Roxb. in climate change scenarios for Colombia. Melo Cruz, O. (*University of Tolima, Colombia; omelo@ut.edu.co*), Martínez Bustamante, E., Rodríguez Santos, N. (*Universidad Nacional de Colombia, Colombia; enmartin@unal.edu.co; natha8902@hotmail.com*).

Gmelina is a tropical tree from Asia that is widely used in industrial-scale plantations in the tropical dry forests of Colombia. A total of 30 even-aged stands between 3 and 7 years old were evaluated on 10 sites located across a precipitation gradient that varied between 900 and 1 800 mm/yr. Circular plots of 500 m^2 were established and monitored for 3 years. DBH (cm), total height (m), and crown radius (m) were recorded. Biomass per functional component (leaves, branches, trunk, root) was determined. Finally, the net assimilation rate, transpiration, stomatal conductance, water use efficiency, and photosynthetically active radiation (PAR) were assessed. A direct correlation between the growth rate and the medium annual precipitation was found. Growth rates varied between 8 and 19 m^3/ha/yr. When water was provided in order to avoid a hydric deficit, growth exceeded 25 m^3/ha/yr. The functional compartment with the highest accumulation of dry matter was the trunk with 42.5%, followed by the branches with 23.8%, the roots with 21.1%, and the leaves with 12.6%. There was a positive correlation between the growth and the net assimilation of CO_2 which exceeded 30 µmol/m^2/seg in conditions without hydric stress (field capacity) and 14 µmol/m^2/seg on sites with the lowest precipitation.

Effects of organic matter removal and nitrogen and carbon leaching fluxes in Douglas-fir plantation. Menegale, M., Harrison, R. (*University of Washington, USA; marcism@uw.edu; robh@uw.edu*), Holub, S. (*Weyerhaueser Co., USA; Scott.Holub@weyerhaeuser.com*), Guerrini, I.A. (*São Paulo State University, Brazil; iguerrini@fca.unesp.br*).

The increasing interest in energy production from woody biomass may possibly affect the uptake of carbon and nitrogen in soil due to the removal of branches and foliage during timber harvesting. This study aimed to look at the influence of organic matter removal during timber harvest. Specifically, how does the presence/absence of harvest debris (such as chips, branches) influence the accumulation of nutrients in the soil and, consequently, the final productivity of a Douglas-fir plantation? The experiment was installed in the Mackenzie River watershed, Eugene, OR, in a tree farm owned by Weyerhaeuser Company. The total area has 20 plots, with 1 acre in each plot. Three types of harvest were conducted in the different plots: bole-only harvest, total-tree harvest, and total-tree harvest plus forest floor removal, as well as soil compaction in combination with these treatments. Lysimeters were installed in the treatment plots and samples are collected once a month at 20 cm and 100 cm depths in order to measure the concentration of nutrients leached along the soil profile. Samples will be analyzed for soil alkalinity, dissolved inorganic carbon (DIC), dissolved organic carbon (DOC), and dissolved organic nitrogen (DON), as well as macronutrients and micronutrients, and results will be presented.

Fate of applied ^{15}N fertilizer in a Douglas-fir plantation. Michelsen-Correa, S., Harrison, R. (*University of Washington, USA; smcorrea@uw.edu; robh@uw.edu*).

As the predominant forest plantation species in the Pacific Northwest, Douglas-fir (*Pseudotsuga menziesii*) and the productivity of its underlying soil are important to the sustainability of the region's timber economy and forest health. Nitrogen (N) is known to be a limiting nutrient in Douglas-fir ecosystems. Previous studies have found that N fertilization can increase tree growth when applied to low productivity sites. However, of the total N fertilizer applied, less than 30% is taken up by the surrounding trees. A better understanding of the fate of the remaining N is necessary to mitigate any potential environmental impacts and increase the financial return of fertilizer applications. The results of a study that seeks to detect enrichment of ^{15}N beyond the boundary of a 100 m^2 treatment plot is presented here. A target tree was selected and treated with 0.5% ^{15}N applied at a rate of 224 kg N/ha. Forest floor and mineral soil (15 cm depth) were sampled along transects radiating from the base of the target tree in each of the four cardinal directions to 2.5 m beyond the fertilizer boundary. Additionally, one foliage sample was taken from the closest tree (>3 cm DBH) along these transects. These samples can track the fate of N moving beyond the boundaries of the application area.

Dominance probabilities for oak seedlings in Pennsylvania: variation in seedling size and ecological sections affects seedling success. Miller, G., Gottschalk, K., Brose, P. (*U.S. Forest Service, USA; gwmiller@fs.fed.us; kgottschalk@fs.fed.us; pbrose@fs.fed.us*).

A study was designed to determine the survival and dominance probabilities of oak advanced regeneration for 5, 7, and 10 years after final removal cuts by ecological classification. A total of 31 stands and 6 235 tagged seedlings in four ecological sections were included. Advanced oak seedlings were classified based on their initial root collar diameter. The larger the initial size of the seedling, the taller the 5-, 7-, and 10-year old stem and the higher its dominance probability. Free-to-grow, a more conservative measure than total height, produced lower probabilities. It is still too early to define reliable dominance probabilities because stands have not reached crown closure. Interim results indicated that probabilities were declining from year 5 to year 7 to year 10. Free-to-grow values were also declining over time and may be a better measure of long-term success. The Blue Ridge Mountains section appears to successfully regenerate oak with smaller seedlings compared to other areas of the state, but this difference decreased from year 5 to year 7 to year 10 and may eventually disappear.

Which management under climate change? An assessment of the provisioning of ecosystem services in mountain forests. Mina, M., Bugmann, H., Cailleret, M. (*ETH Zurich, Switzerland; marco.mina@usys.ethz.ch; harald.bugmann@env.ethz.ch; maxime.cailleret@usys.ethz.ch*).

In mountain areas, forests are of crucial importance for the provision of multiple ecosystem services (ES). In a fast changing environment, this can only be maintained if forest managers take into consideration the sensitivity and adaptability of these ecosystems. Forest succession models are important tools to assess whether adverse climate change effects on ES can be counteracted by adaptive management. We evaluate whether business-as-usual management (BAU) can still provide multiple ES in European mountain forests under climate change or if adaptive management regimes need to be applied to match this objective. A climate-sensitive forest succession model (ForClim) was improved and applied in five case study areas across European

mountains using different management regimes and climate change scenarios based on new algorithms for capturing specific harvesting regimes. A set of up-to-date and novel indicator-based approaches were used for assessing the provisioning of ES. Simulation results revealed that in certain regions, climate change is likely to have negative effects on most ES, but these effects can be mitigated by adaptive management, while in other sites such changes in management strategies would not be sufficient to maintain the desired level of ES.

Growth and nutrient dynamics of plantation forest of *Eucalyptus* hybrid as raw material for pulp industry in Indonesia. Mindawati, N. (*FORDA, Indonesia; ninapulp@yahoo.co.id*), Indrawan, A., Mansur, I., Rusdiana, O. (*Bogor Agriculture University, Indonesia; andrecol1@yahoo.com; irdikam@gmail.com*; *O_rusdiana@yahoo.com*).

The objective of this research was to study growth and nutrient dynamics of *Eucalyptus urograndis*. This research used field data collected in the first and second rotation. Research results showed that at 5 years of age, stand growth in the first rotation reached a volume of 159.89 m^3/ha, whereas in the second rotation volume was 142.49 m^3/ha. Maximum volume in the first rotation was reached at age 5.4 years and in the second rotation at age 6 years. With a cutting rotation of 5 years, nutrient balance was predicted to be negative after the end of the first rotation. With a cutting rotation of 6 years, nutrient balances of N, K, and Ca were positive only at the end of rotation 1. At a cutting rotation of 7 years, nutrient balances of N, K, and Ca had been negative since the end of rotation 1. Quality of site with cutting rotation of 5 years decreased more rapidly as compared with 6 and 7 years. Fertilizer application and several silvicultural techniques are required for recovery of sites and nutrient balance. It could be suggested that the optimum rotation for *E. urograndis* in fertisol soil is 6 years.

Initial yield of biomass production in wood energy plantations in the Guanacaste Province, Costa Rica. Molina Quesada, S., Esquivel, E., Arias, D., Briceño-Elizondo, E. (*Instituto Tecnológico de Costa Rica, Costa Rica; samolina117@gmail.com; eesquivel@itcr.ac.cr; darias@itcr.ac.cr; ebriceno@itcr.ac.cr*).

With an increase in energy demand, a steady sustainable supply of energy is of increasing importance for emerging countries. At the same time, industrialized countries are proposing changes in traditional energy sources and shifting towards zero emission alternatives. Energy from forest biomass provides an important option in degraded areas with limited water supply. In a collaboration between a private enterprise (Taboga) and a public university (Technological Institute of Costa Rica), high density plantations were established at selected sites. Taboga generates power from sugar cane bagasse, however, this crop is seasonal, and the company needs a complementary supply during the off season. To determine the performance of high-density plantations, a three-block experimental design was established using six treatments, combining two species (*Gliricidia sepium* and *Gmelina arborea*) and three stocking densities (5 000, 10 000 and 20 000 trees/ha). Soil nutrients, biomass accumulation, and individual carbon storage in soil was periodically evaluated in 900 m^2 plots. After a year of growth, evidence of differentiated yields per treatment was achieved, preliminarily suggesting the more favorable species and density, knowledge of great importance for Taboga and other energy consuming companies.

Experimental forests: an anchor in a changing scientific world. Moser, W. (*U.S., Forest Service, USA; moserk@safnet.org*).

Individual trees in forested ecosystems generally outlive the professional careers of those who study them. If we are to continue to expand our understanding of the patterns and processes of these ecological assemblages, we need consecutive generations of researchers to study, discover, and pass on their knowledge to succeeding scientists. This process benefits from having a focal point that connects research around a location or theme that transcends time and events. The U.S. Department of Agriculture, Forest Service's experimental forests were formed so that research could be conducted with a focus on management possibilities over the long range, insulated from short-term management constraints. This paper will present examples of long-term research that provides insight into the questions facing resource professionals today and potential approaches, even though the original research questions posed had very different objectives and expected implications. Our examples will illustrate how long-term data from experimental forests, born in an era of more utilitarian intent, can help address today's questions about the expected impacts of potentially different climate and disturbance regimes.

Variations of vegetation biodiversity in a wild pistachio forest among different altitudinal levels: case study. Negahdarsaber, M. (*Research Institute of Forests and Rangelands, Iran; siamaksaber@hotmail.com*).

This research investigates the biodiversity of vegetation in a wild pistachio forest, south Zagros, Fars Province, Iran. This semi-arid cold region has xerofluvent soil with a calcareous origin and a community of trees including mainly *Pistacia atlantica, Amygdalus scoparia, A. ebornea, A. lycioides,* and *Acer monspessolanum*. The area of the study site was 9 374 ha. A list of bush, shrub, and tree species and their abundance was recorded during sampling trips in spring 2013. The area was divided into three altitudinal levels (level 1: <1 800 m, level 2: 1 800–2 000 m, and level 3: >2 000 m above sea level (a.s.l.)). Species diversity, evenness, and richness indices were calculated and analyzed using PAST 2.17. Results showed that species diversity, evenness, and richness indices of level <2 000 m a.s.l were higher than the other levels while levels >1800 m and 1 800–2 000 m a.s.l were not significantly different. It can be suggested that enrichment programs including seed and shoot planting might be more effective in areas with altitude <2 000 meter a.s.l in this region, compared to other elevations.

Height growth of Korean pine saplings planted under strip-cut larch plantations in northeast China. Owari, T., Tatsumi, S. (*University of Tokyo, Japan; owari@uf.a.u-tokyo.ac.jp; jeyms23@gmail.com*), Ning, L. (*Dabiangou Forest Farm of Qingyuan County, China; yinssssjp@yahoo.co.jp*), Yin, M. (*Shenyang Agriculture University, China; yinssss@163.com*).

To enhance ecosystem functioning while maintaining the economic benefits of larch plantations, a pressing need exists to develop alternative forest management regimes in northeast China. Two-storied forest management in which overstory larch trees are strip-cut and Korean pine (*Pinus koraiensis* Sieb. et Zucc.) saplings are under-planted has been deemed a viable option. However, limited knowledge exists on the growth patterns of Korean pine saplings planted under strip-cut larch plantations. This study examined the height growth of Korean pine saplings planted under the larch canopy openings created by different types of

strip-cutting treatments in northeast China. We used a generalized linear mixed model to quantify the sapling height growth of under-planted Korean pine. The derived growth model predicted a 39–45% reduction in annual height growth for the narrowest strip-cuts (4.5 m) versus the open site (i.e., a site with no canopy), while a 17–33% reduction in annual height growth was predicted for the wider strip-cuts (6.0–7.5 m) versus the open site. To maintain adequate height growth, it is recommended that forest managers create wider strip-cuts (i.e., ≥6.0 m) for the purpose of under-planting Korean pine saplings in larch plantations.

Variation throughout the year of N^2-fixation of *Acacia mangium* in pure stand or in association with *Eucalyptus grandis*. Paula, R.R., (*University of São Paulo, Brazil; ranieri@usp.br*), Bouillet, J. (*CIRAD, France; jean-pierre.bouillet@cirad.fr*), Gonçalves, J. (*University of São Paulo, Brazil; jlmgonca@usp.br*), Laclau, J. (*CIRAD, France; jean-paul.laclau@cirad.fr*. Trivelin, P.O. (*University of São Paulo, Brazil; pcotrive@cena.usp.br*).

N_2-fixation by leguminous trees can be an important source of nitrogen in forest plantations, but little is known about its seasonal variations. We estimated N_2-fixation by *Acacia mangium* growing in pure stands (100A) and in association with *Eucalyptus grandis* (50A:50E) in Brazil. At 27 months of age, we applied ammonium sulphate (99.8 atom % ^{15}N) diluted in water (1.1 kg N/ha) to the litter. Every 3 months during one year we selected four trees per species in each treatment and collected all the leaves from two branches distributed in each third of the canopy. The average percent of N derived from fixation (%Ndfa) was 70.3±5.2% and 48.1±10.8% in 50A:50E and in 100A, respectively. The higher %Ndfa in mixture could be due to lower soil N availability than in 100A and to strong competition of *Eucalyptus* over *Acacia* for soil N uptake. The highest and lowest values of %Ndfa were observed at the end and at the beginning of the rainy season, respectively. N_2-fixation showed lower seasonal variations in 50A:50E than in 100A. In this last treatment, %Ndfa was about 30% higher at the end of the rainy season than during other periods.

Analysis of seedling production in forest nurseries in the Alto Paraná District of Paraguay. Perdomo Rolón, M. (*Instituto Forestal Nacional, Paraguay; titaperdomo@hotmail.com*).

In order to obtain good results in a forest plantation, it is of utmost importance to use high-quality forest reproductive material. The present study was aimed at analyzing the seedling production in the forest nurseries of the Departamento Alto Paraná by means of personal interviews. It turned out that 91% of the nurseries included in the study produced seedlings exclusively from seeds and 9% performed clonal propagation. The majority of producers preferred seed collection. In certain zones of the district, only 8% acquired certified seeds from the National Forest Institute. The native species with the highest production was *Handroanthus impetiginosus* (Mart. ex DC.) Mattos which was present in 73% of the nurseries considered in the study. Among introduced species, production was highest for *Eucalyptus grandis* Hill ex Maiden which was present in 86% of the nurseries. The study found evidence of a high potential for seedling production and of the need to establish a control mechanism for the production of seedlings with better genetic qualities and safe provenance. In addition, the importance of complementing such a mechanism with a system to support producers was identified in order to improve production.

Tropical dry forests aboveground biomass measurements in West Africa, Abdoulaye Wildlife Reserve (Togo). Pereki, H. *(University of Lome, Togo and Hamburg University of Applied Sciences, Germany; pereki@daad-alumni.de*), Wala, K. (*University of Lomé, Togo; kpwala75@yahoo.fr*), Thiel-Clemen, T. (*Hamburg University of Applied Sciences, Germany; thomas.thiel-clemen@haw-hamburg.de*), Bessike Balinga, M., Zida, M. (*Center for International Forestry Research (CIFOR), Burkina Faso; mpbalinga@yahoo.fr; m.zida@cgiar.org*), Dourma, M., Akpagana, K. (*University of Lomé, Togo; dourmamarra@yahoo.fr; koffi2100@gmail.com*).

In West Africa, researchers typically focus on forest diversity assessment and structure without regards to biomass measurements and carbon cycling. To address this issue, we evaluated and quantify tree biomass in Abdoulaye Wildlife Reserve in Togo. Tree height, diameter at breast height, and crown diameter were collected in 157 Modified-Whittaker plots (20 m × 50 m). We performed a one-way ANOVA with Tukey's honest significant difference multiple comparisons computation. The highest density was recorded for *Anogeissus leiocarpa* individuals. Thus, we specified its dendrometric parameter as a control and applied Dunnett's general linear model method. Results showed significantly that dense dry forests recorded higher aboveground density (54.88%) than the other vegetation types. Aboveground biomass density per plant species varied between 1.156 ± 0.123 and 8.64 ± 0.001 Mg/ha. Stem biomass density (12.35 ± 1.33 Mg/ha) recorded the highest value ($P < 0.001$), whereas biomass densities of branches and leaves were 2.59 ± 0.26 Mg/ha and 0.41 ± 0.04 Mg/ha, respectively. Matrix scatterplots reported a positive significant quadratic relationship ($P < 0.001$). The highest R^2 of the regression ranged from 95.2 to 99.5% of the curvatures and confirms this close allometric correlation.

Effects of different harvesting intensities on the macronutrient pools in aged oak coppice forests. Pyttel, P., Bauhus, J., Köhn, M. (*University Freiburg, Germany; patrick.pyttel@waldbau.uni-freiburg.de; juergen.bauhus@waldbau.uni-freiburg.de; merlekoehn@gmx.de*).

Improved knowledge concerning nutrient removals through harvesting in former coppice forests is crucial for the sustainable management of these forests. This is especially true if the resumption of coppicing is being considered to serve increasing fuel wood demands. In this study, the nutrient contents of various tree compartments of sessile oak (*Quercus petraea* (Mattuschka) Liebl.) and hornbeam (*Carpinus betulus* L.) were determined to calculate the nutrients removed under different harvesting intensities. Independent of site and species, the highest nutrient concentrations were found in twigs and stem bark. Simple power functions to predict the nutrient content in the various tree parts showed high coefficients of determination ($R^2 = 0.51$ to 0.98). The comparison between the amount of nutrients stored in tree biomass and in soil indicated that sustainable nutrient management must consider different harvesting intensities according to site type. On sites with large soil nutrient pools, even whole trees can be harvested without causing deleterious effects. However, on sites with a low nutrient capital, current harvesting practices would result in high rates of nutrient export, and therefore exploitation of soil pools. In these stands, harvesting intensity should be based on careful selection of the tree compartments removed to conserve nutrients on site.

Can tree-fall gap characteristics be used to improve forest management? A case study in the virgin Hyrcanian forest in northern Iran. Rahbari Sisakht, S., Moayeri, M. (*Gorgan University of Agricultural Sciences & Natural Resources, Iran; rahbari.saeed@gmail.com; Moayeri@yahoo.com*).

Virgin forests in northern Iran provide a unique opportunity to study the disturbance regimes of forest ecosystems without human influence. The aim of this study was to determine relationships between size, shape, and the spatial pattern of tree-fall gaps and regeneration using ecological principles. This study was carried out in three compartments (15, 18, and 19) of a virgin forest in northern Iran. Tree-fall gaps, size, location, and regeneration were measured in all three compartments. One-way ANOVA was used to compare gap features and regeneration. Spearman's rank correlation coefficient was used to test the relationship between gap size and regeneration density. The results showed that total opened area in the three compartments was 13.72 ha (7.4%), and on average there were 1.06 gaps per hectare. The size of opened area averaged 658.2 m^2. Most gaps (69.2%) ranged between 200 to 1 000 m^2. Results of spatial pattern analysis showed uniform and irregular shapes for gaps in three compartments. ANOVA analysis showed that there was statistical significant difference between gap size and regeneration number. Also the Spearman's rank correlation showed direct relativity between gap size and regeneration, and when gap size increased, number of seedlings also increased. These results can be used with ecological forestry principles to improve forest management.

Wood carbon storage in a semidecidual seasonal secondary fragment in the Atlantic Forest domain in Brazil over 20 years. Reis, M.F., Reis, G., Souza, F., Caliman, J. (*Universidade Federal de Viçosa, Brazil; mgfreis@ufv.br; greis@ufv.br; felippe.souza@ufv.br; jpcaliman@gmail.com*), Oliveira, C. (Espirito Santo State University, Brazil; *carlos.oliveira@ifes.edu.br*). Amorim, J. (*Universidade Federal de Viçosa, Brazil; junio.amorim@ufv.br*).

The Atlantic Forest, one of the biodiversity hotspots, encompasses thousands of small and degraded fragments in varying successional stages that may be capable of sequestering and storing carbon. This study aimed to evaluate the carbon sequestration potential in two sites with different successional stages in a fragment of a semidecidual seasonal forest in the Atlantic Forest domain in Brazil over a 20 year period. Diameter and height were measured for all tree individuals with diameters over 10 cm, and volume was obtained with a nondestructive method. The available information for wood density for each species was used to estimate wood biomass. Carbon storage was obtained by multiplying the biomass by 0.5. The carbon storage in the site with the most advanced stage of succession was 70.85 t/ha in 1992, and there was an increase of 50.9% in 20 years. In the site at an initial stage of succession, the stored carbon increased 178.3% in the same period, starting from 17.68 t/ha. These results indicate the importance of the secondary forest fragments in the Atlantic Forest domain in reducing the impacts of greenhouse gas emissions.

Characterizing aspen regeneration by presence of ungulates, topography, and tree species composition. Rhodes, A., St. Clair, S., Wan, H. (*Brigham Young University, USA; aaron.rhodes0@gmail.com; samuel_stclair@byu.edu; hoyiwan@gmail.com*).

High ungulate densities in forest ecosystems change tree species composition and lead to drastic changes in plant and animal communities. In many aspen forests, wildlife management policies and extirpation of natural predators have allowed historically high ungulate densities. Aspen is considered a preferred browse species of elk and deer and is an important forage for cattle. While the degraded state of aspen in many regions of North America is recognized, the effects of herbivory by species type on aspen regeneration are understudied. Further, stand tree species composition and topographical features such as elevation, slope, and aspect may predict successful aspen forest regeneration. The objective of this study was to characterize the impact of herbivory across broad geographical ranges and track aspen regeneration as a function of ungulate density, stand type, and topographical features. Using GIS, we extracted topographical features at each site. We evaluated aspen basal shoot height and density using AIC model selection as a function of stand type, ungulate density, slope, elevation, and aspect. We found that high elevation was a strong predictor of aspen suckering density and height. We found that the presence of deer and cattle was correlated with the lower height of aspen suckering, which may prevent recruitment into the overstory.

Environmental limitations to natural regeneration in a restored seasonally dry tropical forest. Sangsupan, H., Hibbs, D., Withrow-Robinson, B. (*Oregon State University, USA; hathai.sangsupan@oregonstate.edu; david.hibbs@oregonstate.edu; brad.w-r@oregonstate.edu*).

Seasonally dry tropical forests (SDTF) have become the world's most threatened tropical terrestrial ecosystem in large part because of its widespread conversion to agricultural land. Today, millions of hectares of converted SDTF land have been degraded and abandoned. Active intervention is required for forest recovery in many of these areas. Although promising restoration techniques are being tested, the environmental factors limiting natural regeneration in restored SDTFs are not yet well understood. To address this gap, we will present the results of a 3-year longitudinal investigation of the relationship between potential limiting environmental factors (i.e., light, soil moisture, and soil nutrients) and naturally recruited seedlings in the understory of a restored SDTF in northern Thailand. We will also present results from an experiment investigating why, even after many years, seedlings of tree species common to adjacent intact forest remain absent from reforested areas. This study tested the hypothesis that the seeds of absent species experience unfavorable microenvironmental conditions that prevent germination and establishment in the restored forest. Results suggest that seedling establishment is not dependent upon the tested understory microenvironmental conditions. Instead, seed dispersal limitations or species-specific early survival strategies may determine species presence or absence in restored forest.

Carbon contents in *Acacia mearnsii* De Wild. plantations. Sanquetta, C., Corte, A.D., Ruza, M., Pscheidt, H., Behling, A. (*Federal University of Paraná, Brazil; carlos_sanquetta@hotmail.com; anapaulacorte@gmail.com; marielisabrina93@gmail.com; heloisaa_p@yahoo.com.br; alexandre.behling@yahoo.com.br*).

The objective of this paper was to study the carbon content in *Acacia mearnsii* De Wild. (black wattle) plantations throughout its farming cycle. Moreover, the implications of using values found in the literature or using a default value were assessed. The study was conducted in a stand of black wattle with ages ranging from 1 to 7 years. The t-test was used to compare measured values of carbon content with values found in the literature and also with the default value of 50%. Carbon content for leaves, bark, branches, and wood averaged 48.1, 45.8, 45.4, and 44.1%. The t-test values were significant, indicating that the observed values

differed from the ones found in literature and the default one. The use of the default value of 50% generated lower α values for bark and wood in all the studied ages, while for other compartments the α values varied. In conclusion, using default values for carbon stock estimations introduced errors that resulted in significant differences from observed values. Therefore, it is recommended that specific values should be used whenever possible.

Epicormic potential of common eastern North American oak species. Saunders, M., Meier, A. (*Purdue University, USA; msaunder@purdue.edu; ameier@purdue.edu*).

In many perennial woody plants, epicormic branches allow plants to respond quickly to changing environmental conditions and rebuild leaf area in response to significant injury. However, epicormic branches cause significant wood quality degradation in many fine hardwood species that are being grown for veneer and other high value products. In many tree improvement programs, there is a strong impetus to understand the influence of genetics and tree vigor on epicormic development. Using both a controlled crown pruning and thinning experiment and two descriptive studies, one with computed tomography (CT) scanning of destructively sampled logs and the other a field survey after harvesting, we described epicormic development in several oak species. Our results suggested that tree vigor had a stronger and more direct role on epicormic development than genetics in pole-sized white oak (*Quercus alba*) individuals, although we suspect that genetics impacts epicormic composition through its effects on sequential branching patterns early in a tree's life. In sawlog-sized trees, epicormic development was related to both species and tree size, but vigorous trees that were free from epicormic branches prior to silvicultural treatment generally do not form epicormics within the lower log. We conclude with discussion of future research needs on epicormic branching.

The effect of increasing biomass demands on forest management in Central Europe. Schumann, C., Pyttel, P. (*University of Applied Science Weihenstephan-Triesdorf, Germany; christina.schumann@hswt.de; patrick.pyttel@hswt.de*), Unseld, R., Weich, T. (*University of Applied Forest Sciences Rottenburg, Germany; ruediger.unseld@waldbau.uni-freiburg.de; thomas.weich@waldbau.uni-freiburg.de*).

Forests play a key role in current German energy policy. Besides rising energy prices, the increasing pressure on forest ecosystems as potential sources of bioenergy is fostered by improvements in harvesting and utilization techniques. To meet the targets for bioenergy production, various silvicultural approaches were developed and are now available for forest owners and practitioners. However, the impact of renewable energy policy on forest management practices and related consequences for nature conservation strategies are largely unknown. Our aim is to investigate how an increasing biomass demand is altering silvicultural decisions, management plans, and harvesting intensities in Central European forests. A questionnaire-based survey was carried out in four federal states of Germany comprising different stakeholders from the forest sector. Our findings indicated an intensification of the use of harvest residues and thinning intensities, especially in stands consisting of broad-leafed tree species. Additionally, traditional forms of forest management (e.g., coppice and coppice with standards) are regaining more importance.

Successional dynamics of community structure and species diversity after clear-cutting of *Abies faxoniana* forest stands. Shi, Z., Cheng, R. (*Chinese Academy of Forestry, China; shizm@caf.ac.cn; chengrm@caf.ac.cn*).

In order to clarify the recovery processes after clear-cutting sub-alpine *Abies faxoniana* forest stands, dynamics of community structure and species diversity at different successional stages (10, 20, 30, 40, and 50 years) were studied. The results showed that size classes of trees in the successional stages of 20–50 years showed reverse J-shaped distributions, with samples mainly distributed in the small-sized and medium-sized classes. Successional stages were classified into three types based on the importance value of dominant species: (1) *Rubus* and *Rosa* shrubs, (2) *Betula* broad-leaved forests, and (3) conifer and broadleaf mixed forests. Shannon-Wiener diversity indices of arbor and shrub layer species increased while the index of herb layer species decreased with succession time. Pielou's evenness indices of the species in all three layers increased with succession time. Simpson's dominance index of arbor layer species decreased with succession time, while the indices of shrub and herb layer species increased within 0–40 years of the succession and decreased at the successional stage of 50 years. Light-demanding pioneer tree species such as *B. albo-sinensis* that regenerated after logging would be replaced by more competitive climax species such as *A. faxoniana,* and thus relayed floristic change along the secondary succession.

Effects of artificial pruning on growth in young plantations of *Nothofagus* in south-central Chile. Soto, D. (*Oregon State University, USA; daniel.soto@oregonstate.edu*), Donoso, P. (*Universidad Austral de Chile, Chile; pdonoso@uach.cl*).

Nothofagus dombeyi and *N. alpina* are highly valuable tree species in Chile. Both species grow rapidly when planted in open fields but have shown problems with forking of the leading branches at early stages, thus artificial pruning may be necessary. To evaluate the effects of pruning on growth, we assessed the temporal effects of artificial green pruning on growth of young plantations with these species. A block design was installed for each species, and we evaluated the effects of pruning on the absolute growth rate (AGR) of diameter at breath height (DBH), height (h), and individual volume index (v). The treatments were: (1) stem pruning (at one third of total height) and top pruning (leaving one leader in forked trees) (BTP); (2) top-pruning (TP); and (3) control. The results showed that BTP had stronger detrimental effects on DBH AGR in *N. dombeyi* after 4 years. In contrast, the height AGR was not influenced by pruning treatments. *Nothofagus alpina* was not affected by pruning treatments. Despite DBH AGR in *N. dombeyi* being affected by BTP, artificial pruning is highly recommended in order to improve the quality of the stems and increase the clearwood production in these highly valuable species.

Selecting cold-hardy *Eucalyptus* species for the Southeastern United States using a regionwide network: 4-years results. Stape, J. (*North Carolina State University, USA; jlstape@ncsu.edu; kbhall2@ncsu.edu*), Fox, T. (*Virginia Tech, USA; trfox@vt.edu)*, Rubilar, R. (*University of Concepción, Chile; rrubilar@ncsfnc.cfr.ncsu.edu*), Albaugh, T. (*Virginia Tech, USA; tim_albaugh@vt.edu*), Alvares, C. (*Institute of Forestry and Education, Brazil; clayton@ipef.com*), Hall, K. (*North Carolina State University, USA; kbhall2@ncsu.edu*).

Eucalyptus species are widely used for wood production across the world, but not in the Southeastern United States, except for the southernmost part of Florida which has a warmer climate. In the last few years, *Eucalyptus* plantations outside of Florida

have been considered given the species potential to be managed as a short rotation woody crop system with coppice. However, this implementation depends on answering fundamental questions like: (1) Which Eucalyptus species can thrive in the Southeastern winters? (2) What are the silvicultural protocols that lead to adequate forest productivity for the different site conditions? and (3) Besides frost, are there other weather-related risks or pest and disease risks? These questions are being addressed by the Forest Productivity Cooperative using a network with 36 *Eucalyptus* trials planted across 18 sites in the Southeast in the spring of 2010, 2011, 2012, and 2013. Frost damage and growth evaluations occurred in April/May of each year together with pests and diseases assessment. The 4-years results of the network will be presented, including the genotype x environmental interactions, yield potential for the cold-hardy species, and the silvicultural and nutrition demands.

Assisted natural regeneration in degraded dry monsoon forests with the participation of rural people in Sri Lanka. Suduhakuruge, B. (*Forest Deparment, Sri Lanka; bandumala03@yahoo.com*).

Most of the natural dry monsoon forests in Sri Lanka have been degraded and converted into open forests through various processes such as shifting cultivation, illegal timber harvesting, forest fire, and development projects. Sri Lanka's Forest Department has taken many attempts to upgrade these degraded lands into productive forests through planting of local timber tree species. Highly eroded and unfertile soils together with the annual fire hazards have retarded the growth and survival of these planted seedlings, wasting government funds. This study investigated the possibility of accelerating the growth of already existing seedlings through the participation of people from areas adjacent to the forest. The study started in 2008 in a dry monsoon forest which initially had approximately 800 trees/ha. The area was highly covered with grasses and was subjected annually to manmade forest fires. People's participation involved establishing and maintaining the fire lines around the study area and encouraging growth of existing tree seedling by removing grasses. Results showed that when compared with conventional tree planting programs, this method was highly cost effective and successful, while generating an income to the adjacent people.

The technological properties of plantation grown mahogany in Ghana: Are they inferior to naturally grown ones? Tekpetey, S., Opuni Frimpong, E., Appiah-Kubi, E., Essien, C. (*Forestry Research Institute of Ghana, Ghana; nii9lartey@gmail.com; eopunifr@mtu.edu*); *appiahkemma@yahoo.com; caessien@ymail.com*).

The dwindling forest cover in many countries coupled with the increasing demand for timber and other wood products has necessitated the redirection of efforts by both government and nongovernmental agencies to increase forest cover and availability of raw materials for their timber industries. Plantation forestry, using both exotic and indigenous tree species, is being expanded in the tropics and other regions. It is estimated that about 4.6 million hectares of tropical plantation exist in tropical Africa. Khaya species are among the indigenous tree species of value that have been introduced into plantations in Ghana. In this study, five trees of plantation grown mahogany (PGM) and three trees of naturally grown mahogany (NGM) were extracted from Pra-Anum Forest Reserves, Ghana. The technological properties that were assessed were lumber quality, machining and mechanical properties, kiln drying characteristics, and sliced veneer quality from both PGM and NGM. Results revealed that values for modulus of rupture ranged between 60–70 N/mm^2 with good kiln drying characteristics and moderately good planing, sanding, and sliced veneer quality. It was concluded and recommended that the properties of plantation grown mahogany trees in Ghana were not inferior to that of naturally grown mahogany in Ghana.

Use of lignocellulosic biomass as biofuel: a key for a sustainable future. Tewari, V.P. (*Institute of Wood Science and Technology, India; vptewari@yahoo.com*).

Using crops to make liquid fuel is not a new idea. Biofuels are not only preferable to petrol, but there is also hope for biofuels' environmental and social redemption. The International Energy Agency has laid out a roadmap to ramp-up the use of biofuels from around 2% of global transport fuel today to 27% by the year 2050. Each year, more than 40 million tonnes of inedible plant material, including wheat stems, corn stover, and wood shavings from logging, are produced. Turning these discarded, woody bits of plants into second-generation biofuels has huge appeal. Two important methods involved in tapping this second generation biofuel from lignocellulosic wastes are biochemical and thermochemical methods. Among these, thermochemical methods coupled with the Fischer-Tropsch process reaction paves the way to liquid fuel which can readily be used by present spark engines. Fast-growing species can be grown on polluted soil, which also helps to reduce soil contamination. These trees convert carbon dioxide into biomass more rapidly than most other plants. To avoid energy crops vying with food crops for land use requires careful selection of species. Advanced biofuels hold promise of an escape from their predecessors' food-versus-fuel conundrum and are a key to reducing our fossil fuel dependence.

How can *Macrotermes* termites provide ecosystem services in a savanna woodland in Burkina Faso, West Africa. Traoré, S. (*Université Polytechnique de Bobo, Burkina Faso; sarantraore_2003@yahoo.fr*), Ouédraogo, J. (*Institut de l'Environnement et de Recherches Agricoles (INERA-CNRST), Burkina Faso; tinsibiri_ouedraogo@yahoo.fr*), Sita, G. (*Université de Ouagadougou, Burkina Faso; sguinko@univ-ouaga.bf*), Lepage, M. (*Institut de Recherche pour le Développement (IRD), Burkina Faso; michelglepage@orange.fr*).

Savannas in tropical zones experience recurring bush fires and herbivore disturbances that can alter soil carbon and nitrogen budgets, vegetation, and soil macrofauna. *Macrotermes* termites can also influence soil organic matter, flora, and plant growth. This study carried out in Tiogo forest was aimed at assessing the effects of *Macrotermes subhyalinus* on soil carbon and nitrogen budgets under controlled grazing and fire regimen in 16 subplots (50 m × 50 m) of which 8 were burned annually and 8 were protected from fire since 1992. The mean annual rainfall between 2002 and 2005 was 840±82 mm. Vegetation was dominated by grass species *Andropogon pseudapricus* and *A. gayanus* and woody families Mimosaceae and Combretaceae. A total of 48 composite soil samples were collected from 0–30 cm deep on and adjacent to mounds to quantify carbon and nitrogen content. Results indicated that *Macrotermes* termites store a large amount of carbon and nitrogen in mounds (1.88±0.37%; 0.15±0.03%) compared to adjacent areas (0.82±0.27%; 0.08±0.01%) while fire and/or grazing had no significant effects on soil carbon or nitrogen. Woody parameters were positively correlated to carbon and nitrogen amounts. As an ecosystem service, termite mounds provided carbon and nitrogen which are significant benefits for a savanna functioning to ensure woody species recovery, multiple taxa conservation, and valuable timber production at a small-scale in managed areas.

Growth characteristic of *Ulmus pumila* L. seedlings from different seed sources in Mongolia. Tsedensodnom, E. (*Institute of Geoecology, Mongolia; enkhii_smile@yahoo.com*), Nyam-Osor, B. (*National University of Mongolia, Mongolia; bnyamosor@yahoo.com*), Tsogtbaatar, J. (*Mongolia; tsogtbaatarj@magicnet.mn*).

Ulmus pumila L. is distributed across Mongolia, including in arid and semiarid regions, and has excellent drought tolerance that enables it to survive under soil water deficits for long and short periods of time. The aim of this study was to determine growth and physiological characteristics of *U. pumila* seedlings grown from different seed sources in Mongolia. Seeds were collected from seven mother trees from three geographical locations including Northern: Selenge province (Orkhun river, Ustai shaamar, Khuurai shaamar), Central: Bulgan province (Elsentasarkhai), Southern: Umnugobi province (Planted tree, Dalanzadgad, Bayankhoshuu). Seeds were sown in the greenhouse and seedling growth and physiological parameters (shoot length, root collar diameter, leaf area, leaf biomass, specific leaf area, relative chlorophyll content) were monitored. Significant differences in shoot length, root collar diameter, and relative chlorophyll content were observed among seed sources. Leaf biomass, leaf area, and specific leaf area did not differ significantly. A significant correlation between leaf area and relative chlorophyll content was apparent in all seed sources. Specific leaf area was reduced in seed sources from dry regions (Dalanzadgad, Shaamar) but increased in semi-arid regions (Elsentasarkhai, Ustai shaamar) which may explain adaptation mechanisms of mother trees in drought conditions.

Salt tolerance of *Ulmus pumila* L. seedlings from geographycally different seed sources. Tsedensodnom, E. (*Institute of Geoecology, Mongolia; enkhii_smile@yahoo.com*), Nyam-Osor, B. (*National University of Mongolia, Mongolia; bnyamosor@yahoo.com*).

Increasing salinity is one of the inhibiting factors of plant growth and production in arid and semiarid regions of Mongolia. The objectives of this study were to investigate effects of salinity on leaf area, leaf biomass, specific leaf area, and relative chlorophyll content of *Ulmus pumila* L. Seeds were collected from three regions in Mongolia: Northern (Selenge province), Central (Bulgan province), and Southern (Umnugobi provinces). The experiment was conducted in the greenhouse, and seedlings were grown in two different soil types: river sand and soil conditions. Three different salt treatments using solutions containing 2 200, 5 100 and 6 900 mg/L of dissolved salts (NaCl, $MgSO_4$, and $CaCl_2$) were applied. Research results revealed that all measured variables were reduced as salt concentrations increased. Two-year-old seedlings of different seed sources of *U. pumila* survived under treatments with salt concentration of 2 200–5 100 mg/l (4.36–10.4 dS/m) which confirms their high salt tolerance. However, combined effects of soil type and leaching capacity of soils had a combined effect on salt tolerance of seedlings, negatively affecting seedling growth and biomass accumulation.

Modelling effects of desertification control measures on the China Tibetan Plateau. Wang, X. Luo, Q., Hao, Y. (*Chinese Academy of Forestry, China; wxq@caf.ac.cn; luqi@caf.ac.cn; hyuguang@163.com*).

The Shazhuyu desertification control demonstration zone was established in the alpine sand lands on the Tibet Plateau in the 1960s. It contains a 1000 hm^2 core area now used for technology distribution and demonstrations of the desertification control projects of the surrounding region. The site promotes the formation of an oasis protection system which is composed of an artificial sand-barrier zone, enclosure and range-land restoration zone, afforestation zone and farmland shelterbelt zone from west to east along the main wind direction in the regional distribution. The objective of this study was to evaluate the ecological effects of desertification control measures in the demonstration zone. A methodological approach was designed to evaluate the ecological impact at the regional scale over a 50-year period, analyzing and identifying the technical characteristics of the demonstration zone. The analysis of this impact was carried out from both statistical and qualitative perspectives. Long-term monitoring and focused research show that with the increase in number of years of sand-fixing and vegetation restoration, vegetation conditions have markedly improved. According to the fixation years of 1964, 1977, 1986, and 2013, the total vegetation coverage reached 83%, 75%, 68%, 8%, respectively. Biomass of herbs was 68.82 g/m^2, 63.45 g/m^2, 38.11 g/m^2, 14.3 g/m^2. Physical and chemical properties of soil have improved.

Initial effects of crop tree release treatment on carbon stocks in a southern China Chinese fir plantation. Wang, Y., Wu, J., Yang, Y., Gu, C. (*Zhejiang A & F University, China; w_yixiang@126.com; 593037927@qq.com; yangyi52314@126.com; Gu_cuihua@126.com*).

The purpose of this study was to evaluate the effect of crop tree release (CTR) on carbon dynamics in even-aged Chinese fir plantations in southern China. A comparison of treated and untreated plots over two growth seasons showed that: (1) the carbon increment of a single crop tree and a general tree in treatments plots were higher than that in control plots (4.25±0.35 kg, 1.57±0.04 kg, 3.27±0.66 kg, and 1.09±0.07 kg, respectively); (2) carbon in soil, shrubs, and grasses was not impacted by CTR; (3) carbon in the tree layer decreased 9.90 t C/ha immediately after CTR and increased to 3.98 t C/ha while values were 3.46 t C/ha in the control; (4) carbon in litter and coarse woody debris (CWD) increased 0.92±0.67 t C/ha and 0.89±0.17 t C/ha in treatment plots, significantly higher than that of control plots; (5) reduced carbon in treatment plots was hypothesized to be kept in harvested wood products and added as tree layer carbon, and it showed that the carbon of tree layer in treatments plots was 11.16 t C/ha higher than that in control plots; and (6) carbon equivalent emissions associated with CTR such as transportation were small compared to the magnitude of the net C sequestration of the tree layer.

Volume or biomass? evaluating tradeoffs in aboveground live tree growth across a range of wood density in temperate forests of the eastern United States. Woodall, C. (*U.S. Forest Service, USA; cwoodall@fs.fed.us*).

The emerging paradigm of trait-based ecology (versus species-based) provides an opportunity to refine our understanding of forest productivity dynamics in light of recent global interest in managing forests for bioenergy feed stocks or carbon sequestration. The goal of this study was to examine trends in forest aboveground volume/biomass production as related to tree wood density using a region-wide repeated forest inventory across eastern U.S. forests. Using quantile regression, it was found that the 90th percentile of volume/biomass accretion was negatively related to the mean wood specific gravity of a stand's constituent tree species. When

managing forest stands for biomass/carbon accretion, it suggested that foresters consider the volume versus biomass tradeoffs when selecting tree species (i.e., using functional traits such as wood density in a decision support system) especially in lightly stocked stands on sites with a large number of growing degree days.

Effects of nitrogen deposition on growth and phosphate efficiency of *Schima superba* of different provenances grown in phosphorus-barren soil. Zhang, R., Zhou, Z. (*Chinese Academy of Forestry, China; ruirui0218@126.com; cafzzc@126.com*), Luo, W. (*Forestry Seed Administration of Zhejiang Provenance, China; zmzlwj@126.com*).

It was determined whether nitrogen (N) deposition on phosphorus (P)-limited soil could increase *Schima superba* growth or alter root formation or P efficiency. The effects of N deposition on *S. superba* were also used to investigate the N/P requirements of plants of different provenances. One-year-old *S. superba* seedlings from eight geographic areas were grown in P-limited soil and treated with 0, 50, 100, or 200 kg N/ha/yr, hereafter designated as control, N50, N100, or N200, respectively. Seedling growth, root development, phosphorus acquisition efficiency (PAE), and phosphorus utilization efficiency (PUE) were measured. *S. superba* responded positively to N supplementation. Seedling growth and dry biomass were highest when treated with N100 and lowest with N200. Root biomass and acquisition of soil P were greatest with N100. Significant differences were observed among plants of different geographical provenances. PAE and PUE each had a strong relationship with root growth in plants subjected to N100 treatment. A threshold for N and P requirements related to different genetic conditions and soil nutrients may exist for *S. superba*. Root growth and PAE can be divided into three categories based on soil nitrate levels. Nutrients were found to control root morphology and to enhance aboveground differences.

Nutrient evaluation and DRIS diagnosis of young teak (*Tectona grandis* L.f.) plantations in acid soil in south China. Zhou, Z., Liang, K., Huang, G., Ma, H. (*Chinese Academy of Forestry, China; zzzhou@ritf.ac.cn; lkn@ritf.ac.cn; huanggh@ritf.ac.cn; fjmhm@163.com*).

Teak (*Tectona grandis* Linn f.) is one of the most well-known timber species in the world and has been introduced to many countries and regions due to its great market demand and high economic, ecological, and social value. In recent decades, teak has rapidly been established in south China. However, about 60% of the soils in the planted areas are acidic to severely acidic. In order to sustainably meet present and future demands for teak timber, a better understanding of the nutrient dynamics and nutrient demands and norms of both trees and soils is vital for the plantations growing in acid soils in south China as well as for those established on the consequential acidified regions affected by global atmospheric pollution and acid deposition in other countries. Investigations in 19 representative teak plantations aged 5–8 years old under different site conditions were conducted. The results indicated that mean annual volume increment was positively correlated with N, Ca, Fe, Zn, and B concentration in leaves and with soil available P concentration and base saturation percentage. Diagnosis and Recommendation Integrated System (DRIS) indicated that the nutrient balance of Ca with Mg, Fe, and Al was the key to promote teak growth in acid soils in south China.

Strategies and practices to grow non-wood forest product species in degraded hilly area of southern China. Zhou, Z., Liang, K., Huang, G., Ma, H. (*Chinese Academy of Forestry, China; zzzhou@ritf.ac.cn; lkn@ritf.ac.cn; huanggh@ritf.ac.cn; fjmhm@163.com*).

Large areas of degraded secondary forests in southern China are classified into ecological forests and are characterized by low ecological function and economic value. Local communities that depend on these forests have become poverty-stricken because the livelihood-based products from the forests are becoming unavailable. Management strategies and practices to rehabilitate the degraded forests in a sustainable way are urgently needed. A pilot demonstration study in growing species of market-driven non-wood forest products is being conducted in Lianghua Forest Farm, Huidong County, Guangdong Province. The objective of the study is to find available rehabilitation means to achieve the tradeoffs between environmental protection, economic development, biodiversity, and sustainable livelihood by intercropping non-wood forest product (NWFP) species. More than ten species with high market value or potential from edible fruits, tea, and medicines extracted from leaves and branches have been planted. Initial surveys indicated that the survival rate of the NWFP species intercropped in the forest alley was over 85%.

GENERAL POSTER SESSIONS

IUFRO Division 2: Physiology and Genetics

Impact of Biochar Soil Amendment on Growth and Physiology of Tree Saplings. Abdollahi, K. (*Southern University, USA; kamrana664@cs.com*).

Biochar from gasification of wood waste in Louisiana was used as a soil amendment in a randomized complete block design study to quantify the impact of biochar soil treatment on the growth and physiology of live oak saplings. Height, diameter growth, net photosynthesis, respiration, and transpiration of live oak saplings were measured one growing season being treated with the biochar soil amendment. In addition, the impact of biochar on the chemical properties of the soil was quantified. The results indicated statistically significant impacts on growth and physiology of live oak saplings treated by biochar soil amendment. Some chemical soil properties were significantly impacted by the biochar amendment.

Heritability of height and diameter for six-year-old *Shorea leprosula*. Abdullah, M.Z. (*Forest Research Institute Malaysia (FRIM), Malaysia; zaky@frim.gov.my*).

Shorea leprosula, commonly known as light red meranti, is one of the better known and most economically valued timbers in Malaysia. Wood density ranges from 425–685 kg/m³. As a general utility timber, it is commonly used for joinery, utility furniture, shop and office fittings, showcases, counter tops, paneling, ceiling, shelving, cabin fittings, fence, boxes, fabricated coffins, light-duty flooring, and interior partitions. Trees are still produced from natural forest. Up to now, the planting materials still come from seeds collected mostly from unknown seed sources, and there is still no available seed orchard for *S. leprosula*. In order to provide genetically improved seeds of *S. leprosula*, a seed orchard progeny test of this species has been established in Ulu Sedili Forest Reserve (FR) and Kemasul Forest Reserve. Seeds (open pollinated) were collected from 40+ trees located in five forest reserves. Trees were selected based on stem persistence, stem straightness, branch size, circularity, free from pest and disease infections, and clear bole height. The trials were laid out using a randomized complete block design (RCBD) with eight replications. Within each plot for each replicate, 160 trees in two rows were planted at a 4 m × 4 m spacing. The performance of progeny tests at 6 years indicated that there were significant differences in height and diameter for all families observed, and some families, such as family No. 5 and No. 14, seemed to show good phenotypes on the test locations. Estimations of heritability for height were moderate on both sites ($h^2 = 0.12$ in Ulu Sedili FR and $h^2 = 0.18$ in Kemasul FR). Meanwhile, the results for heritability of diameter were low in Kemasul FR ($h^2 = 0.06$) and moderate at Ulu Sedili FR ($h^2 = 0.17$). This indicates that the genetic factor contributes more to determining these two characteristics than the environmental factor.

Mycorrhiza enhanced growth and heavy metal tolerance of *Acacia mangium*, *A. aulacocarpa,* and *Swietenia macrophylla* in minewaste soil. Aggangan, N. (*University of the Philippines Los Banos, Philippines; nelly_aggangan@yahoo.com*), Aggangan, R. (*Forest Products Research and Development Institute, Philippines; raggangan@yahoo.com*).

A screenhouse experiment was conducted to determine growth and heavy metal tolerance of three fast growing tree species, *Acacia mangium, A. aulacocarpa and Swietenia macrophylla,* in minewaste soil and to determine the ameliorating effect of mycorrhizal fungi. Aseptically germinated seedlings were either uninoculated or inoculated with arbuscular mycorrhizal fungi (*Gigaspora margarita, Glomus etunicatum*, Mykovam, a commercial mycorrhizal inoculant and mycorrhizal fungi from mine sites coded as Paracale isolates) during pricking and grown first in commercial potting medium. After 2 months, seedlings were transferred to mine waste soil. Mine waste soil was collected in Paracale, Camarines Norte and was characterized as very acidic (pH 3.5) and contained 1 262 mg Pb/kg, 12.87 mg Cd/kg, 3.51 mg Cu/kg and 1.44 mg Zn/kg. Four months after the transfer, all the mycorrhizal seedlings showed greater height and biomass and took up more Cu than the uninoculated counterpart. The best growth was obtained from those inoculated with the Paracale isolates (isolated from mine waste sites). Mykovam inoculated plants gave the highest P and Cu uptakes. In conclusion, the commercial mycorrhizal inoculant Mykovam and Paracale isolates enhanced the heavy metal tolerance of the three fast growing tree species and could be used for the rehabilitation and reforestation of heavy metal contaminated areas in the Philippines.

Slow release fertilizer and mycorrhizal inoculum potential effective for *Acacia mangium* under nursery conditions. Aggangan, N. (*University of the Philippines Los Banos, Philippines; nelly_aggangan@yahoo.com*), Aggangan, R. (*Forest Products Research and Development Institute, Philippines; raggangan@yahoo.com*).

A nursery experiment was conducted to determine the best combination of slow release fertilizer and mycorrhizal inoculum potential effective for *Acacia mangium*. Aseptically pre-germinated seedlings were inoculated with 23 to 230 spores/plant during pricking. Mycorrhizal inoculants included a mixture of eight species belonging to the genera: *Glomus*, *Gigaspora*, *Scutellospora*, *Acaulospora,* and *Entrophosphora*. Seedlings grown in polybags (250 g oven sterilized medium) were applied at five rates (0–2 g/plant) of NPK slow release fertilizer (14-14-14 Osmocote) 2 inches below the soil surface. Results show that fertilizer level and mycorrhizal inoculum potential and their combination have significant effects on growth of *A. mangium*. The tallest and largest diameter was obtained at 0.50 g/plant. Three mycorrhiza treatments promoted the greatest height and stem diameter while two treatments resulted in lower values than the control. The control plants showed increasing height and stem diameter even up to 2 g/plant while all the mycorrhiza treated counterparts had their highest height and stem diameter at 0.5 g/plant. Growth of non-mycorrhizal plants at 2.0 g NPK/plant was similar to that obtained by mycorrhizal plants at 0.25–0.5 g NPK/plant. In conclusion, mycorrhizal inoculum potential below 230 spores/plant in combination with 0.5 g NPK/plant was the best protocol for producing healthy *A. mangium* for use in nursery rehabilitation programs.

Effect of pre-treatment and sowing media on germination of *Tetrapleura tetraptera* (Schum. & Thonn) seeds. Akinyele, A., Onasanya, O. (*University of Ibadan Nigeria; akinyelejo@yahoo.co.uk; tee1980boy@yahoo.com*).

This study investigated the effects of pre-treatments and sowing media on germination of *Tetrapleura tetraptera* seeds. A total of 420 *T. tetraptera* seeds were pre-treated by soaking in boiled water (T1), sowing directly into topsoil (control (T2)), soaking in water for 24 hours at ambient temperature (T3), and soaking in different concentrations of hydrochloric acid (HCL) (10 mg/L (T4), 15 mg/L (T5), 20 mg/L (T6), and 25 mg/L (T7)). Riversand (S1), topsoil (S2), and sawdust (S3) were used as sowing media. Cumulative germination counts were recorded for 12 weeks. Least Significant Difference (LSD) was used to separate significant means. Epigeal germination was first observed in S1 after 3 days. Pre-treatment, sowing media, and interaction between pre-treatment and sowing media were significantly different ($p<0.05$). T2 using S1 medium had 85% germination. Rate of germination was faster in riversand than topsoil medium. Zero germination was recorded in seeds pretreated with HCL at 20 mg/L and 25 mg/L sown in sawdust. *Tetrapleura tetraptera seeds* were easily germinated without any pre-treatment using both river sand and top soil. However, further research could be carried out on the effects of different pre-treatments on this species to further enhance its productivity.

Effect of different watering regimes on germination and early seedling growth of *Irvingia gabonensis var. gabonensis*. Aya, F., Ogogo, A., Eyo, B. (*University of Calabar, Nigeria; ayafelix@yahoo.co.uk; auogogo@yahoo.com; jeyo56@yahoo.com*).

A 16-week experiment using four watering treatments was conducted to assess the effect of watering regimes on germination and early seedling growth of *Irvingia gabonensis var.gabonensis* in a greenhouse at the University of Calabar, Nigeria. Each watering regime was divided into two 0.9-litre applications given in the morning and evening. Treatment One (T_1) consisted of a daily watering regime of 1.8 litres (12.6 litres/week); Treatment Two (T_2) consisted of watering two days/week with 3.6 litres; Treatment Three (T_3) was one day/week with 1.8 litres; and Treatment Four (T_4) was zero watering, i.e., no watering at all, and served as the control. Computing total water amounts for the experiment revealed that each seedling per polypot/bag 16 weeks after sowing utilized: 201.6 litres (T_1); 57.6 litres (T_2); 28.8 litres (T_3); and zero (T_4). Germination percentage for each treatment was 46.9%, 62.5%, 78.1%, and 62.5% for T1, T2, T3, and T4 respectively, rating best performance as $T_3>T_2$, $T_4>T_1$. Other growth parameters including dry weights of leaves, stems, and roots were significantly different at $P<0.05$. In conclusion, *Irvingia* seedlings preferred the lower water amounts. Hence, we recommend seedlings be grown in well-drained soils, while avoiding marshy or water-logged areas.

Genetic diversity and relation of Zoysiagrasses (*Zoysia* spp.) native to South Korea. Bae, E., Lee, K., Park, Y., Kim, D., Hong, K., You, B. (*Korea Forest Research Institute, Republic of Korea; gosorock@korea.com; beldel660@forest.go.kr; ybpark@forest.go.kr; skimds@forest.go.kr; honeutal@forest.go.kr; boyoofri@forest.go.kr*).

In this study, zoysiagrasses (*Zoysia* spp.) naturally growing in South Korea were collected in order to identify their morphological and genetic characteristics. Amplified fragment length polymorphism (AFLP) markers were used to analyze the genetic diversity of native zoysiagrasses to use the results as basic data to enhance its genetic variation. As a result, K-means clustering analysis was performed using cluster part of the ratio for each group, and it resulted in five clusters. Then, Bayesian clustering analysis was conducted to obtain the probability of reassignment into the five clusters with morphological classification being a precondition, and the results showed representative species of four clusters. The average genetic similarity value was found to be 0.77, which meant that the species were closely related genetically. As such, the analysis of the morphological variation and genetic diversity of native zoysiagrasses resulted in the classification into four major groups. Three of the groups were *Zoysia japonica, Z. sinica and Z. matrella*. One of the groups was assumed to be a hybrid and/or mutant with intermediate characteristics. These results give a better understanding of the levels of genetic diversity present in native zoysiagrasses and can aid in the utilization of these materials in future breeding.

Spatial expression analysis of developing xylem specific cellulose synthase gene from *Eucalyptus tereticornis* and its molecular characterization. Balachandran, K., Dasgupta, M. (*Indian Council of Forestry Research and Education (ICFRE), India; biokarpagam@gmail.com; ghoshm@icfre.org*).

Genomics research in woody perennials mainly focuses on deciphering the genetic control of wood formation. During xylogenesis, cellulose is synthesized by multi-subunits of ellulose synthase (CesA) complexes either in primary or secondary cell wall. In the present study, the spatial expression of EtCesA1 transcript was studied in different tissues of *Eucalyptus tereticornis* including leaf, internodes, developing xylem tissue, and mature xylem tissues by qRT-PCR. A 55-fold relatively higher expression of the gene was observed in the developing xylem tissues indicating its secondary cell wall specificity. Subsequently, the complete coding domain sequence of 2 940 bp was isolated [Genbank: JX276651]. It showed 94% similarity with *Eucalyptus globulus* EglCesA1, and the translated product had a predicted size of 979 amino acids which harbored the functional domain of glycosyl transferase superfamily with eight trans-membrane (TM) helixes. Further, the expression of the EtCesA1 gene was characterized during hormone signaling by qRT-PCR and in situ hybridization. Gibberellic acid and 3-Indoleacetic acid was found to significantly up-regulate the expression of the gene while 2, 4-epibrassinolide had no significant effect on its expression. Molecular analysis of CesA genes from a woody species like *E. tereticornis* will assist in better understanding cellulose biosynthesis during xylogenesis.

Assessing variability and divergence of *Jatropha curcas* Linn. germplasm under ex-situ conditions. Baragur, D. (*Indian Council of Forestry Research and Education, India; bndsira@gmail.com*).

An evaluation of 100 genotypes of *Jatropha curcas* L. was carried out to assess variability and character association and to identify diverse genotypes with superior growth traits. Variability studies revealed that 39 accessions performed better in terms of above average values for volume index (479.41 cm^3), indicating better vigor of the plants. Genotypes IC 55380, IC 555381, IC 555379, and IC 569133 were found to be superior on the basis of plant height (100.34 cm), collar diameter (3.59 cm), number of branches (3.34) and volume index (1054.91 cm^3), respectively. Estimates of broad sense heritability ranged from 5.28 to 29.78%. Genetic advance in percent of the mean ranged between 4.24 and 32.82, with number of branches giving the lowest value and volume index giving the highest value. All the growth traits showed positive significant correlations at both genetic and phenotypic levels with volume index. Path analysis of growth traits revealed that the height (0.719) is the most pronounced trait

contributing directly to volume index followed by collar diameter (0.206) and number of branches (0.110). Diversity analysis using Mahalanobis-D2 resulted in seven clusters. Genotypes in cluster 2,3,4,5, and 6 have a combination of desirable traits and can be directly selected for further improvement.

Multipurpose trees as tools for ecosystem services deployment: a case study in Uruguay. Bennadji, Z. (*Instituto Nacional de Investigaciones Agrícolas (INIA), Uruguay; zbennadji@tb.inia.org.uy*).

This work aims to present the main results of two projects on multipurpose trees as tools for ecosystem services deployment in Uruguay. The projects were executed from 2007 to 2013. The first project included an Internet survey and two national workshops, allowing the identification of a nucleus of forest owners and producers interested in the identification and priority setting of multipurpose trees. The participatory involvement of this target nucleus allowed the identification and priority setting of a native multipurpose tree (*Prosopis affinis* Spreng) and an exotic one (*Carya illinoinensis* (Wangenh.) K. Koch). The second project was oriented to the evaluation of the potential of these two species for traditional wood uses: (i) timber, energy, nonwood forest products, and (ii) the exploration of ecosystem services. The main ecosystem services identified were soil restoration and use and conservation of forest genetic resources. A collect of germplasm from all over the country was realized for the establishment of a network of 10 provenances and progenies trials in five national forestry zones. Adaptation and productivity results data at 3 years of age show preliminary trends on seed sourcing and transfer for the two species. Effects on soil properties are under study.

Sex ratio and status number in progenies test of dioecious tree species. Cambuim, J. (*São Paulo State University (UNESP), Brazil; josecambuim@yahoo.com.br*), Aguiar, A. (*EMBRAPA, Brazil; ananda.aguiar@embrapa.br*), Zaruma, D., Moraes, M. (*São Paulo State University (UNESP), Brazil; darlin@fca.unesp.br); ma_apmoraes@yahoo.com.br*), Freitas, M. (*Forestry Institute of São Paulo, Brazil; miguellmfreitas@yahoo.com.br*), Moraes, M., Sebbenn, A.

The dioecious trees *Astronium fraxinifolium* and *Myracrodruon urundeuva* occur naturally in some forest fragments of savannahs in Brazil, but are threatened due to agricultural development in the region. To conserve and maintain genetic diversity of the remaining populations of these species, we need information about genetic parameters, mating system, reproductive phenology, and sex ratio. Maintaining a sex ratio of 1:1 can maximize the effective population size. Progeny of two species (*M. urundeuva* and *A. fraxinifolium)* were evaluated for the sex ratio and estimates of the status number [N_s= 4.Nm.Nf/(Nm+Nf)] in Selvíria, Brazil. The design was a randomized complete block with 28 progenies, 4 repeats, and 10 trees per plot in a 1.5 m × 3.0 m spacing. At 19 years of age, male and female trees were evaluated. The sex ratio of the two species was 4:1 (81.3% males and 18.7% females) which deviated from the expected 1:1 ratio. *M. urundeuva* presented 158 females and 685 males and *A. fraxinifolium* presented 158 females and 685 males. The estimated status numbers were 514 and 481 for *M. urundeuva* and *A. fraxinifolium*, respectively. This value is approximately 60% of the census size of each species. Comparing the results from these studies suggests that the progeny test of these species exhibits sufficient genetic variability for long term *ex situ* conservation strategies.

Effect of silvicultural intensity and spacing on crown architecture of four loblolly pine clones. Carbaugh, E., Fox, T., Yanez, M. (*Virginia Tech, USA; ecarbaug@vt.edu; trfox@vt.edu; myanez@vt.edu*).

Four loblolly pine clonal genotypes have been established in three contrasting study sites in order to determine whether they retain consistent crown architecture with their respective counterparts at each study site, as well as to assess the effect of silvicultural intensity and spacing deployment on growth and crown architecture. Two of the study sites were established in the United States, one at the Reynolds' Homestead Research Center, VA, the second at Bladen Lakes State Forest, NC, and the third in Parana, Brazil. The study consisted of a split-split-plot design with two silvicultural treatments, four clones, and three spacing deployments. Three trees from each clonal plot were selected in the intermediate spacing of 1 235 trees/ha. On each selected tree, every branch was measured and evaluated for branch height above ground, length, basal diameter, and position relative to stem. The crown architecture for each clone was quantified. Results indicate that crown architecture of individual clones remained consistent among study sites and silvicultural intensity.

Effect on chlorophyll fluorescence in seedlings of four families of *Pinus leiophylla* under drought and recovery. Castelán Muñoz, N., Campos García, H., Jiménez Casas, M., Vargas Hernández, J. (*Agricultural Sciences Graduate College, Montecillo, Mexico; nayaritzin@yahoo.com.mx; hcamposg@colpos.mx; marcosjc@colpos.mx; vargashj@colpos.mx*), López Delgado, H. (*National Institute for Agriculture, Forestry and Livestock Research, Mexico; lopez.humberto@inifap.gob.mx*).

The evaluation of the relationship between moisture regimes and plant physiology in phenological stages of development is essential for the proposal of successful reforestation alternatives in regions that suffer from water shortage or where water shortage may increase due to climate change. The variation between seedlings of four families of *Pinus leiophylla* of the seed orchard at the Postgraduate College of Montecillo, Mexico, was determined. These seedlings were submitted to a cycle of drought and subsequent irrigation for recovery. The fluorescence was evaluated four times by JIP analysis parameters using PEA, and the hydric potential (Ψw) was determined with a Scholander chamber. The test seedlings maintained Ψw close to –0.4 Mpa, while the average Ψw of the seedlings exposed to drought amounted to –2.34 MPa and –3.38 MPa on days 17 and 26 of the cycle and –0.61 MPa on day 17 after recovery. Seedling of the mother from Tlalmananco, Edo Méx., showed a higher abatement of photochemical activity and very little recovery. The seedlings from the family stemming from Santa María Atepetzingo, Puebla, showed early susceptibility to the stress but a better recovery capacity. Seedlings from San Juan Tetla, Puebla, were the least affected, and those from San Rafael, Edo. Méx., had an intermediate response.

Selection of poplar clones to combat desertification in Inner Mongolia, China. Cho, W., Kang, H. (*Dongguk University, Republic of Korea; valkyre@naver.com; hdk0225@dongguk.edu*).

The objective of this study was to select poplar clones with enhanced survival rate and potential for advanced growth for combating desertification in Inner Mongolia autonomous region. After establishment of research sites in Inner Mongolia, China,

long-term monitoring results of seven domestic hybrid poplar clones from China and seven exotic hybrid poplar clones introduced from the United States and Europe are presented. Comprehensive analysis results of long-term monitoring measurement show that Hanan, Beikang, 110, DN-34 clones have a high early survival rate, height and DBH. These characteristics when continuously expressed for a long period are considered to be appropriate for poplar clones to combat the desertification in Inner Mongolia, China. Therefore, for poplar afforestation to combat desertification in Inner Mongolia, China, Hanan, Beikang, and 110 domestic hybrid poplar clones from China and the DN-34 clone which is a D×N exotic hybrid poplar clone introduced from the United States and Europe are considered to be appropriate.

454 sequencing to assess the differential expression of genes due to ozone stress in *Viburnum lantana* L. Cristofori, A., La Porta, N., Sablok, G. (*Edmund Mach Foundation, Italy; nicola.laporta@fmach.it; sablokg@gmail.com*), Pellegrini, E. (*University of Pisa, Italy; elisa.pellegrini@for.unipi.it*), Baldi, P. (*Edmund Mach Foundation, Italy; paolo.baldi@fmach.it*), Nali, C., Cristofolini, F., Gottardini, E.

Individuals of the shrub species *Viburnum lantana* L. (wayfaring tree) treated with ozone (60 ppb for 45 days for 5 hours per day) or maintained in filtered air (control) were analyzed through suppression subtractive hybridization (SSH) in order to assess the main differences of induced (I) and repressed (R) libraries, representing the response of plants at a biological, cellular, and molecular level. Biomolecular procedures consisted of: RNA extraction, PCR select (SSH), and 454 cDNA library sequencing. A total of 38 800 and 12 495 high quality reads were assembled (Newbler and CAP3 softwares) after filtering for the induced and repressed libraries, resulting in a total of 543 and 705 UniGenes, respectively. Functional annotation and gene ontology assignment were used to define the different relevance of gene ontology (GO) categories in the libraries. Results showed an enrichment of GO categories involved in the defense to oxidative stress for the induced library, with an increase in glutathione (GSH), thioredoxin-1 (Trx1), and heat shock proteins (HSP). On the contrary, the GO categories involved in carbon utilization and photosynthesis (light harvesting complexes) were repressed in ozone exposed plants of *V. Lantana*.

Evaluating the water use efficiency of selected plantation species in the Philippines. Combalicer, M. (*University of the Philippines Los Baños, Philippines; msc1330@gmail.com*), Lee, D. (*Seoul National University, Korea, Republic of; leedk@snu.ac.kr*).

Water use efficiency (WUE) is commonly used as a selection criterion to improve yield in a dry environment where water is a limiting factor. The study aimed to evaluate the WUE of different plantation and reforestation species in the Philippines. The WUE of *Acacia auriculiformis*, *Acacia mangium* and *Pterocarpus indicus* was determined from 2-year-old, 10-year-old, and 20-year-old age classes. Parameters obtained were stomata size and number, net photosynthesis (P_N), transpiration rate (E), and stomatal conductance (g_s), each of which were observed in the lower, middle, and upper portions of the forest canopy. Results showed that significant differences in P_N, g_s, and WUE were observed and were higher in 20-year-old *A. mangium* and *A. auriculiformis*. Consequently, *Acacia auriculiformis* and *A. mangium* showed better ecophysiological attributes which are important features of species for rehabilitating degraded areas of the country. These species could serve as nurse species for other native species that would eventually lead to successful forest succession in the future.

Genetic characterization of marginal pedunculate oak populations adapted to xeric conditions: implications for conservation and sustainable management. Curtu, A., Sofletea, N. (*University of Transilvania, Romania; lucian.curtu@unitbv.ro; nic.sofletea@unitbv.ro*), Finkeldey, R. (*Georg-August-University Göttingen, Germany; Reiner.Finkeldey@zvw.uni-goettingen.de*).

Over the last two decades, the average temperature has increased by 0.9 °C in southeastern Romania and will continue to rise under most climate change scenarios. The steppe bioclimatic region which is confined to this territory is supposed to enlarge, and the pedunculate oak (*Quercus robur*) populations situated at its margins will be exposed to drier environmental conditions. Here we address the question of genetic differentiation between marginal populations of pedunculate oak (known as *Q. pedunculiflora* and situated in the vicinity of the steppe), and core populations of pedunculate oak. Even though the two groups of populations can be distinguished in terms of pubescence on the abaxial leaf surface, little is known about the genetic differences between them. We sampled three pairs of populations along southeastern Romania and tested both genomic and EST-SSR markers. We found strong support for two genetic clusters that correspond to marginal and core populations, respectively. Based on our set of microsatellite markers, we are now able to characterize *Q. pedunculiflora* populations to determine the degree of admixture and to test the purity of seed lots. Our results suggested that genetics can have a significant impact on conservation of oak resources and their sustainable management.

Promoting heartwood formation of young trees of *Santalum album* by plant growth regulators. Daping, X. (*Chinese Academy of Forestry, China; gzfsrd@163.com*).

Sandalwood (*Santalum album*), one of the most valuable tree species cultivated in large areas in southern China in recently years, is renowned for its aromatic heartwood which contains fragrant essential oil. Generally, sandalwood takes from 10~13 years or longer to form fragrant heartwood. Therefore, accelerating heartwood formation in young sandalwood is one of the most urgent issues in sandalwood plantations. In this paper, we evaluated the influences of five plant growth regulators (PGRs), including abscisic acid, benzyladenine, ethrel, jasmonic acid, and methyl viologen, on growth, heartwood formation, as well as essential oil composition of 6-year-old sandalwood through a stem injection method. The results indicated that all the above PGRs treatments can induce young sandalwood to form aromatic heartwood, but no significant differences were found in height and DBH growth, but obvious different were observed in oil content and quality. Stem injection of 0.6% benzyladenine got the highest oil content in the induced heartwood among all the treatments (9.34% in average), while treatment with 0.15% methyl viologen got the least oil content (2.54% in average). Oil quality induced by benzyladenine was higher than the ISO standard for *S. album* oil regardless of the injection concentration and dosage. That may imply that benzyladenine plays an important role in the induction of heartwood formation in sandalwood.

Management of Cedar (*Cedrela odorata* L.) by means of in vitro propagation techniques. Delgado Mendez, M., Beltrán, Y. (*Instituto de Investigaciones Agroforestales (INAF), Cuba; ccforestal.leicet@ciget.camaguey.cu; beltran@yahoo.es*), Daquinta, M., Aragón, C. (*Universidad de Ciego de Ávila, Cuba; daquinta@bioplantas.cu; eduardo@bioplantas.cu*), García, R. (*Universidad Católica del Maule, Chile; rgarciag@ucm.cl*).

Cedar (Cedrela odorata L.) is one of the most important timber species for the Cuban forest sector. However, there are problems related to intensive exploitation of their natural forests. *In vitro* culture techniques applied in mature trees that can express characteristics of interest are effective at reducing the period of time necessary to obtain improved base plantations. The replication of mature trees is difficult, but it can be achieved with the use of factors to rejuvenate the vegetative material. In this work, four solutions of growth regulators were tested for shoot development in cedar cuttings. The shoot development indicators in cuttings and growth (dry mass and fresh mass) as well as biochemical indicators (content of chlorophylls pigments, enzymatic activity of the enzymes guayacol-peroxidasa and fenoles content) in the shoots were evaluated. These indicators were of great utility for the selection of *solution I* (H_2O + 6-BAP 5 mg/L) as the most suitable for rejuvenating the vegetative material and the shoots induced with this solution they were introduced to the *in vitro* culture. The results constitute fundamental premises for the later establishment of a methodology of efficient micropropagation starting with mature trees in this specie.

Isolation, characterization, and expression profiling of two homeodomain-leucine zipper transcription factor genes in *Eucalyptus tereticornis*. Dharanishanthi, V., Dasgupta, M. (*Institute of Forest Genetics and Tree Breeding, India; vdharanishanthi@gmail.com; modhumitaghosh@hotmail.com*).

Recent genome-centric approaches provide new insight into transcriptional regulation of secondary growth in vascular plants. Homeodomain- leucine zipper (HD-Zip) is one of the plant-specific transcription factors known to play a key role in organ development, meristem maintenance, plant hormone signaling, and photomorphogenesis. In the present study, we reported the isolation of two HD-Zip transcription factor genes (*EtHB1* and *EtHB2*) from *Eucalyptus tereticornis.* The full length gene of *EtHB1* was 1 223 bp in length, encompassing three exons and two introns with coding domain sequence (CDS) size of 759 bp. The translated product harbored the homeodomain and leucine zipper conserved domains. The *EtHB2* was 6 181 bp in length with 18 exons and 17 introns. The complete CDS was 2 535 bp in length and harbored the signature domains of HD-Zip transcription factor including homeodomain, leucine zipper, START, and MEKHLA. Expression profiling of both genes in leaf, internode, and developing xylem tissues was conducted using qRT-PCR. The analysis revealed a four-fold increase in expression of *EtHB2* in developing xylem while the expression of *EtHB1* was not significantly different across tissues. The expression of *EtHB2* in the developing xylem suggests its role during xylogenesis in woody perennials like eucalypts.

Effect of drought on physiological and growth processes of selected beech and spruce provenances in Central Europe. Ditmarová, Ľ., Jamnická, G., Pšidová, E., Majerová, J. (*Slovak Academy of Sciences, Slovakia; ditmarova@sav.savzv.sk; jamnicka@sav.savzv.sk; psidova@sav.savzv.sk majerova@sav.savzv.sk*), Kurjak, D. (*Technical University in Zvolen, Slovakia; kurjak@tuzvo.sk*), Ježík, M., Blaženec, M.

Growth and distribution of beech (*Fagus sylvatica* L.) and spruce (*Picea abies* Karst. L) in Central Europe are considerably influenced by water availability. The current climate change is associated with more frequent drought periods, resulting in a reduction in the tolerance of trees to other adverse environmental conditions. The objective of the study was to evaluate primary responses of selected beech and spruce provenances to water deficit with the intention of identifying material with good growth and adaptation abilities under drought conditions. We focused on changes associated with drought response, primarily in basic parameters of photosynthesis, metabolism, parameters connected with effectiveness of water use efficiency, and in growth processes. The results indicated that the provenances that originated from the optimum beech and spruce territory were manifested in general as the most viable under perfect conditions. However, under water stress, these provenance manifested major changes at both the biochemical and photochemical levels. In contrast, the highest resistance against drought stress was recorded in the provenances originating from low situated localities with a dry climate. Findings on the properties of ecotypes with lower sensitivity to drought should be used in the selection of species tolerant to drought and in forest management and reforestation-related activities.

Lateral root and shoot formation in *Rhizophora styloza* Griff. (Rhizophoraceae) geared towards effective mangrove conservation and management in the Philippines. Endonela, L., Pampolina, N., Dionisio-Sese, M. (*University of the Philippines Los Banos, Philippines; e_endonela@yahoo.com; nelsonmanguiatpampolina@yahoo.com; mldsese@yahoo.com*).

Root and shoot development in mature *Rhizophora stylosa* hypocotyls were assessed under screenhouse conditions to understand broadly its reproductive biology. The experiment was set up such that 30% of hypocotyls length was submerged in the following conditions: distilled water (control); Hoagland's solution (half- and full-strength)); and granulated complete fertilizer solution (3 g/L and 5 g/L). The experiment was maintained under full sunlight and in shaded conditions. Shoot and root parameters were measured at 5-day intervals after treatment. True leaf emergence was observed 30 days after lateral root elongation in all treatments. Although numerous root initials were observed on the submerged hypocotyl portion, lateral root formation was concentrated within 3 cm from the hypocotyl tip. Tertiary roots, however, were formed on older roots. Lateral root formation, elongation, and shoot development were more pronounced on hypocotyls subjected to half-strength Hoagland solution and 3 g/L granulated complete fertilizer solution kept under shaded conditions. The above observations are morphological evidence of effective community-based nursery production and conservation management of *Rhizophora* spp. For use in rehabilitating degraded mangrove forests in the Philippines.

Severity and control of foliar bacterial disease in *Eucalyptus* spp. seedlings according to the technological level in nurseries. Faria, J., Furtado, E., Silva, M., Passos, J. (*São Paulo State University (UNESP), Brazil; j.rdecarvalho@hotmail.com; elfurtado@fca.unesp.br; magaliribeiro@fca.unesp.br; jrpassos@ibb.unesp.br*).

In past years, a slow increase in bacterial diseases was observed, especially in diseases occurring on leaves. Disease severity varies among nurseries, and one of the hypotheses to explain this is that differences can be related to a nursery's technology

levels. The present study aimed to evaluate the severity of foliar bacterial disease in two clone seedlings from commercial nurseries of hybrids *Eucalyptus* spp. and to verify what the best disease control treatment was by relating it to the technology level present in each nursery. Treatments consisted of using the resistance activator acibenzolar-S-metil (Bion®) in three doses (0,064; 0,126 and 0,26 g/L1) and the fungicide/bactericide (Kasumin©) in the dose 2 m/L1. Evaluations consisted of measuring the level of foliar bacterial disease severity and utilization percentage of diseased seedlings. The highest technology nursery showed greater efficiency in controlling the disease and reducing its severity, and the most efficient treatment was the application of resistance inductors together with the bactericide. Regarding the medium technological level nursery, no treatment was able to control the foliar bacterial disease; therefore, there was greater seedlings mortality**.**

Micropropagation of ruil (*Nothofagus alessandrii*): biotechnology applied for conservation and management of a threatened species. García, R., Quiroz Bravo, K., Arencibia, A. (*Universidad Católica del Maule, Chile; rgarciag@ucm.cl; kquiroz@ucm.cl; aarencibia@ucm.cl*), Carrasco, B. (*Pontificia Universidad Católica de Chile, Chile; bcarrasco@puc.cl*), Palma, P. (*Universidad Católica del Maule, Chile; ppalmagarrido@gmail.com*), Candia, A., Cancino, P.

Nothofagus alessandrii is a native species from Chile, endemic of the Maule Region. Its distribution is restricted only to the coast of this region near the towns of Curepto, Constitucion, and Empedrado. It is considered a biological relict, as it is the oldest member of the *Nothofagus* genus in the Southern hemisphere. The current populations of this species are continuously decreasing because of the reduction of its natural habitat. The aim of this work was to develop an efficient protocol for embryo rescue and plant micropropagation by using mature seeds and field shoots. The best results were obtained when mature embryos were cultivated on MS medium supplemented with 2 mg/l GA3 during 30 days at 4 °C and a photoperiod of 16 hours light and 8 hours dark at 40 µmol/m2/s. Micropropagation was also achieved by cultivating nodal segments isolated from seasonal shoots of old trees. After disinfecting the explants, the shoots were cultivated into MS medium supplemented with 2 mg/L of 2-iP, inducing an average of four shoots per explants. Rooting was induced in vitro by cultivating the individualized plants on MS supplemented with IAA at 1 mg/L1. All the plants developed normally during the ex vitro culture.

Aspects and prospects of eucalyptus improvement in India. Ginwal, H. (*Forest Research Institute, Dehradun, India; ginwalhs@rediffmail.com*).

This paper describes the efforts and achievements of eucalyptus domestication and improvement in India over the past three decades. Average productivity from commercial eucalyptus plantations in India is around 20 to 25 m^3/ha/yr. However, in some cases farmers are able to achieve 50 to 58 m^3/ha/yr with improved planting material, making farm forestry an economically attractive land use option. About 58 species of *Eucalyptus* and their provenances have been tested in the past under provenance trials in various locations across the country. The initial results revealed that provenances of only two species, *E. camaldulensis* and *E. tereticornis,* performed well under rain fed conditions. The various trials indicated the superiority of north Queensland seedlots in northern and southern parts of the country. This suggests that *E. camaldulensis and E. tereticornis* breeding populations should primarily include selections from the best Queensland provenances. Seeds from the selected trees of the best performing provenances have been used to establish seed orchards and breeding populations. A series of inter-specific hybrids having the potential of producing three to four-fold more volume of wood than their parent species have been developed and deployed for commercial plantations. Some of these hybrids clones have reached new productivity standards for India conditions.

Genetic diversity and population structure of Himalayan Cedar (*Cedrus deodara*) in Western Himalayas determined with cpSSR markers. Ginwal, H. (*Forest Research Institute, India; ginwalhs@rediffmail.com*), Chauhan, P. (*Indian Council of Forestry Research and Education* (*ICFRE), India; priti14@rediffmail.com*).

Cedrus deodara, commonly referred to as deodar, is one of the most important temperate timber species of Western Himalayas and is considered one of the endangered conifer species in the region. Chloroplast microsatellites (cpSSR) were used to study genetic variation within and among populations and geographical structure in natural populations of *C. deodara* throughout its entire distribution range in Western Himalayas. Ten chloroplast microsatellite primer pairs showing consistent polymorphism were selected for studying the population genetic structure of 21 large populations of *C. deodara.* When alleles at each of the 10 loci were jointly analysed, 167 different haplotypes were identified among 1 050 individuals. The cpSSRs indicated that *C. deodara* appears to maintain a moderately high level of genetic diversity (mean *H*e = 0.79), as observed in most coniferous species. AMOVA analysis showed that most of the variation in *C. deodara* occurs within populations and confirmed the general tendency of gymnosperms to display lower values of population differentiation than angiosperms. STRUCTURE analysis showed that nearly 77% of the populations were categorized as having admixed ancestry. The results are interpreted in context of future conservation plans for *C. deodara* in Himalayas.

Seasonal and diurnal water relations in four native shrubs, Northeastern Mexico. Gonzalez Rodriguez, H., Cantu Silva, I., Ramírez Lozano, R, Gómez Meza, M. (*Universidad Autonoma De Nuevo Leon, Mexico; humberto.gonzalezrd@uanl.edu.mx; icantu59@gmail.com; roque.ramirezlz@uanl.edu.mx; marcovgmeza@hotmail.com*).

Water deficit is one of the most limiting factors in northeastern Mexico. The aim of this study was to determine the water relations of four native shrub species and its relationship with soil water content and evaporative demand components. Water potential (WP) data was collected from January to October 2011 at predawn (pd) and midday (md) for *Amyris texana* (Rutaceae), *Bumelia celastrina* (Sapotaceae), *Cordia boissieri* (Boraginaceae), and *Leucophyllum frutescens* (Scrophulariaceae). During the wettest period, WPpd ranged from –0.40 MPa (*B. celastrina*) to –0.92 MPa (*L. frutescens*). In contrast, during the driest period it ranged from –1.86 MPa (*L. frutescens*) to –4.0 MPa (*A. texana*). Midday WP during the wettest period ranged from –1.08 MPa (*C. boissieri*) to –1.56 MPa (*A. texana*), while during the driest period ranged from –2.0 MPa (*L. frutescens*) to –4.0 MPa (*A. texana*). On a seasonal basis, WPpd and WPmd were positively correlated with soil water content and negatively with air temperature. Diurnal WP was negatively correlated with air temperature and vapor pressure deficit, whereas relative humidity showed a positive relationship. Since *B. celastrina*, *C. boissieri,* and *L. frutescens* showed high WP during water stress, these species are considered tolerant to a water shortage induced by drought.

Variation in fiber dimensions and basic density of plantation grown African mahogany from three forest ecological zones of Ghana. Govina, J., Opuni-Frimpong, E., Ebanyenle, E. (*Forestry Research Institute of Ghana, Ghana; kudjogovina@gmail.com; eofrimpon@csir-forig.org.gh; ebanyenle@csir-forig.org.gh*), Darkwa, N. (*Kwame Nkrumah University of Science and Technology, Ghana; nicdarkwa@yahoo.com*), Oteng-Amoako, A. (*Forestry Research Institute of Ghana, Ghana; oamaoko2002@yahoo.com*).

Ten-year *Khaya grandifoliola* C. CD. wood from three tropical forest ecological zones of Ghana (DSD, MSD, and ME) was investigated to establish variation, if any, in fiber dimension and basic density. Three trees were randomly selected from each ecological zone, and wood specimens were collected from sapwood and heartwood regions at 2%, 50%, and 95% of stem height. The mean values of fiber length (FL) in mm were 1.10±0.10, 1.23±0.03, and 1.12±0.06; fiber diameter (FD) in µm were 21.75±0.71, 20.66±0.76, and 20.96±0.40; fiber lumen diameter (FLD) were 13.57±1.16, 12.00±0.64, and 12.15±0.22; double wall thicknesses (DWT) were 8.18±0.55, 8.64±0.28, and 8.81±0.23 while the mean values in g/cm³ were 0.71±0.01, 0.71±0.01, and 0.72±0.02 for dry semi-deciduous, moist semi-deciduous, and moist evergreen zones, respectively. FL and DWT increased as precipitation increased across DSD, MSD, and ME zones. FD and FLD decreased from DSD to MSD zone but increased from MSD to ME zone. ANOVA used for mean separation on fiber dimensions were significant ($p<0.05$). The study results were comparable with naturally grown African mahogany wood, implying that *Khaya grandifoliola* plantation wood may exhibit a quality similar to natural wood.

The influence of drought on the density of different softwood species and provenances grown in eastern Austria. Grabner, M., Karanitsch-Ackerl, S. (*University of Natural Resources and Life Sciences, Austria; michael.grabner@boku.ac.at; sandra.karanitsch@boku.ac.at*), Schueler, S. (*Federal Research Centre for Forests, Austria; silvio.schueler@bfw.gv.at*), Klumpp, R. (*University of Natural Resources and Life Sciences, Austria; raphael.klumpp@boku.ac.at*).

In lowland forests with high temperatures and limited precipitation, the occurrence of drought is a limiting factor for tree growth. Soil conditions and precipitation influence the availability of water for the trees. Due to global warming, temperature-induced droughts are becoming a serious problem. The eastern part of Austria is characterized by low precipitation and high temperatures in summer. Different broad leaf tree species as well as conifers are growing in this area. Softwood species are of high economic importance here, but are also most affected by drought periods. In this study, the analysis of the density profiles (x-ray densitometry) from provenance trials of Norway spruce, different dine species, European and hybrid larch and different fir species revealed interesting differences in the density level itself as well as in the reaction of the trees to drought. During the drought periods, the mean ring density increased due to higher latewood percentage. However, an increase in earlywood density during these periods was obvious, too. First analyses showed differences in the reaction during drought of trees from different provenances, suggesting the potential to select best fit provenances according to drought resistance.

Long night treatment for induction of cold hardiness using artificial lights: effects of photoperiod on seedling storability and energy consumption. Hernandez Velasco, M., Mattsson, A. (*Dalarna University, Sweden; mhv@du.se; amn@du.se*).

Human-assisted forest regeneration in Nordic climates is considerably limited by the harsh outdoor conditions. There is only a small open window of time during the summer when the weather is favorable for transplantation and establishment of pre-cultivated seedlings in open land. Greenhouses and modern growth chambers help to cope with this limitation by allowing year-round seedling cultivation. Nonetheless, production levels are constrained to the cold storage capacity during the nontransplanting season. This storage is in turn dependent on the ability of the conifer to adapt to freezing temperatures and withstand the overall stress associated with cold hardening. Long night treatments can induce dormancy with cessation of growth and terminal buds initiation, leading to a better cold resistance. When growing forest regeneration materials under artificial lights, the lengths of the long night treatment and the photoperiod will have a significant impact not only on the biological response of the seedlings but also on the energy consumption, and thus on the CO_2 emissions. The aim of this work was to explore different long night treatment regimes for induction of cold hardiness in *Picea abies* and *Pinus sylvestris* seedlings using artificial lights. This was done with the purpose of studying the relationship between the energy consumption and the biological responses.

Cryopreservation of teak (*Tectona grandis* L.f) seeds. Hine, A. (*Universidad Nacional, Costa Rica; ana.hine.gomez@una.cr*), Abdelnour, A., Vargas, P. (*Instituto Tecnológico de Costa Rica, Costa Rica; aabdelnour@itcr.ac.cr; mpvargas@yahoo.com*).

Teak (*Tectona grandis* L.f) is a tropical tree of commercial value due to the high demand of its high quality wood and rapid growth. Genetic improvement programs for this species have resulted in seeds of better quality, and at the same time, improvement in the quality of plantations. To preserve genetic diversity and guarantee the raw material for improvement programs and for future reproduction, seeds are kept under conventional seed banks conditions with temperature ranging between 4 to –20 °C. However, there are other means to conserve this valuable germplasm. Cryopreservation is the storage of plant material in liquid nitrogen (–196 °C), and its major advantage is the conservation of material for long periods of time, under high genetic stability conditions. Survival and regeneration of plants after seed freezing in liquid nitrogen were evaluated in this work after applying the dessiccation and rapid freezing technique of cryopreservation. The methodology was tested on both seeds isolated from endocarps (seeds) and seeds inside endocarps (seeds with endocarps). Germination rates after thawing and after 28 days in culture were 84% and 70%, respectively.

Provenance study of *Cassia fistula* L. for pod, seed and seedling traits. Honnurappa, S., Nayak, R., Palaiah, S., Krishna, A. (*University of Agricultural Sciences-Dharwad, India; shivanisir59@gmail.com); renuka484@gmail.com; psurendra63@gmail.com; krishna.comar@gmail.com*).

Cassia fistula L., a member of the family Caesalpiniaceae commonly called Amaltas, is an important tree with many medicinal properties. Recently this species has been gaining more popularity in India for its medicinal value and wide adaptability to diverse edaphic and climatic conditions. The pods and seeds are economically important, having medicinal properties and sennoside content of commercial importance. With this point in mind, the present study was carried out in the College of

Forestry, Sirsi during 2012–2013. *Cassia fistula* L. starts flowering in the month of April to July in India, although some trees flower late in October, followed by pod setting. The average pod weight was 59.28 g, length was 57.60 cm, and the width was about 17.24 mm. The average seed length of *Cassia fistula* L. was 6.80 mm, seed width was 5.96 mm, seed weight was 16.68 g. Out of 12 different pre-sowing seed treatments, the maximum germination percentage (81.47%) was recorded in cold water soaking for 24 h followed by a dipping in concentrated H_2SO_4 for 1 min. The quality indexes including mean daily germination, peak value, germination value, germination rate of seeding were also high. Significantly increased seedling growth attributes were observed in the hilly zone for seedling height (38.20 cm), collar diameter (3.74 mm), number of leaves (12.00), shoot length (40.70 cm), root length (19.00 cm), shoot fresh and dry weight (8.50 g).

Propagation of *Entada rheedii*: a threatened climber species in Bangladesh with extremely thick and hard seed coat. Hossain, M. (*Putra University, Malaysia; aktar_forestry@hotmail.com*), Dey, J., Shumi, W. (*Chittagong University, Bangladesh; Joyeta@yahoo.com; wahhida_shumi@hotmail.com*).

This study explored the propagation techniques of *Entada rheedii*, a threatened climber species of medicinal value with an extremely hard seed coat, through seed germination with various pre-sowing treatments and clonal propagation by stem cutting. Per-sowing treatments included soaking both cut (notching) and intact seeds in water for 0 h, 24 h, 48 h, or 72 h or intact seeds in 5% acetone solution for 5 min, 10 min, or 20 min and sowing in polybags. Rooting ability of stem cuttings was investigated by treating summer or autumn cuttings with 0%, 0.4%, or 0.8% IBA solution in a non-mist propagator. The fastest seed germination with highest percentages (73.3%) and better seedling growth in terms of height, collar diameter, leaf number, and total dry mass was observed in cut seeds soaked in water for 48 h (TC2) followed by cut seeds soaked in water for 72 h (TC3), and the slowest germination with lowest percentage (3.3%) and growth performance was in intact seeds without any treatment (TU0). The highest rooting percentage with maximum number of roots (36.6) was obtained from the summer cuttings treated with 0.4% IBA solution followed by autumn cuttings with 0.8% IBA, and the lowest (43.33% and 8.25 roots) was noticed in summer cuttings in the control treatment. Results can lead to better survival and growth of rooted cuttings in nursery conditions.

Effects of exogenous GA3 application on growth and fiber quality of selected varieties kenaf (*Hibiscus cannabinus* L.) plants. Hossain, M., Muniandi, S., Abdullah, M., Shukor, N.A.A. (*Putra University, Malaysia; aktar_forestry@hotmail.com; smallmammal@yahoo.com; puad@upm.edu.my*), Abdul Malek, N. (*Forest Research Institute Malaysia, Malaysia; norlia@frim.gov.my; anishukor@yahoo.com*).

Kenaf (*Hibiscus cannabinus*), a multipurpose crop is one of the potential alternatives for natural fibers of wood for biocomposite materials including pulp and paper, insulators, packing materials, security notes, and bullet proof vests. Usually, longer fiber length and higher cellulose contents are required for better quality biocomposite materials. However, the average length of kenaf fiber is 2.6 mm in bast and 1.28 in the whole plant which is below the critical length of 4 mm needed for fiber for biocomposite production. The present study investigated whether the fiber length and cellulose content (biomass) of kenaf plants of selected varieties can be increased with the exogenous application of GA_3. Various concentrations of GA_3 were sprayed on keanf plants from 5 to 18 weeks after germination, and their vegetative and reproductive growth along with the fiber morphology were assessed. Vegetative growth of plants of all varieties were significantly enhanced with the exogenous GA_3 application up to a certain concentration, but the reproductive growth of the plants was severely impaired and failed to flower even when the control plants were at fruiting stage. The fiber quality of the kenaf plants was also significantly influenced with the exogenous GA_3 application. The findings of the study will be discussed in context to their application in the biocomposite industries.

Effects of open-field experimental warming using the infrared lamp on seed germination characteristics of major coniferous species in Korea. Hwang, J., Cho, M., Yang, A. (*Korea Forest Research Institute, Republic of Korea; jhwang@forest.go.kr; ramrami0130@gmail.com*), Han, S., Son, Y. (*Korea University, Republic of Korea; cheiron@korea.ac.kr; yson@korea.ac.kr*).

The purpose of this study was to investigate the effects of experimental warming using infrared lamps on seed germination characteristics of four major coniferous species (*Pinus densiflora, Pinus koraiensis, Abies holophylla,* and *Abies koreana*) in Korea. The experimental design consisted of a control and experimentally warmed plots with three plots (1 m^2 each) for each coniferous species. The air temperature of experimentally warmed plots was increased by 3 °C compared to control plots. Seeds of four coniferous species were sowed in April 2012. Percent germination of all four coniferous species was higher in experimentally warmed plots than in control plots, but significant differences were only noted in *A. holophylla*. In addition, *P. densiflora* and *A. holophylla* showed shorter mean germination time and higher germination energy (%) in experimentally warmed plots. The germination rate (per day) was increased by experimental warming for all species except *A. koreana*. *P. koraiensis, A. holophylla,* and *A. koreana* showed lower survival rates in experimentally warmed plots, while *P. densiflora* showed no significant difference due to experimental warming. Higher temperatures due to experimental warming induced higher percent germination, germination rate, shorter germination period, and mortality. Changes in air temperature due to global warming might bring a variation in seed germination characteristics.

Effects of irrigation period on growth performances and photosynthesis of container seedlings of *Fraxinus mandshurica*. Hwang, J., Cho, M., Yang, A., Lee, S. (*Korea Forest Research Institute, Republic of Korea; jhwang@forest.go.kr; mscho@forest.go.kr; ramrami0130@gmail.com; sg12612@forest.go.kr*).

Controlling irrigation is very important for physiological characteristics, growth, and quality of container seedlings in the container nursery system. This study was conducted to investigate growth performance, photosynthesis, water use efficiency (WUE), and stomatal conductance (gs) of container seedlings of *Fraxinus mandshurica* under three different irrigation periods (1 time/1 day, 1 time/2 days, and 1 time/3 days) for the acquisition of optimal irrigation period. The growth of root collar diameter and height of *F. mandshurica* seedlings was greatest with 1 time/1 day irrigation. The total biomass and seedling quality index of seedlings were about 1.5 times higher with 1 time/1 day than with other irrigation treatments. F. *mandshurica* seedlings showed the highest photosynthetic rate (7.62 μmol $CO_2/m^2/s^1$) with 1 time/1 day. As irrigation period was elongated, gs of *F. mandshurica* seedlings decreased, while WUE increased significantly. Based on these results, container seedlings of *F. mandshurica* should be irrigated 1 time/1 day.

The effects of seed pre-treatment, media conditions for germination of *Ricinus communis* in in-vitro system. Jang, H., Lee, S., Kang, H. (*Dongguk University, Republic of Korea; jang870331@naver.com; nash7700@hanmail.net; hdk0225@dongguk.edu*).

Ricinus communis, which is commonly known as castor bean, is an important species whose oil is used for medicine and food in spite of ricin which is a toxic component. Recently it has been used commercially in the manufacture of cosmetics, plastics, and textile materials. Various kinds of research have been conducted, but recent interest is particularly focused on using castor bean as a hyperaccumulator in metal contaminated sites. However, there are few basic studies about the introduction of *ricinus* seed, leaf, and stem in *in-vitro* system for phytoremediation. The aim of this research was to investigate the best method of introducing *Ricinus* seeds in *in-vitro* system for promoting phytoremediation experiments. This study was conducted to determine the optimal conditions for seed germination and growth along with pre-treatment prior to germination. The effects of several media (MS, WPM, SH, B5, White) as well as carbon sources (sucrose, maltose, glucose) were determined.

Investigating the interception of photosynthetically active radiation (PAR) among selected deciduous trees at Prairie Pines Preserve, Lincoln, Nebraska, USA. Kalibo, H. (*University of Nebraska, USA; hwafula@yahoo.com*).

Knowledge of how plants use photosynthetically active radiation (PAR), the light in the 400- to 700-nm waveband, is fundamental for understanding vegetation growth and productivity. The amount of light transmitted through a vegetation canopy can be an indicator of how much radiation is retained by a plant for the photosynthetic process. This presentation reports on an on-going effort at Prairie Pines Preserve, Lincoln, Nebraska (USA), where PAR measurements are underway for 12 large deciduous tree species with differing leaf and canopy structures. The amount of PAR reported is calculated as a ratio of open light to the amount transmitted through each tree canopy. Initial findings show varying levels of light interception, with eastern cottonwood (*Populus deltoides*), honeylocust (*Gleditsia triacanthos*), and Siberian elm (*Ulmus pumila*) showing the highest percentage of transmission for both direct and diffuse light. Vegetation fraction across the growing season also differed from one tree type to the next, and was similarly lower among these species. All the species also display differences in how they modulate below-canopy microclimatic conditions. These findings provide potentially valuable information about how trees in their natural settings partition incoming solar radiation for the process of photosynthesis through the growing season.

Provenance variation of growth and stem-form characteristics of *Khaya senagalensis* and future improvement strategies in Sri Lanka. Kangane Mudiyanselage, B. (*Forest Conservation Department, Sri Lanka; research.badulla@yahoo.com*).

Natural provenances of *K. senagalensis* from 21 locations throughout Western Africa (Benin (2), Burkina Faso (2), Mali (10), Niger (2), and Senegal (5)) and 3 Sri Lankan seed sources were assessed for growth (tree volume) and stem-form traits (axis persistence and straightness) at 3.5 years. Axis persistence was assessed with a 6-point scale where the highest score (6) was assigned for complete persistence and the lowest score (1) for multiple stemmed trees. Trees which were branched below the first, second, third, and fourth quarters of the tree were assigned 2, 3, 4, and 5 points respectively. Straightness was assessed with a 5-point scale. There was significant variation (0.05>P) among provenances for growth and stem-form traits. No significant trend was observed between tree volume and provenance origin parameters (latitude, longitude, and altitude). The individual tree volume of the provenances ranged from 1.45 to 2.27 dm^3, axis persistence ranged from 3.5 to 4.5, and straightness ranged from 2.8 to 3.5 among provenances. Results clearly indicate that the selection of provenances and selections within provenances, along with establishment of clonal seed orchards, clonal bank will improve the log quality and the volume production of *K. senagalensis* plantations in Sri Lanka.

ABTS radical scavenging activity from fruit water extracts of selected Korean wild pear species. Kim, H., Kim, S., Song, J., Kim, M., Park, Y. (*Korea Forest Research Institute, Republic of Korea; hyeusoo@gmail.com; goldtree@korea.kr; sjh8312@forest.go.kr; spresources@forest.go.kr; ykpark@forest.go.kr*).

The genus *Pyrus*, with the common name pear, belongs to the family Rosaceae. This study was conducted to assess the ABTS radical scavenging activity of fruit extracts of five Korean wild pear species. The superior clones of four *P. pyrifolia* (Burm. fil.), four *P. ussuriensis* Max., five *P. ussuriensis* Max. var. *hakunensis* (Nakai) T. Lee, three *P. pyrifolia* (Burm. fil.) (Jeongseon), and one *P. ussuriensis Max.* var. *ovoidea Rehder* were selected according to their major characteristics. ABTS radical scavenging activity of fruit water extracts of these plants was performed using the ABTS radical cation decolorization. At the 1 000 µg/ml, *Pyrus pyrifolia* (Burm. fil.), *P. ussuriensis* Max., *P. ussuriensis* Max. var. *hakunensis* (Nakai) T. Lee, and *P. pyrifolia* (Burm. fil.) (Jeongseon) showed strong ABTS radical scavenging activity and similar BHA. Especially, *P. ussuriensis* Max. and *P. pyrifolia* (Burm. fil.) showed highest ABTS radical scavenging activity at the 500 µg/ml (92.5, 95.3, and 94.4%). On the other hand, *P. ussuriensis* Max. var. *ovoidea* Rehder showed weak antioxidant activity. In conclusion, *P. pyrifolia* (Burm. fil.) and *P. ussuriensis* Max. had the greatest potential for the development of new antioxidant functional food.

Nuclear population structure of the Austrian *Picea abies* population. Konrad, H., Geburek, T., Schueler, S. (*Federal Research Centre for Forests, Austria; heino.konrad@bfw.gv.at; thomas.geburek@bfw.gv.at; silvio.schueler@bfw.gv.at*).

Norway spruce (*Picea abies*) is the most important tree species in Austria. In this study its genetic variation and population structure was assessed to provide the basis for breeding and conservation efforts. Samples were collected during the Austrian Forest Inventory (AFI) in 2007. A representative sample of 2 773 individuals from the Austrian Norway spruce population was obtained. Six nuclear microsatellite loci were facilitated for genotyping all samples. The results of the nuclear markers show that Norway spruce harbors a high amount of neutral genetic diversity. Heterozygosity in the sample was very high and averaged almost 90%. The efficiency of pollen flow was deduced from spatial genetic structure, as significant association between genotype and geographic distance was found at a large scale. Individual based population assignment methods using spatial information revealed five as the most likely number of founding populations. Comparisons between autochthonous and managed forests show that patterns of genetic diversity–despite intense management and documentation of long-term transnational transfer of forest reproductive material–are very similar to the potential natural state. In some regions of Austria, however, strong deviance of allelic patterns gives evidence for (historic) use of allochthonous reproductive material.

Male sterilization of *Cryptomeria japonica* by the barnase/barstar system. Kurita, M., Konagaya, K., Tsubomura, M, Hirao, T. (*Forestry and Forest Products Research Institute, Japan; mkuri@affrc.go.jp; konagaya@affrc.go.jp; mtsubo@affrc.go.jp; hiratomo@affrc.go.jp*), Watanabe, A. (*Kyushu University, Japan; nabeatsu@agr.kyushu-u.ac.jp*), Taniguchi, T. (*Forestry and Forest Products Research Institute, Japan; toru.t@affrc.go.jp*).

Cryptomeria japonica D. Don (sugi) is one of the most important commercial coniferous tree species in Japan. Enabling the rapid induction of favorable traits through genetic modification would be a powerful tool to shorten the time the traditional breeding methods have required for improving trees. However, some apprehension exists regarding the possibility of gene flow from transgenic trees to their wild relatives in the field. To address this issue, we attempted to develop male-sterile transgenic *C. japonica* to reduce the likelihood of unwanted genetic transfer by pollen. First, we constructed male sterilization vectors consisting of a male strobilus-dominant promoter and the barnase (*RNase* from *Bacillus amyloliquefaciens*) gene. The male strobilus-specific genes were isolated from a male strobilus-specific suppression subtractive hybridization (SSH) library, and the promoter sequences were isolated by the TAIL-PCR method. Male strobilus-dominant promoter::barnase fusions ligated to a nopaline synthase (*NOS*) promoter-driven barstar (barnase inhibitor) gene were introduced into *C. japonica*. After gibberellic acid treatment, all transgenic *C. japonica* formed male strobili. However, none of the *C. japonica* transformants harboring CjMALE1:: barnase-NOS::*barstar* produced pollen. Furthermore, the growth rates of transformants were comparable to those of early growth-stage wild type trees in early growth stage.

The assessment of *Populus* spp. and *Ulmus pumila* for combating desertification in Mongolia. Kwak, M., Woo, S. (*University of Seoul, Korea, Republic of; 016na8349@hanmail.net; wsy@uos.ac.kr*), Kang, H. (*Dongguk University, Republic of Korea; hdk0225@dongguk.edu*), Lee, S. (*University of Seoul, Republic of Korea; earlymay1004@yahoo.com*), Lee, S. (*Korea National Arboretum, Republic of Korea; i820316@dongguk.edu*).

Seventy percent (128 million hectares) of the grassland ecosystem in the Mongolian territory has been affected by desertification. Reforestation has become an important practice as a way of combating desertification. The objective of the present experiment was to evaluate the vitality for both *Populus* spp. and *Ulmus pumila* planted as combating means in desertification in Lun Soum (steppe ecosystem) and Tujiin Nars (forest ecosystem) of Mongolia. The visualization of differences in surface temperature by the thermal imaging camera was used to assess the transpiration rate and stomatal activity. Seedlings were planted in a flat field with and without furrows in 2008, 2009, and 2010, respectively. Most of air temperatures were higher than leaf temperatures (excepting *Ulmus pumila* planted in a flat land without furrows in Lun Soum, Mongolia). The leaf temperature of *Populus* spp. in the field with furrows was lower than those without furrows. This present study provides direct evidence that *Populus* spp. shows a positive growth in planting with furrows rather than without furrows in arid land, and *Ulmus pumila* especially displays an enhanced vitality in planting with furrows.

Discovery of genic microsatellite markers from transcriptome sequences of *Eurycoma longifolia* root. Lee, C., Abdul Malek, N., Tnah, L., Lee, S., Ng, C., Ng, K., Hasnida, H. (*Forest Research Institute Malaysia, Malaysia; leechait@frim.gov.my; norlia@frim.gov.my; leehong@frim.gov.my; leesl@frim.gov.my; chinhong@frim.gov.my; kevin@frim.gov.my; hasnida@frim.gov.my*).

Eurycoma longifolia is a highly sought after medicinal plant in Malaysia. It belongs to the family Simaroubaceae and is locally known as Tongkat Ali. The plant extract, particularly from the root, has been used in traditional medicines for treatment of various illnesses as well as for an aphrodisiac. Due to its popularity, it has succumbed to tremendous harvesting pressure. In order to ensure sustainable utilization, a conservation and management program based on baseline genetic information should be in place. For that purpose, we embarked on developing genic microsatellite markers to complement the existing 18 genomic microsatellites previously developed through enrichment approach. Based on the transcriptome sequences from a 10-year-old *E. longifolia* root generated via Illumina sequencing, a total of 48 polymorphic genic microsatellite markers were successfully developed. These markers were subsequently screened using 28 samples from Semangkok Forest Reserve. The number of alleles ranged from two to seven, whilst the observed heterozygosity ranged from 0.036 to 0.893. Significant deviation from Hardy-Weinberg equilibrium was detected in one locus (*EloT*028) after conservative Bonferroni correction. Null alleles were detected in two loci (*EloT*028 and *EloT*070). These markers can be used in DNA profiling for clonal identification, genetic diversity assessment, molecular breeding, and germplasm characterization.

Effect of soluble sodium silicate on wild *Panax ginseng* growth in red soil in Korea. Lee, S. (*Dongguk University, Republic of Korea; ssora4rang@nate.com*).

Korean Wild ginseng (*Panax ginseng* C.A. Mayer: Araliaceae) is a medicinal forest plant of great pharmacological and commercial value cultivated in Korea and elsewhere. The addition of sodium silicate to soils increases water use efficiency in cultivated plants such as ginseng and improves their tolerance to cold weather and high altitude environments. Two experiments were carried out to examine the effects of soluble sodium silicate on ginseng germination and growth. In the first experiment, seeds sown in field plots were treated at two-week intervals with 500 ppm, 1 000 ppm, 2 000 ppm concentrations of soluble sodium silicate and 500 ppm, 1 000 ppm concentrations of EM (effective micro-organisms). In the second experiment, somatic embryos produced from cotyledon segments of ginseng were cultured on MS and White media with soluble sodium silicate. The results of the field experiment showed that plant dry and fresh weight, leaf length, and root diameter were greatest in the 1 000 ppm soluble sodium silicate treatment, which also favored high photosynthesis rates and leaf chlorophyll content. The number of roots and plant height were not significant different among treatments. In the second experiment, ginseng germination and growth was better in White media mixed with a 1 000 ppm concentration of soluble sodium silicate than in MS.

The eco-physiological responses of *Quercus variabilis* seedlings to increased atmospheric CO_2 and N supply. Lei, J., Xiao, W. (*Chinese Academy of Forestry, China; leijingpin@hotmail.com; xiaowef@caf.ac.cn*).

The effects of CO_2 enhancement, nitrogen (N) deposition, and their interaction on *Quercus variabilis* seedlings were studied in Wuhan City, using a FACE (Free Air CO_2 Enrichment) facility in 2013. The treatments were elevated (EC: 700 μmol/mol) and ambient CO_2 (AC: 400 μmol/mol), and 0 kg (CK) and 120 kg N/hm^2/year (AC). The results showed that the *Quercus variabilis*

seedlings' leaf size, photosynthetic pigments and leaf nitrogen content tended to decrease under elevated CO_2, as well as the dark respiration rate decreased by 63.3% and the soluble sugar concentration increased by 2.6% compared AC plants. Nitrogen deposition significantly increased the leaf size, photosynthetic pigments, and leaf nitrogen content, but leaf potassium content decreased, and nitrogen to potassium ratio increased by 26.7%. CO_2 and N interacted to affect leaf size and photosynthesis. Plants treated with CO_2 and N had higher maximum net photosynthetic rate 8.92 μmol $CO_2/m^2/s$ (1.4 times) and light saturation point 7.43 μmol/s (2.6 times), but lower dark respiration (–65.9%) and light compensation point (–50.0%) than CK plants. Elevated CO_2 and Nitrogen deposition had positive effects on *Q. variabilis* seedlings in some degree, and their interaction promoted most.

Preliminary study of root penetration on degradable bioplastic-based planting pots. Liew, K., Khor, L. (*Sabah University of Malaysia, Malaysia; liewkc@ums.edu.my; lkim89@hotmail.com*).

Nowadays, the industry is searching for alternatives to reduce the usage of petroleum-based nondegradable conventional seedlings plant pots commonly called the polybag. In this study, three different types of bioplastic planting pots incorporated with newspaper pulp fibers were produced. The pots included different amounts of bioplastic (B) to newspaper pulp fibers (N) in the following ratios: B75%:N25%, B50%:N50%, and B25%:N75%. B0%:N100% acted as the Control. The bioplastic materials used in making the pots were made from a heat-blended mixture of starch, glycerol, vinegar, and water. All cylinder square shape molded pots with 100 mm height and 2 mm thickness were planted with *Leucaena leucocephala* seedlings for 60 days at two ground levels (below ground and above ground). Root penetrations for bioplastic pots were evaluated at an interval of 15, 30, 45, and 60 days. Results showed that bioplastic pots with a lower percentage of bioplastic (Control, B25%:N75%, and B50%:N50%) had higher root penetrations. The pots of B50%:N50% had the highest root penetration where 10% of the tested bioplastic pots had six root penetrations.

Variation of stem growth and morphology traits of some pine hybrids in southern China and their correlations. Luan, Q., Jiang, J. (*Chinese Academy of Forestry, China; luanqifu@hotmail.com; exotic-pine@hotmail.com*).

Variations in the stem growth and morphological traits of several pine hybrids in southern China were studied. The hybrids included *P. elliottii* Engelman var. *elliottii* (PEE) × *P. caribaea* var. *hondurensis* (PCH), PEE × *P. caribaea* var. *caribaea* (PCC), PEE × *P. caribaea* var. *Bahamensis* (PCB), *P. taeda* L. (PTA) × PCH, PTA × PCC, and PTA × PCB. All hybrids were tested with a randomized complete block design with five replicates of a single tree row plot planted in the field in the hilly area of the mid-north subtropical zone of China. Tree stem height (H), diameter at 1.3 m height (DBH), stem straightness (SF), branch size (BZ), branch layer number (BLN), and branch angle (BA) of the pine crosses at the age of 5 years were measured. At the same time, needle length (NL) and fascicle sheath length (FSL) of the hybrids and their parents were measured. The results of variance analysis showed that the stem growth and morphology traits of six pine hybrids have abundant diversity among different pine taxon, families, and individuals. The coefficient of variance for stem volume and straightness was 30–50% and 2–30% for other growth and morphology traits. Some of the variances have the potential to be used in the selection of pine varieties with high yield with good stem form and tolerance to the bad weather.

Genome-wide effects of selective breeding on adaptation of reforestation seedlots for future climates. MacLachlan, I., Tuytel, J., Smets, P., Wang, T. (*University of British Columbia, Canada; ianrmaclachlan@gmail.com; jtuytel@telus.net; pia.smets@ubc.ca; tongli.wang@ubc.ca*), Hamann, A. (*University of Alberta, Canada; andreas.hamann@ualberta.ca*), Aitken, S. (*University of British Columbia, Canada; Sally.Aitken@ubc.ca*).

Climatic change is predicted to cause a lag in the productivity of western Canada's forests that will have negative economic, ecological, and social impacts. We are evaluating how selective breeding affects the adaptive genetic diversity and the phenotypic and genomic architecture of reforestation seedlots in lodgepole pine (*Pinus contorta* var. *latifolia*) and interior spruce (*Picea glauca, P. engelmannii*, and their natural hybrids). Seedlots have been sampled across British Columbia (BC) and Alberta to obtain representative natural (>250 seedlots per species) and selectively bred reforestation seedlots (~20 orchard lots per species). Seedling common gardens have been established for both species in Vancouver, BC and at a field site in the central interior of BC. Phenotypic data has been collected on climate-related traits including bud phenology, cold hardiness, and growth. All trees are being genotyped for ~ 50 000 candidate adaptive SNPs selected through exome capture, re-sequencing, and subsequent analyses of associations with climate and phenotypic traits, as well as outlier tests within the broader AdapTree Project. This research will allow evaluation of reforestation seedlot diversity standards in western Canada based on adaptive rather than neutral genetic variation, and will contribute to developing climate-based seed transfer recommendations.

Nocturnal isoprene emission from deciduous trees in Japan. Miyama, T. (*Department of Meteorological Environment, Japan; tmiyama@affrc.go.jp*), Kominami, Y. (*Forestry and forest products Research Institute, Japan; kominy@ffpri.affrc.go.jp*), Okumura, M. (*Kyoto University Graduate School of Agriculture, Japan; okumura.motonori.2m@kyoto-u.ac.jp*).

Establishing accurate inventories and estimating net carbon budgets, including biogenic volatile organic compounds (BVOC), necessitates detailed evaluation of BVOC emission. Emissions of isoprene, the most abundant BVOC, presumably contribute to atmospheric chemistry through the formation of photochemical oxidants and secondary organic aerosols. We used proton-transfer-reaction mass spectrometry (PTR-MS) and an automated closed chamber to measure isoprene emissions from deciduous trees in a warm-temperate forests. In continuous foliage chamber measurements, we observed daily variations of isoprene emissions and continuous nocturnal emissions from leaves. The nocturnal emissions from trees may not be negligible.

The effects of CO_2 transfer via sap flow and bark conductance on stem respiration. Naramoto, M., Fujiwara, S., Kageyama, H., Mizunaga, H. (*Shizuoka University, Japan; amnaram@ipc.shizuoka.ac.jp; t0016036@ipc.shizuoka.ac.jp; t0916011@ipc.shizuoka.ac.jp; ahmizun@ipc.shizuoka.ac.jp*).

Stem respiration, which represents the CO_2 efflux from tree stem surface, is one of the key components concerning the carbon cycle of forest ecosystems. However, stem CO_2 efflux is not only determined by the CO_2 generated from local respiring cells, but

also is affected by xylem sap CO_2 concentration, which is influenced by the transported dissolved CO_2 via sap flow as well as the diffusion resistance of CO_2 from xylem to ambient atmosphere. In order to evaluate the effect of transported CO_2 from lower parts of the stem via sap flow, we measured responses of stem respiration rate by blocking CO_2 releases from the lower stem in a sapling of *Quercus glauca*. Stem respiration rates increased with the blocking of CO_2 released at the lower stem. This result indicated the xylem sap CO_2 concentration in the upper stem increased by blocking CO_2 released at the lower stem. In addition, we compared the bark conductance of CO_2 between different species grown in warm-temperate and temperate forests in Japan, by measuring stem respiration rates during night time when sap flow is absent.

Predicting storage life and viability of *Melia volkensii* seeds after extraction. Ndung'u, S., Angaine, P. (*Kenya Forestry Research Institute, Kenya; stephenmn06@gmail.com; pangaine2002@yahoo.com*).

Melia volkensii is a popular indigenous agroforestry tree species in arid and semiarid lands (ASALS) of Kenya. It is fast growing, tolerant to dry conditions, and is compatible with most crops, though management through root and crown pruning are recommended to minimize competition. *Melia volkensii* fruit is bulky, and even after extraction, the number of stony endocarp in a kg is around 200 stones, and therefore storage and distribution of bulky seeds is expensive as they occupy a large space. S simulation formula was used to predict the storage life and loss of viability with storage of extracted seeds by using the data collected after testing seed viability by germinating *Melia volkensii* seeds stored at different temperatures. The results showed that there was a significant difference in viability between seeds stored for different periods and at various storage temperatures (ANOVA, $p<0.05$). The results also confirmed that the formula can be used to calculate the seed viability at different times during the storage life and to estimate the period that the seed can remain viable under different storage temperatures.

Eucalyptus in Orinoco, Colombia: challenges and opportunities. Nieto, V., Barrios, A., Lopez, A. (*Corporación Nacional de Investigación y Fomento Forestal (CONIF), Colombia; victornieto@conif.org.co; alonsobarrios@conif.org.co; anamilenalopez@conif.org.co*), Borralho, N. (*Private Consultant, Portugal; nunoborralho@sapo.pt*).

Colombia has large reforestation plans across the country, hoping to reach the goal of one million hectares in the coming years. One of the regions with the greatest development potential for plantation establishment is the Orinoco of Colombia, an area with an estimated potential of about 4 million hectares suitable for afforestation. Within the range of usable species, the eucalyptus stands out as a genus with wide possibilities of use. *Eucalyptus pellita, E. tereticornis, E. camaldulensis, E. urophylla, E. grandis,* and some hybrids are among the most likely species with a high potential of success in the area. A series of plots for genetic and silvicultural monitoring have been established on which the growth and adaptation of these species is being tracked. A conclusion on the possibilities of products, processing, and markets for eucalyptus in the region based on the results and data for the studied species has been reached, and a suitable plan of action for genetic improvement is being developed.

Seedling emergence and growth of African locust bean (*Parkia biglobosa* R. Br. ex (G. Don) under different light conditions. Olayode, O., Olatunji, A. (*Ekiti State University, Nigeria; funkefaboy@yahoo.com; bamiolat@yahoo.com*).

Light as a climatic factor is vital for plant growth and determines where different species are found. Seedling emergence and growth of *Parkia biglobosa* under different light conditions were investigated to determine its suitability in other ecosystems apart from savanna where it is popularly found. Composited seeds of *Parkia biglobosa* collected from their area of natural range in Ekiti State, Nigeria were sown under the following three light conditions: direct light (DL), medium light (ML), and low light (LL). Daily germination count was done till no further germination occurred for about a week. Uniformly growing seedlings under the light conditions were assessed fortnightly for some variables. Highest germination rate of 77% was recorded under LL while the lowest rate of 58% was obtained in ML. Analysis of variance showed significant differences in the assessed variables with mean values for seedling height showing significant difference at 10, 14, 18, and 20 weeks. Also, seedling collar diameter revealed significant difference at 10, 12, 14, 16, and 18 weeks while number of branchlets showed significant difference at 10, 12, 14, and 16 weeks. The results are discussed based on *P. biglobosa*'s suitability in other ecosystems and adoption for agri-silviculture.

Sustainable regeneration of African mahogany: the effects of potting mixtures on vegetative propagation of *Khaya ivorensis* and *Khaya grandifoliola*. Opoku, E., Nyarko-Duah, N., Opuni Frimpong, E. (*Forestry Research Institute of Ghana, Ghana; Opokuensah2414@yahoo.com; nayanyd@yahoo.com; eopunifr@mtu.edu*).

Application of vegetative propagation in producing resistant progenies as part of integrated pest management of ubiquitous pests like *Hypsipyla robusta* (Moore) could ensure the sustainable regeneration of mahogany in plantations. A suitable rooting medium that promotes rapid rooting and is easily available is key to the adoption of technologies developed for farmers. This study was conducted to assess the rooting capacity of African mahogany (*Khaya ivorensis* and *Khaya grandifoliola)* in the following rooting medias: river sand, loamy soil, and mixtures of river sand and loam (50:50 v/v). Twenty cuttings per treatment with three replicates were arranged in a completely randomized block design. Number of roots, root length, and survival rate of cuttings were collected after 10 weeks in a propagator and analyzed. The 50:50 v/v mixtures of river sand and loam recorded the highest root formation (5.92), root length (8.72 cm), and survival of cuttings (71%) for *Khaya grandifoliola. Khaya ivorensis* exhibited the highest root formation (4.16) in loamy soil, root lengths (8.58 cm) in river sand, and survival (61%) in loamy soil. Hence, a 50:50 v/v mixture of river sand and loam is best for *Khaya grandifoliola* for rapid rooting while loamy soil is suitable for numerous root formation and survival in *Khaya ivorensis.*

Impact of biochar on potting media for the rooting of *Khaya ivorensis* and *Khaya grandifoliola* leafy stem cuttings. Opuni Frimpong, E. (*Forestry Research Institute of Ghana, Ghana; eopunifr@mtu.edu*), Sarfo, Y., Abbeberese, I. (*Kwame Nkrumah University of Science and Technology, Ghana; yvonnesarfo1@yahoo.com; abebus@yahoo.com*), Tagoe, C. (*Soil Research Institute, Ghana; calystagoe@gmail.com*).

The establishment of African mahogany plantations in the tropics can offset the reduced stocks of these valuable hardwoods in their native forest. Large scale plantation establishment requires sustainable production of quality seedlings. To enhance effective

rooting, a study was conducted to look at the effects of biochar additions to rooting media on *Khaya grandifoliola* and *K. ivorensis* growth. The experiement was a completely randomized block design with mixtures of 20 v biochar added to three rooting mediums of river sand (80 v), loamy soil (80 v), and 40:40 v/v mixtures (river sand and loam), and their 100% controls. Data on callusing, root number, length, and survival rate of cuttings were collated and analyzed with ANOVA. In *Khaya grandifoliola*, the 20 v biochar with 40:40 v/v mixture (loam and river sand) influenced highest root lengths (12.84 cm) and survival (67%) of the cuttings while river sand recorded the highest number of roots (2.4). The 20 v biochar with 40:40 v/v (loam and river sand) recorded highest number of roots (1.5), root length (7.17 cm), and survival rate (58%) in *Khaya ivorensis*. The 20 v biochar with 40:40 v/v (loam and river sand) medium were influential in most of the parameters measured for the tropical hardwoods *Khaya ivorensis* and *Khaya grandifoliola,* and thus are suitable for their vegetative propagation.

Genetic variation at microsatellite markers in four North American *Quercus* species. Owusu, S. (*Michigan Technological University, USA; saowusu@mtu.edu*), Sullivan, A. (*Umea University, Sweden; arslliv@mtu.edu*), Hipp, A. (*The Morton Arboretum, USA; AHipp@mortonarb.org*), Gailing, O. (*Michigan Technological University, USA; ogailing@mtu.edu*).

Models of ecological speciation indicate that new species evolution occurs through effective reproductive isolation from strong, environmentally mediated divergent selection. Oaks have become model taxa for the study of ecological speciation due to their high tendency to hybridize while maintaining distinct species identity. Twenty-eight microsatellites were characterized in natural populations of four known hybridizing *Quercus* species: *Quercus ellipsoidalis*, *Q. coccinea*, *Q. rubra,* and *Q. velutina*. These oak species are similar morphologically, suggesting the possibility of gene flow between these species. The present study was aimed at assigning individual samples to putative species and assessing past gene flow and taxonomic relationships among the four species at the microsatellite markers. We hypothesize separation of the four species into distinct clusters but with evidence of past gene flow among species with the highest level between *Q. ellipsoidalis* and *Q. velutina*. Results based on the highly variable microsatellites showed a clustering of the *Q. ellipsoidalis* and *Q. velutina* populations with the highest proportion of genetically intermediate and introgressive forms between them and a clear separation from *Q. rubra* and *Q. coccinea*. The analysis of genetic characters will allow a better characterization of the taxonomic relationships in this taxonomically difficult group of red oak species.

Genetic diversity of *Quercus ilex* L. as a tool for retracing the dynamics of the Mediterranean forest ecosystems. Paffetti, D., Labriola, M., Giovannini, G., Salbitano, F. (*University of Florence, Italy; donatella.paffetti@unifi.it; mariaceleste. labriola@unifi.it; gianluca.giovannini@unifi.it; fabio.salbitano@unifi.it*).

Forest dynamics is strongly related to disturbances that have occurred over time. Disturbance frequency and severity affects the selective processes of populations and communities. In the case of Mediterranean forests, fire induced substantial changes in the population genetics of plant species. In the frame of the research on forest dynamics, the role of vegetative regeneration as a reaction to natural (fires) or anthropogenic (coppicing) disturbances was very poor. The research was carried out in 2011 and 2012, aiming to describe the genetic structure of *Quercus ilex* populations in coppices and to assess the relationships between vegetative regeneration and diversity in genetic structure. The assumption is that vegetative regeneration tends to slow down the genetic diversity of plant populations over time. Two permanent plots in central Italy were established in former coppice woodlands dominated by *Quercus ilex* where, at least over the last five centuries, vegetative propagation is the prevailing tree regeneration system. The spatial structure of the coppice stools was measured and leaves and buds of 30 stool-shoots sampled to perform the molecular characterization by using microsatellites techniques. The results show a medium-high complexity in the genetic pattern of *Quercus ilex* coppice shoots, pointing out the residual diversity of the system.

Genetic linkage map development in *Eucalypts* for abiotic stress tolerance. Ramasamy, Y. (*Institute of Forest Genetics and Tree Breeding, India; yasodharaja@yahoo.com*), Viswanathan, S. (*Nehru Arts and Science College, India; v.subashini85@ gmail.com*).

India is the largest planter of *Eucalyptus* at about 18 m ha. It is used as the source of pulp, fuel wood and energy. *E. tereticornis* and *E. camaldulensis* are the most commonly grown species due to their adaptability to arid regions. Under the genetic improvement program for eucalypts, seed orchards and clones were developed for plantation programs. Recently, inter-specific hybrid production through controlled pollination has been practiced to harbor heterosis through clonal propagation. Simple sequence repeat (SSR) markers were identified for parentage confirmation of hybrids and quality control genotyping during propagation. A genetic linkage map was developed for the first time in the cross *E. tereticornis* x *E. camaldulensis* by selecting the high yielding clones but differing for the salinity tolerance traits using SSR markers. A total of 273 SSRs were screened for polymorphism between parents, and 139 showed clear polymorphic alleles. Using two-way pseudo-testcross strategy, 53 loci were mapped in 11 linkage groups in both the parents. The total map length for male and female parents was 1 422.28 cM and 1 845.8 cM, respectively.

Somatic embryogenesis in *Hyeronima alchorneoides* (Euphorbiaceae) from zygotic embryos. Rojas, A., Hine, A. (*Universidad Nacional de Costa Rica, Costa Rica; alejandra.rojas.vargas@una.cr; ana.hine.gomez@una.cr*).

There is an interest in developing a protocol for somatic embryogenesis in *Hyeronima alchorneoides*. This species is of particular interest because in Costa Rica it is a fast growing tree species with high ecological and economic value. Also, it presents problems with recalcitrant seed storage, and in the country it is seriously attacked by a wasp that feeds on the embryo, which greatly reduces seed production. Therefore, somatic embryogenesis was proposed as a solution to mass propagation *H. alchorneoides*. In this research, we were able to induce embryogenic callus after 60 days of culture on MS medium supplemented with 2.68 µm NAA or 9.05 µm 2,4-D combined with 1.34 µm NAA. After 120 days of culture, we were able to obtain 254 and 147 somatic embryos in the respective culture mediums. Maturation and germination conversion of somatic embryos was obtained in a culture medium free of growth regulators on light conditions. This technique and its advantages are verified with the establishment of *Hyeronima alchorneoides* somatic embryogenesis from zygotic embryos. However, like other woody species, we conclude that a lack of synchrony in the development of somatic embryos remains one of the challenges to overcome in somatic embryogenesis.

Annual climate variation shapes adaptive seedling characters: A contribution to the adaptation of trees to future climates? Schueler, S. (*Federal Research Centre for Forests, Austria; silvio.schueler@bfw.gv.at*).

The adaptability of forest trees to changing climate conditions mainly depends on two requisites: firstly, on the genetic variation of tree species, and secondly, on the epigenetic status of the responsible genes, that is whether genes are being expressed or not. We aimed at testing the effects of weather conditions during pollination, embryogenesis, and seed development on the performance of seedlings from open-pollinated seed orchards and seed stands from different provenances of the conifers *Pinus sylvestris, Picea abies*, and *Larix decidua.* Extreme environmental conditions that were found in different seed years represent the environmental trigger. In a nursery trial with a normal and a water deficit treatment, we characterized various quantitative traits (i.e., phenology, drought tolerance). Significant differences were found among the tested species, among provenances, among the precipitation treatments, and most importantly, among the years in which the seeds were produced. This suggests that the effect of interannual variation of climate during pollination and seed maturation has a larger effect on the performance of produced seeds, respectively the seedlings emerging from these seeds, than previously thought and that it contributes to the adaptations of forest trees to climate change.

Genetic diversity and breeding strategies for genetic improvement of *Melia composita* Willd. Sharma, S., Dobhal, S., Kumar, A. (*Indian Council of Forestry Research and Education (ICFRE), India; shrutiddn@gmail.com; shivanido@gmail.com; ashok@icfre.org*).

Melia composita Willd. is an important tree species for ply and pulp wood and has a great potential to be cultivated under agro and farm forestry programs. Bridging the ever increasing gap between demand and supply for such woods is possible by screening genetically diverse and productive parents and multiplying them on a commercial scale for wider deployment. Although this native to the Indian sub-continent has attracted great attention from growers and industrialists, limited research has been carried out on its genetic improvement and breeding that would allow for supplying quality planting stock. This research originated with DNA fingerprinting by optimizing DNA extraction protocols and screening molecular markers for genetic analysis so that field deployment and breeding strategies could be drawn out appropriately. The DNA was extracted from juvenile leaves by standardized extraction protocols. The quantity and quality of DNA obtained was evaluated for PCR-based analysis, and 28 ISSR primers of the University of British Columbia were screened for amplification. Different annealing temperatures were examined to optimize amplification conditions, and eventually primers producing clear, robust and reproducible bands were recommended for evaluating existing genetic diversity**.**

Wastelands rehabilitation by growing genetically improved *Melia composita* Willd. Sharma, S., Kumar, A. (*Indian Council of Forestry Research and Education (ICFRE), India; shrutiddn@gmail.com; ashok@icfre.org*).

Melia composita Willd. is an important multipurpose tree species grown commercially under various afforestation programs for fodder, timber, and industrial woods. The availability of genetically improved planting stock is almost non-existent and has become a serious challenge. Therefore, the selection and characterization of genetically divergent genotypes using breeding techniques was initiated to select 230 candidate plus trees using index method based on height, diameter at breast height, straightness, clear bole height, crown diameter, and knots. Trees with an index value of >75 (58 trees) were selected as plus trees, and the average index value of plus trees was 81.81. Genetic evaluation of the 21 most suitable progenies was carried out in six geographical locations to analyze stability and adaptability and screening of suitability of genotypes for arid and semi-arid regions. The progenies/genotypes which survive and sustain in the toughest conditions of more than 48 °C of temperature and very little rain are expected to play a crucial role in rehabilitation of arid and semi-arid zones. The program would essentially ensure development of suitable ideotypes with sustainable water use for such degraded regions and contribute substantially to carbon sequestration when deployed commercially.

Species diversity effects on productivity and water use in a tropical tree plantation. Sinacore, K., Asbjornsen, H. (*University of New Hampshire, USA; ksinacore@gmail.com; heidi.asbjornsen@unh.edu*), Hall, J. (*Smithsonian Tropical Research Institute, USA; HallJe@si.edu*), Ducey, M. (*University of New Hampshire, USA; mjducey@cisunix.unh.edu*).

High global rates of tropical deforestation are increasingly being countered by tree planting, providing a unique opportunity to restore many critical ecosystem services and functions that have diminished as a result of past land use. Although the majority of forest plantations have involved monocultures, there is growing emphasis on mixed-species systems as a means of increasing productivity and providing multiple ecosystem services. However, a possible consequence of greater productivity in mixed-species stands is greater plant moisture stress during periods of drought. We hypothesize that planting mixtures of species having complementary or facilitative interactions (e.g., root architecture, phenology, nutrient cycling capability) can enhance stand-level water use efficiency, thereby maximizing productivity and resilience to drought. Two questions we seek to answer are: (1) how do different combinations of plant traits influence stand productivity and transpiration, and (2) how is this relationship further mediated through differences in individual species and stand-level water use efficiency? Our research at the Agua Salud Project in Panama will use a combination of sap flow, photosynthetic rates, and isotope analysis techniques in monocultures, two-species, and six-species plantings to explore these questions. This paper presents preliminary results from this work and discusses implications for tree planting efforts and future research.

An association mapping approach using ISSRs and AFLPs to identify molecular markers for resin yield in *Pinus roxburghii* Sarg. Singh, A., Barthwal, S., Ginwal, H. (*Indian Council for Forestry Research and Education (ICFRE), India; anitasrawat@gmail.com; santan@icfre.org; ginwalhs@icfre.org*).

In *Pinus roxburghii*, marker-trait associations were studied for resin yield using 238 molecular markers derived from 9 ISSR and 5 AFLP primer pairs. Regression analysis identified 16 ISSR and 12 AFLP markers showing significant associations with resin yield accounting for 87.53 and 97.56 percent of the phenotypic variation respectively. To avoid false positive associations, a model-based cluster analysis implemented in the software STRUCTURE was performed which revealed the population to be stratified into five subpopulations. The grouping of genotypes into five subpopulations had no correlation with their resin yield

thereby eliminating the possibility of shared ancestry among them. Structured association test was then carried out using the software STRAT conditional on the inferred population structure. In the absence of population structure, 34 ISSR and 31 AFLP loci showed significant association out of which 2 ISSR and 6 AFLP loci were common with those identified by regression analysis. Upon considering population stratification, 51 ISSR, and 17 AFLP loci revealed association out of which one ISSR ($UBC873_{1319}$) and one AFLP locus (E_{ACA} M_{CTA51}) was found to be common with those identified by both regression analysis and structured association test assuming no population stratification showing their strong association with the trait.

Genetic evaluation of Pinus roxburghii genotypes varying in resin yield using microsatellite markers. Singh, A., Barthwal, S., Ginwal, H. (*Indian Council for Forestry Research and Education (ICFRE), India; anitasrawat@gmail.com; santan@icfre.org; ginwalhs@icfre.org*).

Pinus roxburghii genotypes collected from Tiunee (Chatra), varying in resin yield from 0.25 to 8.0 Kg/year were tested for differences in their genetic constitution using microsatellites. The hierarchial clustering using UPGMA implemented in the software DARwin 5.0.158 grouped the genotypes into two distinct clusters based on their resin yield rather than their site of collection. The dissimilarity coefficients ranged from 0.04 to 0.72 suggesting high genetic variability among the genotypes. Model based clustering identified five sub-populations in the sample. The distribution of genotypes into different subpopulations had no correlation with their resin yield showing that resin yield of the genotypes was not attributed to their ancestry but it was because of their genetic constitution. AMOVA by collection site revealed no significant variation among the groups whereas in AMOVA by resin yield, percentage of variation among the groups was 10.96% with an F_{ST} value 0.109 which was highly significant ($p < 0.001$). The F_{ST} value 0.1096 indicated that there was moderate genetic differentiation among the groups. The study suggested that the variation among the genotypes at the molecular level was correlated with the variation in resin yield and not their site of collection thus highlighting the genetic basis of the trait.

Genetic diversity and evolutionary relationship of *Dyera costulata* and *Dyera lowii* in Jambi, Indonesia based on AFLP markers. Siregar, U. (*Bogor Agricultural University, Indonesia; siregaruj@gmail.com*), Hamzah, S. (*Jambi University, Indonesia; hamzahtbr@yahoo.com*), Suharsono, U., Siregar, I. (*Bogor Agricultural University, Indonesia; ututsuharsono2002@yahoo.com; izsiregar@yahoo.com*), Finkeldey, R. (*University of Gottingen, Germany; rfinkel@gwdg.de*).

Dyera costulata and *D. lowii* are endangered indigenous tree species that grow in two different habitats in Jambi, Indonesia. *D. costulata* grows on hill areas while *D. lowii* is usually found in lowland swampy forest. Both trees are intensively harvested by the local community for their latex and wood. Although listed as two different species, the local community often uses these species interchangeably in reforestation programs in the area. This study investigated the genetic diversity of randomly sampled trees of *D. costulata* and *D. lowii* planted in the area using AFLP markers. Two primer combinations (i.e., E-ACC/M-CTA and E-AGG/M-CTC) generated AFLP bands. *D. costulata* (He=0.38) had twice the diversity of *D. lowii* (He=0.19). Dendrogram based on Nei's genetic distance separated the two species, however, some *D. costulata* acessions showed a closer association with *D. lowii*. The possibility of gradual evolutionary changes from one species to another as the habitat changed from hill area to swampy lowland is discussed.

Transition wood age from early wood to late wood of *Pinus radita* D. Don, in the Andean region of Cochabamba City, Bolivia. Sirpa Espinoza, E., Vargas, J. (*Universidad Mayor de San Simon, Bolivia; eve.sirpa@hotmail.com; j.vargas@umss.edu.bo*).

In the department of Cochabamba (Bolivia), there is a large number of forest plantations, among which the species *Pinus radiata* D. Don can be found. Currently the use of this wood has increased significantly. Noticing the lack of scientific information on this species, we wanted to determine the age of transition from early wood to late wood and assist the optimization in silvicultural interventions for industrialization. The following methodology consisted of the analysis of samples (timber core samples) from permanent forest sample plots of different ages and different places. In each sample (timber core sample), growth rings were selected and samples were extracted from the vegetable late wood to be disaggregated to obtain tracheids which were observed under the microscope and were photographed. The photographs were analyzed with SigmaScan Pro to obtain the length and diameter of the tracheids. The age of transition was found to be 19 years old, with a period of transition from early wood to late wood from 17 to 23 years old. The results of the study suggest that forest plantations of *Pinus radiata* D. Don that are 19 years old (age of transition) could provide wood that has culminated in the early wood period.

Mass propagation of Korean raisin tree through veneer grafting. Song, J., Kim, S., Kim, M., Kim, H., Park, Y. (*Korea Forest Research Institute, Republic of Korea; sjh8312@forest.go.kr; goldtree@korea.kr; spresources@forest.go.kr; hyeusoo@gmail.com; ykpark@forest.go.kr*).

Korean raisin tree (*Hovenia dulcis* var. *koreana Nakai*) is considered not only a fruit but also an herbal medicine in East Asia including Korea, Japan, and east China. As honey plant, the value of this species was rising steadily. This study was conducted to develop the propagation techniques and determine effects of scion collection time, scion age, and use of a vinyl house on survival rate of *H. dulcis* var. *koreana Nakai*. The survival rate by veneer grafting showed no significant differences among the three new cultivars. The most appropriate time for scion collection in the northern temperature zone was observed to be before the spring equinox when plants are fully dormant. The installation of a vinyl house showed above 86% of grafting survival rate. The scion age did affect survival rate with 1-year shoots having an increased grafting survival rate than 2-years shoots. In this case, the installation of vinyl house can contribute above 80%.

Conservation monitoring of *Erythrina velutina* in riparian forest area. Souza, D., Melo, M. (*São Paulo State University (UNESP); danillacristina@ig.com.br; mariliafvm@yahoo.com.br*), Gois, I. (*Viçosa Federal University, Brazil; itamarafloresta@gmail.com*), Silva-Mann, R. (*Sergipe Federal University, Brazil; renatamann@hotmail.com*).

One of the major challenges for the agricultural system is to establish agricultural production coupled with the conservation of genetic resources, mainly aiming at the preservation of permanent protection areas. In this context, the species mulungu

(*Erythrina velutina* Willd.), among other natives, has been suffering with anthropogenic pressures in various ecosystems. The objectives of this research were to (1) use ecological and genetic population parameters, including molecular markers (allozymes and ADN), as indicators of sustainability in two natural populations of mulungu in the State of Sergipe, Brazil, and (2) to evaluate the tendency sustainability of populations intended for monitoring and conservation. The matrix pressure-state-impact/effect-response (PSI/ER) along with the selection of 14 indicators (density of species, population effective size, density of seeds, tree height, diameter at breast height, polymorphic fragments of ADN, polymorphic loci, Shannon index, genetic diversity among populations, heterozygosity, gene flow, inbreeding coefficient, number of publications, and Germplasm Active Banks) can serve as a reference for monitoring forest fragments in riparian areas for their ability to maintain native species, such as mulungu, in rarity character. The populations studied showed low tendency toward sustainability.

Genetic admixing of two evergreen oaks, *Quercus acuta* and *Q. sessilifolia* (subgenus Cyclobalanopsis), is the result of frequent interspecific hybridization. Tamaki, I. (*Gifu Academy of Science and Culture, Japan; garageit@gmail.com*).

It is well known that the species boundaries of oaks are relatively weak, and hybridization is reported frequently. Our study species are *Quercus* acuta and *Q. sessilifolia* (subgenus *Cyclobalanopsis*), and the existence of their putative hybrid *Q.* x *takaoyamensis* has been known. We investigated leaf morphological traits and microsatellites of the two oaks in the area where the two species are distributed. Although, each leaf trait of the two species was duplicated, the two species could be distinguished morphologically by PCA based on all leaf traits. They were also genetically differentiated with $F_{ST} = 0.104$. However, they shared most of the alleles in all studied loci, and considerable genetic admixing was detected. Model-based testing showed that this admixing was created by not only shared ancestral polymorphism but also hybridization. The effective numbers of migrants per generation to *Q. acuta* and to *Q. sessilifolia* were 9.32 and 68.05, respectively. Theoretically, it is considered that 1–10 migrants per generation are required to prevent complete genetic differentiation. Based on the results of this and several previous studies on *Quercus* species, it appears that genetic admixing with most allele sharing is probably common in this genus and is maintained by interspecific hybridization.

Identification of *Ganoderma* species associated with *Acacia cyclops* mortality in the Western Cape region of South Africa. Tchotet Tchoumi, J., Coetzee, M., Wingfield, M. (*University of Pretoria, South Africa; michel.tchotet@fabi.up.ac.za; martin.coetzee@up.ac.za; Mike.Wingfield@up.ac.za*), Rajchenberg, M. (*Centro de Investigación y Extensión Forestal Andino Patagónico, Argentina; mrajchenberg@ciefap.org.ar*), Roux, J. (*University of Pretoria, South Africa; jolanda.roux@fabi.up.ac.za*).

Acacia cyclops is an invasive tree in the Western Cape region of South Africa, although it also has value in providing fuel wood for local communities. Approximately three decades ago, it was noted that these trees were dying in large numbers and this die-off has continued to occur. Dying trees have been shown to suffer from a rapidly developing root disease resulting in the wilting of trees and a white rot of the affected roots and bases of trees. Previous attempts to determine the cause of the disease suggested that the fungus *Pseudolagarobasidium acaciicola* was affecting the trees. However, sporocarps of a fungus resembling *Ganoderma* are also commonly associated with the roots and bases of dying trees. The aim of this study was to identify the possible *Ganoderma* species using DNA sequence analyses. Isolates were obtained from sporocarps and roots of diseased trees, and DNA sequences were generated from the ITS and mtSSU regions. Results suggested that a *Ganoderma* sp. in the *Ganoderma lucidum* complex is associated with the disease. Future studies will focus on pathogenicity trials in order to verify the role of this fungus, as compared to *P. acaciicola*, in causing the wide scale death of *A. cyclops*.

Ex situ germination behavior of stored seeds of medicinal plants from Indian Himalayas. Thapliyal, M. (*Forest Research Institute, India; manishapasbola@rediffmail.com*).

The increase in global demand for medicinal plants has increased the exploitation of their natural populations through crude and unsystematic extraction methods. The Indian Himalayan Region is rich in diversity of valuable species of known medicinal value. However, dwindling populations due to over-exploitation necessitates evolving effective propagation and conservation strategies, and seeds are the most efficient means for most species. To develop *ex situ* conservation strategies for six Himalayan medicinal plants viz. *Artemisia vulgaris, Berberis asiatica, Berginea ligulata, Hippophae salicifolia, Saussurea lappa* and *Myrica nagi*, seeds were studied for germination behavior, seed dormancy levels, and pretreatment and storage behavior using standard ISTA methods. Dormant seeds were pretreated with growth promoters like GA_3 and KNO_3. *B. asiatica* seeds responded best to GA treatment (80%) and lost viability in 6 months; *S. lappa* yielded 75% germination under GA_3 pretreatment against 40% in untreated seeds; 32% of seeds of *M. nagi* germinated in GA_3 pretreatment while untreated seeds yielded only 7% germination. *B. ligulata* seeds responded best to KNO_3 pretreatment (68%), while untreated seeds of *A. vulgaris* germinated for more than a year. The study determines the viability period of the seeds in storage conditions for regenerating the species in posterity.

Assessment of seed quality and mycoflora of *Bauhinia retusa* in different storage conditions. Thapliyal, M., Singh, Y., Kainthola, C., Bagwari, A. (*Forest Research Institute, India; manishapasbola@rediffmail.com; singhyp@icfre.org; tinni0509@gmail.com; archana.bagwari25@gmail.com*).

Bauhinia L. is a genus of shrubs and medium -sized or large trees of more than 200 species having traditional and medicinal application. In sub-tropical Himalayan belt of Uttarakhand, (India), *B. retusa* is a good source of green fodder during dry summer months. Seeds of *B. retusa* from various sources were observed for their storage behavior and for conservation of germplasm in seedbanks. Fresh seeds were tested for viability and vigor and then stored in plastic containers at ambient and low temperatures. Seed viability and seed health were assessed every 3 months, because fungi can lower the quality of seeds by causing discoloration and reducing germination. Among different causal agents, the impacts of fungi are considerable because pathogens of maturing seed reduce the yield. Mycoflora in seeds were detected by blotter method by the International Seed Testing Association. Viability of seeds declined from 90% to 24% in about 2.5 years in seeds from the Rambaar source while in the Majhera source, loss was slow from 94% to 86%. Seeds in stored condition had significantly more fungal colonies than in fresh. In stored seeds, *Aspergillius* count was highest. Periodic checks of seed health are important because a rise in fungal infection under stored condition may lead to its deterioration.

Genetic variation in natural and planted populations of *Shorea guiso* (Dipterocarpaceae) in the Philippines revealed by microsatellite DNA markers. Tinio, C. (*University of the Philippines Los Banos, Philippines; crusty.estoque@yahoo.com*), Finkeldey, R. (*Georg-August-University Göttingen, Germany; Reiner.Finkeldey@zvw.uni-goettingen.de*), Prinz, K. (*Friedrich-Schiller-University Jena, Germany; kathleen.prinz@uni-jena.de*), Fernando, E. (*University of the Philippines Los Banos, Philippines; edwino.fernando@gmail.com*).

The genetic diversity of four natural and four planted populations of *Shorea guiso* in the Philippines was investigated using microsatellite DNA markers to compare patterns of variation within and among the populations. Leaf samples were collected from trees in eight sites and three islands in the archipelago and extracted for genomic DNA. Six polymorphic microsatellite markers were used. We employed standard genetic diversity measures to quantify genetic variation. Results indicate a high level of genetic diversity within populations of *S. guiso.* The natural populations in Bohol (N_BOH) showed the highest genetic diversity among the four natural populations while Bislig (P_BIS) was highest among the planted populations. An AMOVA revealed high variation within populations (95.39%) and low variation among planted populations (4.61%). Further, an AMOVA among both population types (natural and planted) revealed no differentiation (-0.80%) among the groups, with 5.2% of variation occurring among populations within groups and 95.6% variation within populations. The largest genetic distance was found between the natural populations N_BOH/N_SUB (0.332) and the smallest was between N_MAK/P_MAK from both population types (0.041). This study proves the usefulness of microsatellite markers in the assessment of genetic variation within and among populations and determination of the origin of the planted populations.

A new approach to propogate *Spondias pinnata* without potting media. Tomar, A. (*Centre for Social Forestry and Ecorehabilitation, India; anitatomar@icfre.org*).

Growing plants without soil is not new. Man started agricultural pursuits by growing plants in soil, but as the knowledge of plant nutrition increased, he learned to grow plants in artificial media. The next step was to eliminate solid media and to grow plants directly. In the present study, an attempt was made to germinate seeds of *Spondias pinnnata* without any potting media. *Spondias pinnata* is a deciduous, glabrous tree with edible fruit, growing up to 25 m in height. Despite being a valuable and threatened plant, *S. pinnata* is not cultivated on a large scale in its native habitat. Seeds of *Spondias pinnata* were collected from sites situated between latitude 25007′ to 25010′N and longitude 81054′ to 81058′ E and at 98 m elevation. Seed germination tests involved four replications of randomly selecting 25 seeds each from the working sample. The commencement of soilless germination started on the 10th day onwards after sowing and continued up to 20 days inside the muslin cloth. The seed germination varied significantly (ANOVA; F-value = 5.46 and p = 0.02) during the study period. Total germination recorded was 96%, of which the maximum germination (64.0%) was observed in the second week of sowing.

Rhizome macroproliferation: a new technique of propagating herb and fern. Tomar, A. (*Centre for Social Forestry and Ecorehabilitation, India; anitatomar@icfre.org*), Srivastava, R. (*Tamil Nadu Forest Department, India; srivastavaraj3@yahoo.com*).

The plants at higher altitudes of the Himalayas are generally propagated by rhizomes. The propagation by rhizome and stem cuttings has emerged as an efficient method of multiplication and conservation of such species. Therefore, this present study was conducted to macro-proliferate *Gentiana kurroo,* an endangered medicinal herb, and *Cyrtomium caryotideum,* a medium sized fern, through rhizome cuttings. For the present study, growing tips of rhizome were split into two, three, and four longitudinal parts. Each split contained ½, ⅓, or ¼ of longitudinal section of the mother rhizome and aboveground part with growing buds. *G. kurroo* and *C. caryotideum* two piece rhizome exhibited significantly higher survival percentage than three and four pieces. *G. kurroo* two and three pieces IBA treated cuttings showed better results than IAA treatments. *C. caryotideum*'s two and three piece cuttings provided the best survival under controlled conditions, and four piece cuttings thrived better under 300 ppm IAA treatment. Rhizome-macroproliferation of *G. kurroo* and *C. caryotideum* is a new, simple, easy and effective technique for multiplication and conservation of these endangered herb and fern species for the production of more plants for future conservation.

Eucalypts in China: research history, present situation of breeding and silviculture and future prospect. Wu, S., Xu, J. (*Chinese Academy of Forestry, China; wushijun0128@163.com; jianmxu@163.com*).

During the past three decades, an increase in research on breeding and silviculture has improved *Eucalyptus* productivity, and to some extent our standing of their effects on tree growth and on wood properties. Unfortunately, very little information about these two procedures on the review of *Eucalyptus* grown in China has been published even though this species was introduced some 120 years ago. This paper reviews the available information regarding research history and progress of breeding and silviculture under Chinese ecological conditions and to outline some suggestions to them. According to the present research situation of breeding and silviculture, we would recommend that: generalizing empirical and useful practices; developing high-value products; creating more clones for demand; carrying out intensively research over different species and clones for different cultivation goals at different sites over time; associating quarantine, identification, control and breeding to reduce the impact of eucalypt pests and diseases; above all, applying breeding strategy, especially for multiple generations and interspecific hybrid breeding.

The effect of plus-tree selection on the genetic diversity of two *Acacia mangium* seedling seed orchards in Indonesia. Yuskianti, V. (*Center for Forest Biotechnology and Tree Improvement, Indonesia; vivi_yuskianti@yahoo.com*), Isoda, K. (*Forestry and Forest Products Research Institute, Japan; keiso@affrc.go.jp*), Nirsatmanto, A. (*Center for Forest Biotechnology and Tree Improvement, Indonesia; arif_nirz@yahoo.com*).

To know the efficiency of phenotypic selection conducted on a seed orchard, it is necessary to measure the genetic diversity of the base population and the population after selection. The genetic diversity of a base and plus-tree population of two *Acacia mangium* seed orchards in Kalimantan (AM006 Group C) and Sumatera (AM004 Group D) that had been established using Australian provenances were analyzed using 12 microsatellite markers. Both had been subjected to similar procedures of plus-tree

selection. FSTAT analysis showed that the level of genetic diversity in the base population of both orchards was comparable. For the plus-tree population there were significant increases in the level of genetic diversity in the AM004 Group D (He=0.609 for base and He=0.625 for plus-tree) but not in the AM006 Group C (He=0.607 for base and He=0.602 for plus-tree). The level of inbreeding decreased in the AM004 Group D (Fis=0.146 for base and Fis=0.094 for plus-tree) and increased in the AM006 Group C (Fis=0.118 for base and Fis=0.150 for plus-tree). Thus, selection applied for the AM004 Group D was more efficient than for the AM006 Group C. Several factors may have contributed to this difference. Management strategies that can be applied for the next selection are discussed.

Genetic diversity of natural populations of endangered *Ormosia hosiei*, endemic to China. Zhang, R., Zhou, Z. (*Chinese Academy of Forestry, China; ruirui0218@126.com; cafzzc@126.com*), Du, K. (*Agriculture University of Hebei, China; kejiudu@yahoo.com.cn*).

Ormosia hosiei is native to China and valued for its timber. In order to help preserve this endangered wild species, we investigated the distribution of *O. hosiei* populations in southern China. Based on ISSR markers, 101 clear and reproducible DNA fragments were generated. Of these, 96 (95.1%) were polymorphic. Shannon's index (I) and Nei's gene diversity (h) were 0.5483 and 0.3747, indicating a high level of genetic diversity. Moreover, there was a lack of significant association between genetic and geographical distances in the populations. The distribution of genetic diversity among the wild populations of *O. hosiei* in southern China may be the result of events in the species' evolutionary history, including habitat fragmentation and habitat damage caused by human activity. Based on these findings, we suggest that areas with larger populations of *O. hosiei* should take effective measures to ensure the conservation.

Genetic diversity and differentiation within three species of the family Lauraceae in southeast China. Zhang, R., Zhou, Z., Jin, G. (*Chinese Academy of Forestry, China; ruirui0218@126.com; cafzzc@126.com; phr2122@126.com*).

A comparative analysis was undertaken of the genetic diversity and genetic structure of three coordinal tree species from southeastern China. The species *Phoebe chekiangensis* C.B. Shang, *Phoebe bournei* (Hemsl.) Yang, and *Machilus pauhoi kanehira* are all valued for their timber. Nine populations from two provinces were screened for variability with ISSR markers. Percentage of polymorphic loci, Nei's gene diversity, and Shannon's index were lower in *P. chekiangensis* (PPL%=78.8%, h=0.2301, and I=0.3522) than in *P. bournei* (PPL%=90.3%, h=0.3223, and I=0.4776) or *M. pauhoi kanehira* (PPL%=92.0%, h=0.3714, and I=0.5412). Larger populations were found to possess greater genetic diversity. Distinct genetic differentiation was found to have taken place in *P. bournei*, and barrier analysis showed two barriers in the four populations studied. Special environments were found to influence population differentiation.

GENERAL POSTER SESSIONS

IUFRO Division 3: Forest Operations Engineering and Management

Urban forest ecosystem assessment in Louisiana, USA, using the i-Tree Eco Model. Abdollahi, K., Ning, Z. (*Southern University, USA; kamrana664@cs.com; Zhu_ning@subr.edu*).

i-Tree Eco, an adaptation of the Urban Forest Effects (UFORE) model, was used to provide urban and community forestry analysis and benefits assessment for the city of Baton Rouge, Louisiana, located in the Gulf Coastal region of the United States. The study was designed in collaboration with the U.S. Forest Service to use field data from randomly located plots throughout a community along with local hourly air pollution and meteorological data to quantify urban forest structure, environmental effects, and value to communities. The analysis of trees in Baton Rouge revealed that this area has about 1 036 175 trees with tree canopies that cover 44.6% of the city. The most common tree species are live oak, sweetgum, loblolly pine, pecan-hickory, baldcypress, water oak, crape myrtle, and Southern magnolia. Trees in Baton Rouge currently store about 2 029 342 tons of carbon/yr with an associated estimated value of US$41 million per year. In addition, these trees remove about 48 699 tons of carbon/yr (178 354 tons CO_2/yr) with an associated estimated value of $1.1 million/yr). Baton Rouge's trees are estimated to reduce residential energy costs by $8 million annually and reduce air pollution by 860 tons per year with an associated estimated value of $6.2 million per year.

Wood harvesting rate, haulage methods, and policies in southwest Nigeria: implications for carbon sequestration. Adekunle, V. (*Federal University of Technology, Nigeria; adekunlevaj@rediffmail.com*).

Wood harvesting rate, haulage methods, and policies and their implications for carbon sequestration were examined in a tropical rainforest ecosystem in southwest Nigeria. Data on logging activities and policies for a 3-year period from both the protected and unprotected areas were collected from each state's forestry department. Differences in harvesting rate and in methods of harvesting and removal were found. Policies also differed between states. The total volume of wood removed from the geo-political zone for the 3-year period was 246 784 cubic meters. Log volumes are directly proportional to the amount of carbon that can be sequestered by the forest. The quantity of carbon removed for the period was 2.3 million metric tons (8.4 million metric tons of CO_2). Annual carbon and CO_2 removal was therefore estimated at 760 120.73 and 2.8 million metric tons/yr, respectively. Economically valuable timber species are disappearing from the forest because of incessant and indiscriminate logging, outdated logging and haulage methods, and government policies that favour harvesting over regeneration. The implications of this decline in forest tree species on biological conservation, wood availability, and climate change were discussed. For this forest to continue its environmental role as a carbon sink rather than the present carbon source, conservation measures and better logging policies were recommended.

Estimating harvesting costs and projecting available amounts of logging residues with small-scale forestry in Nasushiobara city, Tochigi prefecture, Japan. Aruga, K. (*Utsunomiya University, Japan; aruga@cc.utsunomiya-u.ac.jp*).

This study estimated supply potentials and costs of small-scale systems operated by a private logging contractor, an individual forest owner, and a forest owners' association using GIS on a regional scale. Total supply potentials of timber and logging residues were estimated as 418 895 m^3 and 254 962 m^3, respectively. Then, economic balances were estimated and available amounts were projected as supply potentials from profitable sub-compartments. Projected available amounts of timber and logging residues were 376 490 m^3 (89.9%) and 203 875 m^3 (80.0%), respectively. Sub-compartments conducted by private logging contractors were almost profitable in the case of selling logging residues at a plant because private contractors' transportation expenses were lower than those of the other systems. On the other hand, there were few profitable sub-compartments conducted by individual forest owners because the number of sub-compartments with extracting distances less than 20 m was small. Logging residue prices of 4 080 yen/m^3 and 6 800 yen/m^3 were examined in addition to a logging residue price of 3 000 yen/m^3. As a result, the number and area of profitable sub-compartments as well as available amounts of logging residues were increased.

Predictive models for estimating the above ground biomass of oil palm plantations using Landsat Thematic Mapper. Asari, N., Suratman, M., Jaafar, J., Md. Khalid, M. (*Universiti Teknologi, Malaysia; nazlinasari@yahoo.com; nazip@salam.uitm.edu.my; jasmee@salam.uitm.edu.my; mazzueen@salam.uitm.edu.my*).

Malaysia is known as the world's top producer of palm oil with a current plantation area around 5.07 million ha. This area has a great potential to provide biomass resources for cellulosic materials for the country. Despite the importance of this resource, a reliable method to assess its availability is lacking. Therefore, the need for a more efficient inventory method is the impetus for research into supplementing ground-based surveys with information from satellite remote sensing. The objectives of this study were to determine the relationships between spectral reflectance recorded by Landsat Thematic Mapper (TM) and oil palm stand variables, and to develop predictive models for estimating the above ground biomass (AGB) of oil palm using TM data. Data sets for the model development were collected from 60 oil palm plantations throughout Selangor, Malaysia. The field stand parameters recorded included stand age, trunk radius, height, DBH, density, crown width, and crown closure. Regression analyses were used to explore relationships between AGB and TM bands and vegetation indices. Relations between TM data and measured oil palm AGB were found to be highly significant ($p<0.00$), with a multiple coefficient of determination (R^2) of 0.52 and standard error of estimates of 1.41 tonnes/ha. The good fit of the biomass model shows the potential of TM data for estimating AGB of oil palm in Malaysia.

Impacts of selective logging on litter input, soil carbon, and nutrient stocks, in the Brazilian Amazon. Bomfim, B., Horwath, W., Silva, L. (*University of California Davis, USA; bdbomfim@ucdavis.ed; wrhorwath@ucdavis.edu; lucascrsilva@gmail.com*), Sérgio Pereira, R., Gatto, A., Emmert, F. (*University of Brasília, Brazil; reginaldosp@unb.br*, *alcidesgatto@unb.br*; *fabianoemmert@yahoo.com.br*).

Litterfall and soil physical and chemical properties were measured in upland (*terra firme*) forest under selective logging. Managed forest tracts (UPAs) were selectively logged in 2003, 2005, 2007, and 2009, establishing a chronosequence to determine logging impacts. Measurements were performed in 15 plots (100 m × 50 m) in 4 UPAs and 1 Protected Area (APA), sampled in Silves, Amazonas, Brazil. In each plot, litterfall was sampled in 0.25-m^2 subplots, soil penetration resistance was determined, and composite soil samples taken (0–10, 10–30, 30–50 cm). Physical and chemical soil properties and litter nutrients (N, P, K, Ca, Mg, S, Al) were determined in the laboratory. Soil properties and calculated litter nutrient inputs were used to compare sites by principal component analyses (PCA). PCA ordinations and cluster analysis showed low dissimilarity between UPAs and APA (<25%), reflecting a limited effect of logging intensity (12.1–19.1 m^3/ha/yr). At the selective logging intensity imposed, the treatments showed minimal effects on ecosystem function. The most affected soil and litter traits were Ca, Mg, and P content and input. High soil organic matter content was found in all UPAs (20.6–64.1 g/kg). These results show resilient carbon and nutrient stocks on managed forest tracts and indicate the sustainability of such selective logging.

Soil impacts and forest operations in the southeastern United States. Carter, E. (*U.S. Forest Service*, *USA; eacarter@fs.fed.us*).

Mechanized forest harvest operations can alter soil physical properties that have the potential to influence subsequent forest productivity and soil sustainability. Soil response to harvest traffic is typically reported as changes in soil volume (compaction) and is of concern to land managers due to its impact on soil structure, soil aeration, soil water availability, nutrient and organic matter status, and erosion potential. Soil compaction status was investigated in several locations within the southeastern United States in the context of soil disturbance types and patterns, machine components, and soil properties. The final compaction status varied in intensity, spatial distribution, and depth of compaction. Final compaction status can be evaluated in the context of maximum compactibility determined via laboratory testing and spatial variability that can be determined with spatial analyses, GPS tracking, or a combination thereof. The movement of soil and water (erosion potential) is a major consequence of harvest activities and was investigated to evaluate site response (soil loss, runoff, nutrient movement) to forest management activities. The effects of machinery on soil resources are expected to intensify as demand for biomass for energy production increases. The impacts that can be expected from forest operations are based on intrinsic soil properties and their response to harvest equipment and systems.

Economic impact analysis of forest road construction using input-output analysis. Chong, S., Lee, H., Jeon, C., Jeon, H., Kim, C. (*Korea Forest Research Institute, Republic of Korea; skchong@korea.kr; hslee77@forest.go.kr; chjeon@forest.go.kr; sun7777@forest.go.kr k561011@forest.go.kr*).

The purpose of the research was to estimate the economic impacts of forest road construction in Korea by using input-output analysis with 2010 inter-industry relation tables (The Bank of Korea, 2011). Inter-industry relation tables were restructured into 29 sections fitting in with the industry of forest road construction. The total length of forest roads in 2012 was about 17 145 km with a density of about 2.69 m/ha. In 2011 total construction of forest roads was about 572 km, at a total cost of 143 552 million Korean won for road construction and management. Hence, the economic impact of forest road construction is as follows: production inducement effects of 2 219 billion won, labor-induced effects of 2 099 people, and value-added inducement effects of 1 704 billion won. Results of the analysis show that the production inducement coefficients and value-added inducement coefficients are somewhat lower than for other industries, but the employment coefficient is somewhat higher than for other industries. In addition, results showed that both influence on other industries and sensitivity to other industries are relatively low.

Identifying priority areas for carbon reservoirs in the Sierra Norte de Puebla, Mexico. Cruz-Huerta, C., González-Guillén, M., Martínez-Trinidad, T., Escalona-Maurice, M. (*Colegio de Postgraduados, Mexico; cruz.carmina@colpos.mx; manuelg@colpos.mx; tomtz@colpos.mx; mescalona@colpos.mx*).

Deforestation and degradation of forest ecosystems modify their structure and function, which may cause a decrease in carbon sequestration and other environmental services. Several population centers in the municipalities of Chignahuapan – Zacatlan, Puebla, in the central region of Mexico, are located on sites with steep slopes and use natural resources intensively. This situation has caused deforestation, damage to other resources, and a decrease in carbon stocks over time. This research used satellite imagery (1986–2010) and GIS techniques to detect land use changes through a probabilistic model. The model, built with biophysical, social, and economic variables, allows the prediction of land use change and deforestation risk from 2010 to 2030. A map of carbon pools was generated using information from forest management programs and GIS. This map together with the deforestation risk map allowed priority areas to be determined for carbon reservoirs. Some management strategies were generated to preserve natural resources and promote payment schemes in the market for carbon services.

Automatic mapping of possible forest operations: a decision support tool for forest planning. Dupire, S., Burger, F. (*National Research Institute of Science and Technology for Environment and Agriculture, France; sylvain.dupire@irstea.fr; frederic.berger@irstea.fr*).

Accessing forest resources in mountainous areas is often difficult and sometimes even impossible. The aim of this work was to develop a numerical tool capable of automatically mapping the areas accessible to different specific harvesting systems. This tool uses different geographic information as inputs, such as digital elevation models, forest road networks, and forest topography. Additional optional geographic information can be provided, such as obstacles for a specific task or information about stand volume. The forest operations considered in this model were harvesting (manual and mechanical) and yarding for three kinds of equipment: skidder, forwarder, and cable crane. For each operation, the model loads the necessary inputs and maps the corresponding accessible area using different scripts coded in the open source Python language. Many outputs are provided for the given operation, allowing the user to geographically evaluate both accessibility and feasibility of forest operations over a large area. This tool provides forest managers useful data for planning forest operations. It enables users to quickly identify the different possible ways for extracting wood from a specific area and can sometimes suggest solutions in the most difficult cases. Inaccessible forests are also mapped, providing information valuable to stakeholders as they decide about the future of such forests.

Optimizing biomass resource allocation for industrial and energy utilization in the light of forest certification. Engler, B. (*University of Freiburg, Germany; benjamin.engler@fobawi.uni-freiburg.de*), Cremer, T. (*Eberswalde University for Sustainable Development, Germany; tobias.cremer@hnee.de*), Brunsmeier, M., Becker, G. (*Albert-Ludwigs-University Freiburg, Germany; martin.brunsmeier@fobawi.uni-freiburg.de; gero.becker@fobawi.uni-freiburg.de*).

Increasing global demand for biomass resources for industrial and energy use is currently leading to high utilization rates of forest biomass. In response to the resulting risk of nutrient loss, forest certification schemes are about to ban harvesting of small-diameter biomass. This step in turn may lead to a shortage of biomass for either industrial or energy use, so knowledge about optimal thinning strategies, in combination with an optimized utilization of the biomass in terms of volumes and economics, is crucial. This study analyzed two different types of thinning operations in 37 forest stands in southern Germany, with a total area of 55.9 ha. Based on real harvested biomass volumes, models were derived to calculate biomass volumes in relation to changing parameters. In particular, the effects of diameter limits on respective volumes of biomass available for industrial and energy utilization could be assessed. Those biomass models were linked with forest harvesting models. Using methods of operations research, an economic valuation of different scenarios of sorting could be derived. Furthermore, effects of forest certification could be assessed in terms of biomass volumes or assortments for different uses, as well as in terms of economic consequences.

Evaluation of environmental impacts of forest harvesting and its effects on sustainability. Freitas, L. (*Federal University of Bahia, Brazil; luiscarlos_ufv@yahoo.com.br*).

Forest harvesting has been shown to have important impacts on sustainability. This research aimed to use the checklist method to evaluate environmental impacts of forest harvesting in eucalypt plantations in southeastern Brazil. The most obvious impacts were described, and mitigating environmental measures were outlined. Impacts from forest harvesting have a strong relation with the physical and biotic environment. Tree removal exposed soil to erosion. To minimize this impact it was suggested that forest waste be preserved on harvesting areas. Impacts of harvesting equipment and vehicles include direct impacts from compaction and indirect ones such as erosion. Defining an optimized layout for traffic was recommended as a mitigating measure for these impacts. Machine traffic during harvesting also damages understory vegetation, which in turn affects animal populations, mainly by reducing habitat. Decreasing the extraction distance through better management of tree falls, proved to be effective in minimizing damage to flora and fauna. In environmental planning of forest harvesting, this checklist can serve as a tool for, helping to identify impacts and recommended mitigation measures, thereby contributing to sustainable, low-impact harvesting.

Evaluation of the drying potential of wood chips inside breathable flexible containers and modeling of changes in moisture content. Fujiwara, M., Iwaoka, M., Matsumoto, T. (*Tokyo University of Agriculture and Technology, Japan; fujiwara@fe.rn.tuat.ac.jp; iwaoka@cc.tuat.ac.jp; tmatsu@cc.tuat.ac.jp*), Inomata, Y. (*Forest Survey, Japan; myumyu_vc3000@yahoo.co.jp*).

The objective of this study was to evaluate the drying potential of wood chips in breathable flexible containers in humid conditions in Japan. Breathable flexible containers were made of 5-mm mesh material. In this study, small, breathable flexible containers were filled with wood chips. During the test, the containers were under indoor conditions, where constant temperature and humidity were maintained using a drying oven. Temperature and humidity inside the containers were measured. Moisture content of the wood chips was also measured periodically. Results showed that the moisture content of the wood chips inside of the containers in an indoor environment decreased continuously during a 2-month period. It could be assumed that the wood chips would be completely dry in the long term. As another result, the drying rate of wood chips inside of the containers depended on the distance from the flexible container's inner surface. Moisture content of wood chips near the surface decreased exponentially with time, and the graph of the change in moisture content of wood chips near the center of flexible container over time was reverse S-shaped. These relationships could be represented by an exponential model and a logistic model, respectively.

Research about raising safety awareness of forestry in Japan. Funasaka, Y., Yamada, Y. (*Nagoya University, Japan funasaka.yukina@f.mbox.nagoya-u.ac.jp; yozo@agr.nagoya-u.ac.jp*).

The Industrial Safety and Health Law established in 1972 concerns safety management for all industries in Japan. This law contributed to the decrease of the incidence and mortality rates of industrial accidents in all industries. Since the recent widespread introduction of high-performance forestry equipment to forestry workplaces, people have been able to work more efficiently and more easily. Despite these changes, forestry has a mortality rate 14 times greater than the average of all industries in Japan. Forestry industrial accidents also occur frequently, because forestry workplaces are still very dangerous. Raising safety awareness of both companies and workers is very important to decrease the incidence and mortality rates of industrial accidents in forestry. Heightened awareness could make forestry workplaces much safer. The purpose of this research was to clarify the current status of and problems with safety awareness, in an attempt to find ways to raise safety awareness. Appropriate educational approaches to greater safety awareness in forestry in Japan are also discussed.

Energy efficiency in intensified production of forest regeneration materials – design of a photovoltaic system for sustainably powering an innovative forestry incubator. Hernandez Velasco, M., Mattsson, A. (*Dalarna University, Sweden; mhv@du.se; amn@du.se*).

Planted forests can help to address problems of global concern, such as climate change, declining biodiversity, and pressure on ecosystems due to high demand for forest products. To be able to profit sustainably from the benefits of planted forests, production rates of forest regeneration materials should be higher than harvesting rates. However, intensive production methods often bring along adverse consequences for the environment. Through the ZEPHYR project, funded by the European Commission under the Seventh Framework Programme, innovative and cost-friendly technologies for pre-cultivation are being developed. They will be integrated into a functional and transportable system for large-scale production of seedlings, with no impact on the environment and without being affected by outdoor conditions. To achieve this, high-efficiency devices with low energy consumption will be used and the incubator will be powered by solar energy. This paper presents the efforts made to reduce the energy loads and optimize the photovoltaic (PV) system. The power system will also be capable of connecting to the electricity grid, using a diesel generator as a back-up, and a battery bank with at least 1 day of autonomy (up to 7 kWh/day) in central European latitudes.

Energy biomass production with downy birch (*Betula pubescens*) on cutaway peatlands. Hytönen, J., Jylhä, P. (*Finnish Forest Research Institute, Finland; jyrki.hytonen@metla.fi; paula.jylha@metla.fi*), Reinikainen, O. (*Vapo Ltd., Finland; olli.reinikainen@vapo.fi*), Ahtikoski, A. (*Finnish Forest Research Institute, Finland; anssi.ahtikoski@metla.fi*).

Forest bioenergy is recovered mainly as a by-product of conventional forestry (e.g., under-sized stems, slash, and stumps). As demand for biofuels increases, production of bioenergy in dedicated plantations is gaining renewed interest. Peat is used as a source of energy in many countries in the Northern Hemisphere. For example, Finland has 60 000 ha in peat harvesting area, and ca. 2 500 ha are removed from peat production each year. Due to the high nitrogen content of the residual peat, these sites show high potential for intensive bioenergy production with woody species. However, deficiencies of phosphorus and potassium can limit biomass production. Wood energy plantations could also act as a carbon sink by absorbing atmospheric CO_2. In the present study, biomass production and its profitability with downy birch (*Betula pubescens*), either by natural regeneration or broadcast sowing, were studied. The study showed that the combination of broadcast sowing and ash fertilization results in thickets with high biomass production. However, rotation length (15–30 years) will be much longer than with willows, for example. Coppice regeneration of natural downy birch stands is a cost-efficient alternative, which results in increased biomass production in the subsequent rotation.

Impact of longer-term storage (3–6 months) on forest chip properties. Jylhä, P. (*Finnish Forest Research Institute, Finland; paula.jylha@metla.fi*).

In 2012, 7.6 million m^3 (15.2 TWh) of forest chips were consumed by Finnish heating and power plants. Most chipping takes place during the winter heating season, when consumption of fuel chips is highest. Currently low machinery utilization in summer results in an increased production cost of forest chips. Costs could potentially be reduced by extending operations beyond the heating season. In addition, ensuring a secure supply of forest chips with reserves produced during the thaw seasons is crucial as the demand for biofuels increases. However, the quality of fuel chips decreases with duration of storage. In summer 2013 a field experiment was established in northern Finland to test the quality of whole-tree Scots pine chips and chips made of delimbed Scots pine or aspen. The impact of longer-term storage on dry matter loss and heating value of the forest chips over a 3- to 6-month period was evaluated. Stockpile temperatures and weather conditions were monitored during the follow-up period.

The storage of Scots pine forest chips – CO_2 fluxes as an indicator of dry matter losses. Jylhä, P., Hytönen, J., Alm, J. (*Finnish Forest Research Institute, Finland; paula.jylha@metla.fi; jyrki.hytonen@metla.fi; jukka.alm@metla.fi*).

Fuel chip quality deteriorates with storage duration. As a consequence, long-term storage is not recommended mainly because of the financial losses associated with a decrease in heating values. The high temperatures recorded in stockpiles indicate increased biological activity, which is manifested as loss of material. Forest chips containing foliage are more susceptible to material losses than forest chips made of stemwood. In the present study, a method based on measuring CO_2 fluxes to quantify dry matter losses and CO_2 emissions was tested in northern Finland. The forest chips tested were made of small-diameter Scots pine, either delimbed or undelimbed. A portable infrared gas analyzer was used to measure weekly CO_2 fluxes from several locations within the stockpiles during the storage period of 3–6 months. Carbon losses were derived from a model that included temperature as its driving variable, and the results were compared with the dry matter losses in pieces of cellulose placed systematically in the chip piles. If there is a strong correlation between CO_2 fluxes and material losses, this method would be a novel way to assess the carbon balance of forest chip production systems, as well as the dry-matter losses within the storage period.

Areas of forest required to maintain sustainable, local wood supplies in Pacific Northwest, USA, communities. Keefe, R., Brooks, R., Smith, A. (*University of Idaho, USA; robk@uidaho.edu; rbrooks@uidaho.edu; asmith@uidaho.edu*).

An analysis was conducted to determine how much forested area is required to provide baseline minimum sustainable timber yields to communities of different sizes in a range of northwest U.S. forest types, in order to establish benchmarks for sustainability. The Forest Vegetation Simulator was used to project current Forest Inventory and Analysis (FIA) plot data forward for 60 years under common silvicultural systems in each forest type. The timberland area requirements for individuals and communities of different sizes to supply their own wood locally were established and summarized spatially. Advancing local wood use is an important opportunity to promote forestry among a general public that values local products. Opportunities for communities to procure local wood from private, state, and federal forestlands for sustainable timber production are discussed.

Effects of elemental composition in wood and different tree compartments on the quality of chips for fuel. La Porta, N., Cerasino, L. (*Edmund Mach Foundation, Italy; nicola.laporta@fmach.it*; *leonardo.cerasino@fmach.it*).

Biomass combustion produces such pollutants as particulate matter, NO_x, and ozone, which severely affect air quality. In this context, the elemental characterization of wood and the element allocation among tree components can provide important information about the quality of the derived wood fuels and give insight into the choice of the most appropriate combustion technique and the right wood fuel for a given combustion technique. Moreover, knowledge of the different concentrations of elements in the different plant tissues can lead to the identification of the best harvesting strategy aimed at producing wood fuel with the lowest possible environmental impact. This work focused on the allocation in three tree compartments (foliage, branches, and stem) of five important macroelements (K, Mg, Ca, N, and P) in Norway spruce (*Picea abies*), and pointed out the possible effects of different harvesting strategies and tree age on the quality of the wood fuels. Results showed that the stem-only harvesting system is preferable to whole-tree harvesting in terms of mineral content loss. Results also showed that it is preferable to avoid biomass from young trees because of the poorer fuel quality of the wood chips.

Mapping of forest disturbance in northeast China using time-series remote sensing data. Li, S., Liu, Q., Li, Z., Chen, E. (*Chinese Academy of Forestry, China; lism@caf.ac.cn; liuqw@ifrit.ac.cn; lizy@caf.ac.cn; chenerx@caf.ac.cn*).

Forest disturbance caused by natural or anthropogenic factors is one of the important drivers of change in the structure and function of forest ecosystems and forest carbon dynamics. The high temporal and spatial variability of forest disturbance events

and of forest biomass loss is a major source of uncertainty in understanding the global carbon cycle. Changes in land surface reflectance and temperature can be attributed to changes in the biophysical characteristics of terrestrial surfaces and can indicate pre-disturbance and post-disturbance conditions. This study uses a forest disturbance index model and object-based image analysis to detect forest disturbance areas in northeast China and to map disturbance severity in a given year by combining time series MODIS vegetation index data and land surface temperature data. The model will then be validated with ground observation data or high spatial resolution remote sensing data.

Technical and technological evaluation of forest areas for machine timber harvesting on the basis of the Cone Index (CI) in European forestry. Lubera, A. (*State Forests, Poland; adamlubera@wp.pl*), Sowa, J. (*University of Agriculture in Cracow, Poland; rlsowa@cyf-kr.edu.pl*).

The previous decade could be called a "decade of multi-operational machines." In that period, the number of harvesters and forwarders used in European forestry increased considerably. Depending on the country, the shortwood volume intended for harvesting is estimated at 20–80% of the total timber harvest in a given year. Given these estimates, it is necessary to determine the types of forest habitats in which the use of multi-operational machinery will bring an economically acceptable return of these machines in the forest environment. One of the most important effects of machine harvesting on the forest environment is the impact on soil. To evaluate the technical and technological impacts of mechanized harvesting on forests, the present study uses the Cone Index (CI) values obtained during field measurements using the 06.15.SA penetrometer (manufactured by Eijkelkamp Agrisearch Equipment, the Netherlands). Research was located in typical European lowland pine forest habitats. The results were related to U.S. standards (American Society of Agricultural Engineers (ASAE) S313, ASAE EP542) concerning forest soil types for the use of multi-operational machines in timber harvesting. The method and characteristics obtained will allow the technical and technological evaluation of forest areas through forestry activity.

Analysis of traffic performance in forest roads using computational methods. Machado, C. (*Federal University of Viçosa, Brazil; machado@ufv.br*), Oliveira, R. (*Federal University of Piauí, Brazil; robinho@terra.com.br*).

Forest roads are the main way of connecting forests and companies. Therefore, there is a need for defining not only the required maintenance activities, but also the exact time for such intervention. Starting from this premise, this paper presents the results of an assessment of two methods of classifying the quality of unpaved roads. The objective was to determine which one better reflects actual conditions and thus can serve as the basis for a management system for unpaved roads. Main defects in forest roads were measured following the unsurfaced road condition index (URCI) method. Data collected formed a database for testing the efficiency of using artificial neural networks (ANN) in the management of forest roads with the goal of minimizing costs and traffic stoppage. It was concluded that the performance of ANN was superior to that of the URCI method.

Durability of chemically stabilized soils for forest road applications. Machado, C., Portugal, C. (*Federal University of Viçosa, Brazil; machado@ufv.br; carlamacport@terra.com.br*), Portugal, R. (*Oregon State University, USA; rsallesp@terra.com.br*).

The durability properties of mixtures of two soils for forest road applications were investigated using laboratory wetting and drying durability tests. Soil mixtures were as follows: soil stabilized with industrial waste grits; soil improved using lime or cement; and soil stabilized with grits and improved using lime or cement. Grits content was 24% in relation to soil dry mass. Lime and cement contents were 10% and 20%, respectively, in relation to grits dry mass. Specimens were compacted at the standard and modified Proctor effort, and mixture specimens were cured for 7 days in a climate-controlled room. The testing program data showed that the soil-lime, soil-cement, soil-grits-lime, and soil-grits-cement mixtures endured all cycles in the durability test. Mixtures of soil 1 and lime compacted at the modified Proctor effort presented the best mechanical response in the durability tests, showing losses of approximately 7%. For soil 2, the best result was for the soil-grits-cement mixture compacted at the modified Proctor effort, showing losses of approximately 9%. To meet durability standards, the soil-grits mixtures showed potential for road engineering applications only in association with lime or cement.

Evaluation of the wood hauling logistic performance in farm forest areas using Petri net. Machado, R., Machado, C., Gomes, M. (*Federal University of Viçosa, Brazil; raianemachado@ufv.br; machado@ufv.br*; *mgommez@terra.com.br*), Portugal, C. (*Oregon State University, USA; carlamacport@hotmail.com*), Portugal, R. (*Oregon State University, USA; rsallesp@terra.com.br*).

The present work uses a model of logistic performance to evaluate production chains centered on the operational cycle time elements of wood transport. A cellulose-producing company in the state of Minas Gerais, Brazil, was used as a case study. The model of chain logistics of wood transport used the Temporal Petri Net for working with two times that correspond to a sensitization period. Their properties are as follows: simulation, dynamic; determinist; continuous; and temporal in the transitions. Scenarios, with the same variations in the two wood-producing regionals were created, to evaluate the operational and economic performance. Rio Doce and Cocais das Estrelas The variations applied to the scenarios were: improvement of the forest roads; increased number of loaders, and improvement of garage efficiency. For both regionals, the scenario with the three variations presented the largest reduction in cycle times of wood transport in relation to the current situation, being 19.24% and 21.48%, respectively, for Rio Doce and Cocais das Estrelas. The analyzed operational cost is the value paid for the freight, not including the investment costs. Both regionals, Rio Doce and Cocais das Estrelas, presented a larger reduction in the Scenario 7, of 20.09% and 21.22%, respectively.

Ergonomic evaluation of skyline models used in forest extraction. Machado, R., Machado, C. (*Federal University of Viçosa, Brazil; raianemachado@ufv.br; machado@ufv.br*), Penna, E. (*Federal University of Mato Grosso, Brazil; penna@yahoo.com.br*), Portugal, C. (*Oregon State University, USA; carlamacport@hotmail.com*).

This study was conducted at a forest company, located in the municipality of Cerro Azul, Paraná, Brazil. The objective of this study was an ergonomic evaluation of three skyline models, K301, K501, and K601 used in the extraction of whole *Pinus* spp.

trees in mountainous regions. The study was based on a questionnaire completed by the operators of three existing towers. Respondents were asked to evaluate the following variables: access to cabinet work, working position of the operator, operator seat, controls and instrumentation, climate in the cabin, cockpit visibility of the field, exhaust fumes and dust, and vibration. The K301 and K501 models do not meet ergonomic standards; therefore, their operators are susceptible to work-related risks. The K601 model has satisfactory ergonomic conditions.

Thinning of Norway spruce stands under changing climate. Mäkinen, H. (*Finnish Forest Research Institute, Finland; harri.makinen@metla.fi*), Sirén, M., Ala-Ilomäki, J., Lamminen, S. (*Finnish Forest Research Institute, Finland; matti.siren@metla.fi, jari.ala-ilomaki@metla.fisami.lamminen@metla.fi*), Mikkola, T. (*University of Helsinki, Finland; tuomas.mikkola@helsinki.fi*).

In Finland, 60% of logging is carried out while the soil is frozen, because Norway spruce stands are susceptible to logging damage and soil compaction. The anticipated climate change has raised the question of whether a dry autumn would be a better season for thinning than a mild winter with little snow but high soil moisture. Two harvester working methods were compared in the thinning of Norway spruce stands. In the normal harvester working method, trees removed farther away from the strip roads were processed outside the strip roads. In the protective method, the harvester processed as many trees as possible on the strip road. The protective harvester working method increased the harvester time consumption by 5%, but a higher proportion (86–92%) of the total logging residue potential was brought to the strip roads. The proportion of damaged trees exceeded 4%, the limit recommended for forestry operations. After two to four forwarder passes, the proportion of deep ruts remained low. It was concluded that the prerequisites for a successful thinning on unfrozen soil are favourable weather, soil, and stand conditions. On dry soils with high bearing capacity, ruts remain shallow. Furthermore, a high amount of logging residue decreases rut formation.

Opportunities and challenges in evaluating medium-term climatic impacts: the U.S. Northern Forest Futures Project. Moser, W.K., Shifley, S. (*U.S. Forest Service, USA; wkmoser@fs.fed.us; sshifley@fs.fed.us*).

As discussions of hypothesized climate change move from the theoretical to the applied, questions arise as to how the forested landscape might be changed. Challenges stem from separating demographic, economic, and normal ecological succession effects from the effect of medium- and long-term changes in regional and local temperature and precipitation regimes. The Northern Forest Futures Project (NFFP) seeks to accomplish this very task for the medium term (2010–2060) for the north-central and northeastern United States. With 69 million ha of forestland and 124 million people, this region is the most densely forested and most densely populated quadrant of the United States. The NFFP looked at ecological, climatological, demographic, and economic factors that the U.S. Forest Service predicts will be extraordinarily influential in large-scale northern forest management needs over the next 50 years. This presentation highlights several of those factors, including: (1) decreasing age class diversity, (2) decreasing forest land area, and (3) the likelihood that management intensity for timber will not change and thus is unlikely to materially influence the first two factors. The advantages and limitations of these types of studies are discussed, and what can be predicted and what cannot are pointed out. In the next several decades, climate change appears to complicate current ecological and demographic trends, rather than radically redirecting them.

Critical factors in damage to the environment from the production chain of charcoal in Brazil. Mota, F., Castro, A., (*University of Brasília, Brazil; fabriciacmm@yahoo.com.br; antonio.gomesdecastro@gmail.com)*, Pereira, R. (*University of Brasília, Brazil; reginaldosergiopereira@gmail.com*), Braga, C. (*National Confederation of Agriculture, Brazil; camila.braga@cna.org.br*), Almeida, G. (*University of Brasília, Brazil; gloriaalmeidaflorestal@hotmail.com*), Mota, D. (*Federal University of Lavras, Brazil; diegomenezmota@gmail.com*).

Research in the production chain of charcoal is needed to detect bottlenecks and suggest initiatives aimed at increasing sustainability. The aim of this study was to identify the critical factors, both technological and non-technological, leading to environmental damage from the production chain of charcoal in Brazil derived from planted forests. The methodology consisted of diagnostic analysis of the charcoal production chain, through the analysis of secondary data and interviews with experts and the panel-of-judges method to identify the critical factors. The critical technology-related factors of environmental damage were the (1) lack of production of ovens for recycling gas and (2) lack of development and incorporation of new technologies. New technologies are expensive to develop and adopt, making innovation impractical both for larger firms and for smaller independent producers of charcoal. Low production of charcoal from planted forests was considered a critical non-technological factor.

Forest woody biomass collection through a bundling process in a mountainous area. Nitami, T. (*University of Tokyo, Japan; nitami@fr.a.u-tokyo.ac.jp*), Kondo, R. (*Dream Works, Co. Ltd., Japan; kondo@dw-net.co.jp*), Suzuki, K. (*Amerika-ya Co. Ltd., Japan; amerikaya@able.ocn.ne.jp*).

This work considered operations for the collection of woody residue for energy use after logging in a mountainous area of Japan. Residue was bundled by a truck-mounted bundler. Scheduling the machine was easy and efficient because of its mobility. The use of GIS in making a feasible operation schedule is discussed. Each bundle of woody residue contained about 500 kg of biomass in a thick log shape that was compressed into one-third of the original volume of slash. Bundles were kept at the side of the forest roads. Storing them in the forest avoided the need for additional storage space at the site of the energy plants, which are typically located in an urban area. Collection of this woody biomass for energy must be balanced with local people's needs, such as fuel for home heating. Collection operations on a business scale are discussed. Timber harvesting operations in the region are also discussed, with attention to forest road networks in this mountainous area.

Log distribution planning for efficient wood supply chains. Opferkuch, M., Smaltschinski, T. (*University of Freiburg, Germany; martin.opferkuch@fobawi.uni-freiburg.de; thsm@gmx.de*), Müller, M. (Bavaria State Forest Enterprise*, Germany; martin.mueller@baysf.de*), Jaeger, D. (*Albert-Ludwigs-University, Germany; dirk.jaeger@fobawi.uni-freiburg.de*).

Supply chain performance is increasingly evaluated by energy efficiency and environmental aspects in addition to economics. Transport plays a key role in all forest biomass supply chains as a major cost factor, energy user, and origin of emissions. Three-fourths of the Bavaria State Forest Enterprise (BaySF) annual cut volume of 5 million.m³ of timber is processed at a single

mill. Traditional planning shows little flexibility in the face of major market changes, such as after calamitous events. The total transport distance of 19 million km for 3 million m³ of softwood assortments is associated with enormous costs, energy consumption, and emissions. Optimal distribution planning requires solving the transportation problem so that demand for forest biomass is met and the raw materials are distributed to customers' sites at minimal transport distance. Optimal distribution planning has been realized with operations research methods such as linear programming and combinatorics. Including back freight optimization the average transport distance for cargo and empty runs was reduced from 175 km to 139 km with savings in costs, energy, and emissions of up to 24%. This method has been successfully applied at BaySF since 2013 for annual log distribution planning and weekly dispatching. The proposed transport optimization increases supply chain performance and helps the forest products industry maintain its good ecological reputation.

Use of LiDAR technology to create a management plan for an urban park in Belo Horizonte, Minas Gerais, Brazil. Petean, F.C.S., Silva Filho, D.F., Polizel, J.L., Görgens, E., Zanlorenzi, H.C.P. (*University of São Paulo, Brazil; coelho.petean@gmail.com*), *dfilho@usp.br; jlpolize@usp.br, gorgens@usp.br, helenapz@usp.br*).

Treefall from wind is one of the main problems identified by managers of urban forests and parks, who are increasingly using remote sensing tools to assist in the management of these areas. The present study aimed to create a management map of an urban park in the city of Belo Horizonte, Minas Gerais, Brazil, which highlights areas that represent greater risk to visitors from falling trees and branches due to wind action. After the LiDAR data were converted, normalized, and filtered, a digital canopy model (DCM) was extracted from the point cloud, transformed into an image file, and then classified according to tree height. The wind circulation pattern of the site was calculated using the DCM height information. The areas more susceptible to falling trees and branches were identified through analysis of the layout of the park (e.g., paths, common areas, and recreational areas), the image classified by tree height, and the wind circulation pattern image. Finally all the data were put together to complete the park's management map as a tool for facilitating the decision-making process.

Slope restrictions on land-use practices: consequences for Borneo of different definitions and limits. Putz, F. (*University of Florida, USA; fep@ufl.edu*), Griscom, B., Ellis, P. (*The Nature Conservancy, USA; bgriscom@tnc.org; pellis@tnc.org*).

Tropical silviculture is being driven into the hills by increases in both global populations and per capita consumption of food, fuel, and fiber. With increased slope angles and lengths, the likelihood of erosion and mast-wasting events increase, logging costs escalate, and problems with logging damage are exacerbated. Unfortunately, most slope-related environmental guidelines promulgated by governmental and non-governmental bodies are unclear. Rather than prohibiting specific activities on slopes above a specified grade, most guidelines recommend adoption of appropriate timber yarding (e.g., switching to aerial systems). Another common deficiency is that slope lengths (or the areas over which slopes are averaged) are not specified. In Indonesian Borneo we used aerial LiDAR to construct digital elevation models (DEMs) with different pixel sizes for five timber concessions. The proportion of those concessions with slopes >40% (the legal limit on ground-based harvesting) ranged from 35 to 85% for 1 m pixels and 12 to 60% for 30 m pixels. The pixel size effect decreased with topographic rugosity. A DEM constructed for the same areas with Aster data (30 m pixels) underestimated slopes measured on the ground and with LiDAR by 10–50%. If the DEM is applied to all production forests in Kalimantan, however, about 20% of their area is on slopes >40%.

Impacts of forest resource competition on future bioenergy production in Austria – answers from a system dynamics model. Rauch, P. (*University of Natural Resources and Life Sciences, Austria; peter.rauch@boku.ac.at*).

Uncertainty will increasingly affect outcomes of forest management decisions. Research on methods that incorporate uncertainty into forest planning models is of increasing relevance. Storms and bark beetle infestations are the most significant causes of forest damage in Central Europe, and have a massive impact on the security of the wood supply. Recent trends such as restrictions on imports, new competitors (e.g., wood plastic composites and biomass to liquid) for raw material, and rising demand for wood for bioenergy production further threaten the security of the wood supply. In order to assess risks and their mid- and long-term impacts on wood supply a system dynamics model of the Austrian wood supply was developed that includes a stochastic simulation of the main risk agents. The model examines the future annual harvests of Austrian forests and evaluates wood supply security under different scenario assumptions. Simulation results provide insights on projected future wood supply security for saw logs and pulpwood used for energy and reveal counterintuitive effects under the climate change scenario. Even though salvaged wood volumes were clearly increasing, the supply of all roundwood assortments declined and supply security decreased because of a marked reduction in wood removals after damaged forest sites had been harvested.

Amount and quality of residue biomass generated in forest harvesting systems for pine and eucalypt plantations in southern Brazil. Sanquetta, C., Sanquetta, M., Dalla Corte, A., Lourenço Rodrigues, A. (*Federal University of Paraná, Brazil; carlos_sanquetta@hotmail.com; mateus.sanquetta@hotmail.com; alourencorodrigues@gmail.com*; *anapaulacorte@gmail.com*), de Miranda, D. (*Federal University of Mato Grosso, Brazil; mirandaufmt@hotmail.com*).

Tactical harvesting planning helps forest companies to improve their performance, reducing harvesting costs and environmental impacts by the rational use of wood residues. Pine and eucalypt are the most important sources of industrial timber in Brazil, producing ca. 270 million m^3 of roundwood a year. This study aimed to inventory wood residues generated by pine and eucalypt harvesting systems in a large-scale forest enterprise. The system for pine was composed of harvester-skidder-slasher and for eucalypt of harvester-forwarder. The study site was the north region of Santa Catarina, southern Brazil. A tactical systematic sampling was applied to sample wood debris in four 17-year-old stands just after harvesting. Log length, diameter, quality (e.g., chipped, broken, rotten, forked) at the stand border and inside it were measured. The pine residue (151.86 and 67.57 m^3/ha, for border and inside, respectively) was much higher than that of eucalypt (22.61 and 23.71 m^3/ha). There was a concentration of debris of pine along the stand border, but it was not noticed for eucalypt. For both genera the wood debris is useable mainly for bioenergy due to low quality and limited size. The main cause of pine residue generation is the slasher, which works close to the stand border.

Assessment of workers' physical workload in semi-mechanized silviculture operations in mountainous regions in Brazil. Schettino, S., Minette, L., Souza, A., Marzano, F., de Moraes, A. (*Federal University of Viçosa, Brazil; stanley.schettino@oi.com.br; minette@ufv.br; amaury@ufv.br; felipe.marzano@ufv.br, angelo.moraes@ufv.br*).

In mountainous regions, forest operations can be performed only by manual or semi-mechanized methods, which present a number of ergonomic problems. A high physical workload, high noise and vibration levels, high forces exerted, awkward postures, and repetitive movements may cause damage to the health and welfare of workers. The objective of the study was to evaluate the operators' physical workload. Operations analyzed were semi-mechanized hole digging and semi-mechanized weed cutting, in eucalyptus plantations. The workers' heart rate was measured during the work day in the mountainous terrain of a pulp production company in Brazil. These data were used to calculate the cardiovascular workload (CVW) following an appropriate methodology. According to this methodology, the CVW limit is 40%, which represents the heart rate during labor as a percentage of the maximum usable heart rate. The CVW for the hole-digging operation activity was calculated as 50%, exceeding, the limit. This value corresponded to a heavy physical workload, requiring reorganization of the work by introducing breaks for resting. The weed-cutting operation had a lower CVW and did not require work reorganization.

A transferable framework to interpret quality results of large data sets. Smith, D., Metzger, S., Taylor, J. (*National Ecological Observatory Network, USA; dsmith@neoninc.org; smetzger@neoninc.org; jtaylor@neoninc.org*).

The ability to assess data validity is essential to any investigation. Manual "eyes on" assessments of data quality have been dominant in the past. Yet, as data set sizes continue to increase, so does the time required to assess their quality. This has resulted in the automation of many quality assurance and quality control (QA/QC) analysis frameworks to assess data quality. Unfortunately, the interpretation of quality results from QA/QC analyses can become quite challenging with large data sets. Therefore, the authors have developed an automated framework to summarize data quality information and facilitate user interpretation. Briefly, the framework consists of first compiling data quality information and then presenting it through two separate schemes: a quality report and a quality summary. The quality report presents the results of specific quality analyses as they relate to individual observations. The quality summary takes a spatial or temporal aggregation of each quality analysis and provides a summary of the results. Included in the quality summary is a final quality flag, which uses a predetermined threshold to assesses whether the observations used to create a data product are valid. Furthermore, this framework can aid in problem tracking and resolution, should sensor or system malfunctions arise.

Production target for workers using hole-digging machines to plant eucalyptus seedlings, as a function of ergonomic factors. Souza, A., Marzano, F., Minette, L., de Moraes, A., Schettino, S. (*Federal University of Viçosa, Brazil; amaury@ufv.br felipe.marzano@ufv.br; minette@ufv.br; angelo.moraes@ufv.br; stanley.schettino@oi.com.br*).

The objective of this study was to determine the production target for workers operating hole-digging machines for planting eucalyptus seedlings in Brazil, as a function of ergonomic factors. The methodologies for motion and time study and ergonomic work analysis were used to quantify and qualify the effect of each of six ergonomic factors on operators' capabilities during an 8-hr work shift. The factors analyzed were vibration, noise, physical work load, heat, repeatability, and forces and postures. Results indicated that the values obtained during the work day for all factors except repeatability for the established production target of 800 holes, exceeded the workers' physical capabilities. The critical factor was vibration, which caused 60% of the rest breaks per shift. These rest breaks may include performing lower level workload activities, except those related to the critical factor. The production target was adjusted to the new work system. Thus, the effective work turn time should not exceed 40%. In this case the production target should decrease from 800 holes to 667 per turn to avoid health problems due to excessive vibration.

A case study of wood fuel utilization by community forestry for sustainable, cost-effective management of a local forest in Japan. Takamura, K., Mori, D. (*Kochi University, Japan; b13m6f29@s.kochi-u.ac.jp, b104m153@s.kochi-u.ac.jp*), Gotou, J. (*Kochi University, Japan; ryosuke@kochi-u.ac.jp*), Suzuki, Y.K. (*Kochi University, Japan; ysuzuki@kochi-u.ac.jp*).

High-performance mechanized operations are generally considered necessary both for reducing costs and for increasing profits in forest operations. However, especially for community forestry, it can be effective to use operation methods that do not have high efficiency but that require only low investment. Self-hired labor can reduce costs; in contrast, if one hires employees and uses corporate-style management, higher profits would be required to pay for labor and management. A case presented in this paper is a woody biomass utilization system in a local community in Kochi, Japan. In this system low-quality residue logs are recovered and processed for fuel by community members, and then burned with high-efficiency wood fuel boilers operated in a local community center. The large amount of money formerly used to pay for imported fossil fuel, now goes instead for wood fuel produced in the area. Utilization of low-quality logs gives community members an incentive to manage local forests, for example, by commercial thinning and small-scale final cutting. In this case management of community forests by local people leads to sustainable management of the forests.

Analyzing the potential and use of forest waste biomass in the production of clean energy in Nepal. Uprety, D. (*Multi Stakeholder Forestry Programme, Nepal; dharam.uprety@gmail.com*).

Forest management operations and clearing of invasive shrub species by forest users are the sources of forest waste biomass, used as raw materials in bioenergy production in Nepal. Nepal imports 420 000 metric tons of coal annually, and brick-making operations are the largest consumers. Forest waste biomass can be an alternative source of energy. The total biomass of stems, branches, and leaves is an estimated 429 million metric tons (air dry) in Nepal and hence several private enterprises have initiated production of bio-coal in different forms. A study carried out in early 2013 in seven districts of Nepal in order to know the potential of forest waste biomass found that 76% of community forests in Nawalparasi, 49% in Rupandehi, 22% in Kapilvastu, 34% in Parbat, 60% in Baglung, 88% in Myagdi, and 25% in Dang have potential for the production of bio-coal. This paper gives an overview of how local communities and the private sector have developed ways of producing bioenergy, and provides insight into how such initiatives contribute to meet energy demands in Nepal.

Establishment of logistics for an economical bioenergy supply chain in Japan. Yoshida, M. (*University of Tokyo, Japan; yoshida@fr.a.u-tokyo.ac.jp*).

Logistics is an important issue for the economic success of the bioenergy business. The increasing demand for forest biomass for energy use is expected to intensify forest management. Forestry companies and the Japanese government have promoted mechanization of forestry and introduced forestry equipment from abroad in order to achieve high productivity. However, the density of forest roads across Japan remains low, and road width is often inadequate because of difficult, steep terrain. Therefore, full use of forestry machinery and vehicles has not been reached in Japan. It is also important when establishing efficient bioenergy logistics to understand the differences between transportation methods available for forest roads versus public roads, and differences in the distribution of biomass among logging systems. This study investigated available biomass production and transportation methods including the newest equipment, and calculated production and transportation costs of different systems based on the condition of the forest road network and terminal landing. Then, the appropriate logistics for the bioenergy supply chain was discussed for the first stage of bioenergy utilization in Japan.

GENERAL POSTER SESSIONS

IUFRO Division 4: Forest Assessment, Modeling and Management

Potential of canopy stratification in modeling planted forests in a changing world: application to pine plantations in Nigeria. Adesoye, P. (*University of Ibadan, Nigeria; adesoyepet@yahoo.com*).

Canopy stratification is an important concept in tropical forest ecology. Views differ considerably on the existence and identification of canopy strata. Canopy stratification studies have focused on mixed forests. Little has been done to investigate canopy stratification in pure plantations. This paper investigates the existence and potentials of canopy stratification for improving yield models under pure plantations. Pine plantations in Oluwa Forest Reserve, Ondo State, Nigeria were investigated. Individual tree growth variables, including diameters, heights, crown measurements, and inter-tree competition measures were obtained in 2010 on twenty-five 0.04-ha plots representing five different stands planted between 1979 and 1991. Visual assessments of the trees within each plot were also done to classify them into four strata (i.e., dominant, co-dominant, intermediate, and suppressed). Tree variables under the canopy strata were analyzed using ANOVA, while yield models with and without canopy stratification were tested using regression analysis. Significant differences were observed among the canopy strata in terms of mean DBH, basal area, stem volume, and competition index. The yield models for the different canopy strata had the least prediction error sum of squares compared to the model for the pooled trees. It was found that canopy stratification improved model accuracy.

A simplified method for assessing forest health changes during 7 years using *Triplochiton scleroxylon* stands in southwest Nigeria. Adesoye, P. (*University of Ibadan, Nigeria; adesoyepet@yahoo.com*).

Forest health assessment is one of the major steps in ensuring sustainable management of forests. However, there are many divergent perspectives on the choice of forest health indicators. This paper presents a simplified approach to forest health assessment. The stands investigated were located in the experimental station of the Forest Research Institute of Nigeria, Onigambari, Oyo State. Some forest health indicators were formulated and assessed in 2006 and 2012 on fourteen 0.04-ha plots in four different stand ages planted between 1973 and 1976. The measured indicators included tree stability, stem vigour, incidence of crown injury, tree density, and incidence of leaf or stem damage from disease or harmful insects. Climatic data between 2005 and 2011 were also obtained for the station. The results indicate an increase in the number of trees/ha susceptible to wind throw between 2006 (27 trees) and 2012 (38 trees). Number of trees/ha in the high vigour class dropped from 18 in 2006 to 13 in 2012. Incidence of crown injury/ha decreased from 96 cases in 2006 to 54 in 2012. An increasing trend was observed in annual precipitation. Health implications and strategies for management are discussed in the paper.

Evaluation of carbon content in forests of northeastern Mexico. Aguirre Calderón, O., Jiménez Pérez, J., Treviño Garza, E., Alanis, E (*Universidad Autónoma de Nuevo León, Mexico; oscar.aguirrecl@uanl.edu.mx; javier.jimenezp@uanl.mx; eduardo.trevinogr@uanl.edu.mx;. alanis_eduardo@yahoo.com.mx*).

The objective of this study was to communicate some initial lessons about the practical challenges of designing and conducting measurements of carbon pools in Mexico. Equations of biomass as a function of the typical diameter for *Pinus pseudostrobus*, *P. teocote*, and *Quercus* spp. were developed for temperate forests of northeastern Mexico. Carbon content of the species was determined with an organic carbon analyzer. The results allowed the construction of biomass and carbon content tarif tables and charts, through which carbon contained in tree species of pine-oak mixed forests, oak-pine mixed forests, and pure pine stands was evaluated. The carbon percentage in *P. pseudostrobus* was 50.35, in *P. teocote* 47.78, and in *Quercus* spp. 48.43. Carbon content tables for pure stands of the two pine species were built for different site indices. The results of the carbon content evaluation in different types of forest were: pine-oak forests 45.24 Mg/ha, oak-pine forests 64.20 Mg/ha, pure forests of *P. pseudostrobus* 73.18 Mg/ha, and *P. teocote* forests 47.01 Mg/ha. Two inventory techniques for the estimation of forest carbon in different forest structures are discussed, and field measurement guidelines for mixed and pure stands are presented.

Systematic review of impacts of the white spruce tree improvement program in the boreal forest of Canada: A meta-analytical approach. Ahmed, S., LeMay, V., Bull, G. (*University of British Columbia, Canada; suborna@alumni.ubc.ca; Valerie.LeMay@ubc.ca; gary.bull@ubc.ca*).

Tree improvement programs in Canada started in the early 20th century, but the specific starting dates, species, and processes differ among provinces. As a result, there is not yet a common framework for measuring gains from tree improvement programs. Further, data for all trials in all provinces have not been amalgamated or summarized across trials. In this study, data from white spruce (*Picea glauca* (Moench) Voss) tree improvement programs across the boreal forest of Canada were combined and analysed using a meta-analytic approach. The combined database includes meta-data extracted from publications for >60 sites and 400 white spruce and white spruce hybrid provenances from six provinces of Canada with active white spruce tree improvement programs. These meta-data were used to quantify any gains achieved from selection, specifically, the expected yield improvements through first-generation genomic selection, using a hierarchical mixed-effects model. A major challenge in estimating the selection gain is that most trials are still very young relative to rotation ages currently used for white spruce in Canada. Therefore, this work also examined the use of age-to-age correlations using an error correlation structure for varying measurement intervals to improve models.

Effect of pistachio canopy on the spatial distribution of soil chemical characteristics in the Zagros forests of Iran. Akhavan, R. (*Research Institute of Forests and Rangelands, Iran; akhavan@rifr-ac.ir*), Tahmasebi, M., Hosseini, V. (*University of Kurdistan, Iran; tmaryam56@yahoo.com; vahidit@yahoo.com*).

In arid and semi-arid ecosystems, isolated trees have an important effect on soil properties and can determine the structure of the soil fauna and herbaceous communities under the tree. The aim of this study was to understand the effect of pistachio canopy on

the spatial distribution of soil nutrients (organic carbon, N, P, K), as well as Na and Li. Soil samples were taken under and around a pistachio (*Pistacia atlantica* Desf.var.*Kurdica*) tree in the Zagros region of western Iran. The samples were taken every 2 m and then at 50-cm intervals in a regular grid of 20 m × 20 m around the tree, in order to analyze the spatial properties using geostatistics. Total N content and soil organic carbon were higher under the tree canopy. Phosphorus content also was higher under the tree. Potassium decreased with distance from the tree base. Sodium had a medium spatial distribution related to tree canopy; Li showed a sparse spatial pattern and its distribution seems to be independent of the tree position. These results support the hypothesis that the presence of a tree differentially affects the spatial distribution of the various nutrients depending on their chemical characteristics.

Three experiences with geostatistics application for estimation and mapping of forest stock in the Caspian region of northern Iran. Akhavan, R. (*Research Institute of Forests and Rangelands, Iran; akhavan@rifr-ac.ir*).

The purpose of this paper was to compare the application of geostatistics for estimation and mapping of forest stock attributes among a natural hardwood unmanaged forest (intact without any intervention), a natural hardwood managed forest (harvested two times), and a plantation forest (18-year-old pure maple) in the Caspian region of northern Iran. Different systematic grids with proportional plot sizes were set up for sampling. Experimental variograms were calculated and plotted for basal area (BA) and stem density in these forests based on the inventoried georeferenced plots fitted by appropriate models. Estimation and mapping were made by ordinary block kriging and evaluated by cross-validation. Results showed that there is no spatial structure for BA and stem density in the natural managed forest. In the natural unmanaged forest spatial structure was found only for stem density, and in the plantation forest spatial structure was found only for BA. Therefore, it was concluded that geostatistics is able to capture and accurately describe the spatial variability as well as estimates and maps for some tree attributes in unmanaged and plantation forests; however, due to high spatial variability, it has no application in managed forests.

Ecological adaptation of the shea butter tree (*Vitellaria paradoxa* C.F. Gaertn.) along a climatic gradient in Benin, West Africa. Akpona, T. (*University of Abomey-Calavi, Benin; ajeandidier@gmail.com*).

This study assessed the ecological adaptation of shea butter trees based on their dendrometric and production traits in four shea parks established in different climatic zones of Benin. A total of 99 rectangular plots of 50 m × 30 m were established within the four parks using a random sampling scheme. In each plot, all trees with DBH 10 cm were inventoried and measured for stem and crown diameters, and total height. Production of 120 productive shea trees was quantified in the four parks. Data collected were used to compute structural parameters for each park. Moreover, stem diameter and height structures of the trees were established. Principal component analysis was performed on the dendrometric variables and the first three components were correlated with climatic parameters. Results revealed significant differences between parks in most of the dendrometric and production parameters of shea trees. For all four parks, stem diameter and height structures present a Gaussian shape; for Sudanian parks, the curve has left dissymmetry. In regions with relatively high rainfall and relative humidity, shea trees developed large crowns, but produced few fruits whereas in the drier regions, the opposite trend was observed.

Tree cork caliber evolution in two consecutive cork extractions: trends and possible causes. Amaral Paulo, J., Tomé, M., Pereira, H. (*Technical University of Lisbon, Portugal; joanaap@isa.utl.pt; magatome@isa.utl.pt; hpereira@isa.utl.pt*).

The objective of the study was to research the influence of precipitation, tree variables, site characteristics, and debarking intensity on the evolution of cork caliber at the individual tree level. A mixed model approach was used in addition to partial least squares analysis. In 23 permanent plots two consecutive cork extraction operations were followed and cork samples were collected. The cork samples, from a total of 357 trees, covered growth years from 1984 to 2010. Since cork samples presented different numbers of years of growth, cork caliber was evaluated with the trough cork growth index (CGI). It was demonstrated that mean CGI from the two consecutive cork extractions, at plot level, decreased significantly in 16 out of the 23 plots for $\alpha = 0.05$. Results show that, although precipitation explained the larger part of the CGI evolution, tree diameter and stand density were also important variables. Debarking intensity was not as important an explanatory variable. The significance of site characteristics indicates that other variables are relevant, pointing out the need for further research.

Validation of five non-linear growth models for plantation-grown *Terminalia superba* in Ibadan, Nigeria. Awosusi, B., Oyeleye, B., Akinyemi, G., Ayodele, O. (*Forestry Research Institute of Nigeria; monisola.bola@yahoo.com; gbemioyebolarinwa@gmail.com; akinyemigab@yahoo.com; yehmmy2010@yahoo.com*).

Five non- linear mathematical models were developed and validated using growth data from one of the indigenous tree species in Nigeria (*Terminalia superba*). The selected models were: Malthusian, Gompertz, logistic, Von Bertalanffy, and Richard. These non-linear growth models were used to predict tree height using tree age as the independent variable. Methods of integrating the differential forms of the models used were also reviewed. Parameters of the models were estimated using the Marquardt iterative method of non-linear regression relating tree height to age. The data used were collected from the Forestry Research Institute of Nigeria, Ibadan, Nigeria. Formulas that provide good initial values of the parameters are specified. It was discovered that the logistic model showed very promising results. It fitted the data very well with a smaller relative standard error (0.4797) and higher R^2 (0.899). Results suggested that the models derived were statistically and biologically acceptable and could be satisfactorily used to predict tree height. The results also show the fundamental importance of growth models in forestry since any of the models here can be used to predict the tree growth and yield at a very early stage.

Climate change impact in the Uruguayan forest sector: an empirical evidences analysis. Bennadji, Z. (*Instituto Nacional de Investigaciónes Agropecuarias, Uruguay; zbennadji@tb.inia.org.uy*).

Since 1990, Uruguay has undertaken actions on climate change mitigation and adaptation, especially in the policy area. At the international level, Uruguay subscribes to the United Nations Framework Convention on Climate Change and complies with the preparation of periodic national-scale reports on greenhouse gas emissions. At the national level, an inter-ministerial committee

was created to follow up on the climate change impact on the main economic activities in the country. However, information for the forest sector was too scarce to allow any objective assessment of its exposure, sensitivity, and adaptive capacity to climate change. The objective of this work was to present empirical evidence as the basis of an analysis of climate change impacts in *Eucalyptus* and *Pinus* spp. plantations. The relationship between disturbance of forest tree phenology and growth, pest outbreaks, and extreme frost, drought, rainfall, and storm events from 1998 to 2012, and temperature and precipitation variations as the main climatic factors was investigated. The aim was creation of the first long-term data series in the country on climate change impacts on forest plantations. The need to consolidate this data series for use in modeling and prediction of climate change impacts on forest plantations at the local level and as a tool for practitioners is discussed.

'Carbon debt' – lost in the forest? Bentsen, N., Graudal, L., Madsen, P., Felbu, C. (*University of Copenhagen, Denmark; nb@ign.ku.dk*; *lgr@life.ku.dk; pam@ign.ku.dk; cf@gmail.com*).

The concept of 'carbon debt' and carbon payback time with reference to bioenergy and biofuels was probably launched by an article in Science in 2008. The concept is increasingly seen as an indicator of the sustainability of bioenergy supply chains. Particularly for forest bioenergy supply chains the time lapse between harvest and regrowth may be a significant factor for the modeled carbon debt. A meta-analysis of more than 250 model scenarios was conducted to evaluate the factors and assumptions determining carbon debts and payback time of forest bioenergy supply chains. Factors such as spatial and temporal scale, biome, origin of the wood resource, which fossil fuels are displaced, forest history, baseline scenario, accounting principle, and data background were included in the analysis. This paper discusses the evolution of the carbon debt concept, how different factors and assumptions influence the outcome of carbon debt studies, the reproducibility of carbon debt analyses, and the applicability of the concept as a measure of sustainability of forest bioenergy supply chains.

Assessing forest change across Canada using successive kNN-based maps of imputed forest inventory data. Bernier, P., Beaudoin, A., Guindon, L., Villemaire, P., Stinson, G. (*Canadian Forest Service, Canada; pbernier@rncan.gc.ca; abeaudoin@nrcan.gc.ca*, *lguindon@rncan.gc.ca; philipe.villemaire@rncan.gc.ca; graham.stinson@nrcan.gc.ca*).

The authors recently produced a suite of national maps of forest attributes for Canada at a resolution of 250 m for the 2001 base year. The non-parametric kNN approach was applied on a set of Canada-wide layers of predictive variables, most notably multi-spectral information from the MODIS sensor, as well as climate variables, topography, and land cover to impute National Forest Inventory baseline measurement data. Yearly maps at 250-m resolution were also produced showing severe forest disturbances, i.e., yearly areas affected by either harvesting or fire from 2001 to 2011. This paper presents updated maps of forest properties for 2011 and evaluates the extent to which changes between these maps and those for 2001 are able to capture the patterns of changes expected based on the yearly disturbance maps. Limitations of the approach as well as avenues for improvements of the kNN products are discussed.

Estimating stand heights and crown structure of subtropical broad-leaved forest using LiDAR data in Okinawa island, Japan. Binti Ahmad Zawawi, A. (*Kagoshima University, Japan; azitazawawi@gmail.com*), Shiba, M. (*Faculty of Agriculture, University of the Ryukyus, Japan; mshiba@agr.u-ryukyu.ac.jp*), Jemali, N. (*Kagoshima University, Japan; idiana0303@yahoo.com*).

The application of LiDAR to extract data at the single-tree level has long been recognized in providing valuable information about forest stands. Most studies involving crown detection and tree height estimation have focused on analysis of plantations, boreal forests, and temperate forests, and less study has been done in subtropical or tropical forests. This study presents an approach for estimating tree heights, stand density, and crown structure using LiDAR in the complex subtropical forest of Okinawa island in Japan. A digital canopy height model (DCHM) was derived from the LiDAR data for tree height estimation, and the watershed segmentation method was applied for individual crown delineation. Dominant tree canopy layers were estimated using multi-scale filtering and local maxima detection. Information on crown structure characteristics such as crown diameter and fractal dimension was also produced. The computed result was compared to field data and validated using IKONOS imagery over the forest area. The results of this study suggested that LiDAR data have huge capability to estimate tree height in subtropical forests, but were not sufficiently capable in the detection of small understory trees and in single-tree delineation. We found that LiDAR computation results underestimated the frequency of trees and overestimated the crown size.

Comparing alternatives for increasing sampling intensity in forest inventories. Blackard, J., Patterson, P. (*U.S. Forest Service, USA; jblackard@fs.fed.us; plpatterson@fs.fed.us*).

Each of the U.S. Forest Service's Forest Inventory and Analysis (FIA) regions has an occasional need to intensify the national sampling grid. A variety of methodologies exist within the various FIA regions and National Forest Systems regions for constructing plot intensifications, and there is no consensus on a national procedure The primary objectives of this paper were to identify various intensification methods being implemented by FIA or used by other groups, examine their advantages and disadvantages for establishing intensified plots within the existing FIA framework, and recommend a potential national FIA plot intensification procedure that might adequately address the needs for all FIA regions.

Paired catchment experimental methodology: a critique. Bren, L. (*University of Melbourne, Australia; lbren@ncable.net.au*), Nettles, J. (*Weyerhaeuser Company, USA; jami.nettles@weyerhaeuser.com*).

Paired catchment experiments have been around for almost a century. This paper examines how the technique has been used since the first project at Wagon Wheel Gap in Colorado, USA. Recent Australian work on the units and length of the calibration period showed that there is a rapid buildup of information in the first year of calibration and there may be little gain in long calibration periods. For this paper this hypothesis was tested in other countries using international data sets. Errors of measurement with this method were compared to alternative approaches such as plots or modeling. Although the presence of a "control" catchment is a great asset, the assumption of this control as a constant is examined given the long duration of some projects, and supplementary

techniques are suggested. This methodology, when scored against criteria of "experiments" taken from scientific literature, shows that the method is sound but could be improved by a more rigorous protocol of analysis. It is concluded that the technique does have a bright future and that a useful project would be a handbook of procedures, standards, and analytical procedures to facilitate the maximum information gain in such projects.

Estimating carbon storage in forest ecosystems in Poland based on data from the National Forest Inventory. Bronisz, K., Zasada, M. (*Warsaw University of Life Sciences, Poland; karol.bronisz@wl.sggw.pl; Michal.Zasada@wl.sggw.pl*), Neumann, M. (*University of Natural Resources and Life Sciences (BOKU), Austria; mathias.neumann@boku.ac.at*).

The objective of this study was to determine the amount of carbon sequestered by forest ecosystems in Poland based on data from the National Forest Inventory (NFI). The NFI is carried out on permanent plots across Poland on a 5-year cycle. The most recent cycle started in 2010. Detailed data about individual stands are provided regardless of ownership status and stand age. Empirical allometric formulas allow the determination of dry biomass of trees and their components on the basis of tree characteristics (height and diameter). Formulas for Scots pine and birch were based on data from Polish stands. To check the logical assumption of the additive character of those formulas, seemingly unrelated regression was used for their final determination. For other tree species, empirical formulas from different literature sources were applied. Amount of sequestered carbon was calculated basing on ratios suggested by the IPCC (50% of dry biomass). Results show that Polish forests are storing an increasing amount of carbon in the biomass of growing stock. However, the unbalanced age structure is cause for concern about the future status of the forest resource.

Global meta-analysis of forest bioenergy greenhouse gas emissions accounting studies (1991–2012). Buchholz, T. (*University of Vermont & Spatial Informatics Group LLC, USA; tbuchholz@sig-gis.com*), Gunn, J., Saah, D. (*Spatial Informatics Group, USA; jgunn@sig-nal.org; dsaah@sig-gis.com*).

The authors conducted a literature review of 59 studies (145 cases) that investigate greenhouse gas emissions (primarily CO_2) of forest-based bioenergy systems. The goal was to identify main drivers for calculating carbon debt across all studies using classification and regression tree analysis (CART). Studies with conclusions of carbon neutral over time (108 cases or 74% of all cases) determined that the carbon debt payback periods are highly influenced by (1) comparative fossil fuel type, (2) conversion technology, (3) feedstock source (including use of additional harvests or residues and plantation vs. natural forest management), (4) disturbance regimes (including wildfire, pest outbreaks, and climatic events), and (5) history of biomass infrastructure on existing landscapes. The use of dynamic as well as reference point baselines has been persistent throughout the period studied, and conclusions are fairly consistent across a variety of ecosystem types/climatic zones and regions. The scope of individual studies varies widely in analytical detail. For example, leakage was considered in only two studies, and product substitution in only 12 cases. Both pools are highly contentious and can have major impacts on overall results.

Measuring photosynthesis of beech seedlings with field imaging spectroscopy. Buddenbaum, H., Hill, J., Rock, G., Werner, W. (*Trier University, Germany; buddenbaum@uni-trier.de; hillj@uni-trier.de; rock@uni-trier.de; werner@uni-trier.de*).

Regional climate change is expected to cause more frequent occurrences of dryness stress in central Europe. To measure the effects on photosynthesis rate, we measured photosynthesis during the course of a day on one pot of fresh and one pot of dryness-stressed seedlings of beech (*Fagus sylvatica* L., 6 years old). At the same time, hyperspectral VNIR images of the plants were recorded from a 4-m high platform with about 1-mm spatial resolution (25 images in total). The photosynthesis time series was correlated with photochemical reflectance index (PRI) of the trees, calculated from the hyperspectral images. PRI was derived for all leaves and for sunlit leaves and shaded leaves separately. High correlations were found, especially for the shaded leaves. Differences of photosynthesis and PRI between fresh and dry plants were highly significant. PRI proved to be a good estimator for photosynthesis activity and for diurnal development. By transferring the results to mature beech stands in an airborne hyperspectral image and in a space-borne Chris-Proba image, routine measurements of photosynthesis and stress-induced reduction of photosynthesis activity from imaging spectroscopy satellites like the upcoming EnMAP will be tested.

Why aren't we making progress with predicting future forest dynamics? Bugmann, H. (*ETH Zurich, Switzerland; harald.bugmann@env.ethz.ch*).

The future development of forests is of utmost concern from not only a scientific, but also a societal, point of view, and appropriate adaptation measures in the face of climate change are thus hotly debated. Dynamic models have a long and seemingly highly successful history in forest science, but this author argues that their robustness is insufficient to serve as tools for deriving adaptive management approaches in the long term (i.e., beyond a few decades). The ability to model future long-term tree population dynamics is hindered by a number of factors, including the inadequate temporal and spatial scale of experimental approaches, the insufficient length of observational time series, and problems with the formulations of key ecological processes in models of forest dynamics. These factors and ways to handle them were reviewed, with the expectation that predictive understanding can be improved by the skillful combination of approaches and methods. In particular tree mortality was the focus as a process that (1) could lead to dramatic impacts in a world of global change, and (2) has attracted a lot of attention over the past years. The author concludes that although multiple challenges remain, there are promising options to pursue by combining empirical with dynamic modeling approaches.

Multi-scale spatial controls of understory vegetation in Douglas-fir – western hemlock forests of western Oregon, USA. Burton, J., Ganio, L., Puettmann, K. (*Oregon State University, USA; julia.burton@oregonstate.edu; lisa.ganio@oregonstate.edu;Klaus.puettmann@oregonstate.edu*).

Forest understory vegetation responds to numerous drivers that vary and interact over multiple spatial scales. This study examined how broad- to intermediate-scale variability in climate and insolation interacts with fine-scale plant-plant interactions and disturbances to affect spatial patterns of understory vegetation. Furthermore, the study examined how these relationships are mediated by traits of early- and late-seral vascular plant species. The authors used an operational-scale manipulative thinning

experiment replicated seven times in the Coast and Cascade ranges of western Oregon, USA. This paper focuses on patterns observed 6 years following thinning. Early-seral cover was related to interactions among broad-scale variation in climate, intermediate-scale variation in insolation, and fine-scale neighborhood interactions. Late-seral species cover was related primarily to fine-scale neighborhood interactions. Furthermore, cross-scale interactions partially explained patterns of spatial correlation among neighboring subplots for early-seral species but not late-seral species. The authors hypothesize that residual patterns of spatial autocorrelation were related to unmeasured environmental variables for early-seral species and historical conditions (i.e., pre-treatment stand composition and structure) for late-seral species. Results suggest responses of understory plants to overstory density management depend on cross-scale interactions among environmental drivers, neighborhood-scale interactions, and species traits.

Future demand for ecosystem services from terrestrial ecosystems from global power production scenarios to 2100: the role of forest biomass. Callesen, I. (*University of Copenhagen, Denmark; ica@ign.ku.dk*).

The world's electrical power production depends on the current energy infrastructure, and future investments in new power supply facilities using renewable and non-renewable energy sources. Continued growth in energy production in the 21st century will cause global environmental change. Along with climate change, global environmental change as an important driver will affect the environment and the economy in multiple ways that can be summarized as losses of biodiversity and changing ecosystem services, but with very diverse temporal and spatial impacts. Using a global growth model for power production that includes non-renewable and renewable energy sources, this paper investigates the potential role of forest biomass, and outlines the demands for ecosystem services imposed by global power production on ecosystems. Three scenarios called 'renewable,' 'efficiency,' and 'fossil' represent environmental impact scenarios for global power supply to 2100 as a simplified proxy of the global energy supply. The introduction of such future electrical power-mix scenarios in product life cycle assessment combines pressures from climate change, nitrogen enrichment, acidification, land use changes, and associated biodiversity impacts with the role of provisioning and regulating ecosystem services delivered by forests.

Influence of spacing regimes on the development of loblolly pine (*Pinus taeda* L.) in southern Brazil. Cardoso, D., Lacerda, A., Rosot, M., Garrastazu, M. (*EMBRAPA, Brazil; denise.cardoso@embrapa.br; andre.biscaia@embrapa.br; augusta_rosot@hotmail.com; marilice.garrastazu@embrapa.br*), Lima, R. (*Ideal Florestas, Brazil; renato.lima@idealflorestas.com.br*).

This paper reports the 24-year growth of *Pinus taeda* in Southern Brazil in response to five cultural regimes. Five initial spacing regimes (2.5 m × 1.2 m, 2.5 m × 2.0 m, 2.5 m × 2.8 m, 2.5 m × 3.6 m, and 2.5 m × 4.4 m) combined with cultural procedures generally used in commercial stands were studied. Dendrometric variables analyzed include DBH, average and dominant height, site index (SI), basal area, volume per tree and per hectare, and assortment volume. The results indicate a final lower average DBH in denser spacing regimes but no significant difference in relation to volume per hectare and basal area at the end of the 24-year cycle. It is possible to obtain the same volume per hectare, on average 385.7 m^3/ha, at the age of harvesting by combining different initial spacings with thinning intensities. The mean annual increment (MAI) has a positive correlation with initial spacing; the densest spacing had a MAI 45% higher than the widest treatment. The results provide managers with long-term data that can be used in forest management planning, for example by allowing companies to adjust their operations depending on the costs of planting, maintenance, and other cultural treatments.

The afforestation present in the squares of the city of Ponta Grossa, Paraná, Brazil. Carvalho, S., Dos Santos, Z. (*State University of Ponta Grossa, Brazil; silviameri@brturbo.com.br; zihngara@hotmail.com*).

Open spaces, especially parks, are an essential element of the urban environment because they are meant to provide the chance for leisure and increase the quality of life for the population. The afforestation in 83 squares in the city of Ponta Grossa, in southern Brazil, was evaluated quantitatively and qualitatively. The size and condition of 2 369 trees from 69 species and 33 families were also evaluated. It was found that 65.86% of the species are exotic. The most frequent species was *Ligustrum lucidum* (22.08%), a percentage considered high. Most of the trees, 57.83%, are in good condition, 36.81% in satisfactory condition, 4.1% in poor condition, and 1.3% dead. Regarding size 48.8% are large trees, 23.17% are medium sized, 21.82% are small, and 6.21% are seedlings. Regarding the Density Index Arborea (IDA) for each square, it was observed that of the 71 squares with vegetation, only 33.8% are above 1, that is, have one or more trees for every 100 m^2. The afforestation of city squares was found to be heterogeneous, as there are squares with many trees, and some without any.

Environmental valuation of trees in the city of Ponta Grossa, Paraná, Brazil, by emergy analysis. Carvalho, S., Carneiro, D. (*State University of Ponta Grossa, Brazil; silviameri@brturbo.com.br; dacriscar@hotmail.com*).

Emergy is a universal measure of the real wealth of the work of nature and society made on a common basis. In this sense, emergy analysis is presented as a methodology that recognizes and measures the universal hierarchy of power, in this case, the urban forests of the city of Ponta Grossa, in southern Brazil. A total of 2 379 trees on the streets and in the city squares of downtown Ponta Grossa were recorded and measured. Their respective values, in terms of components of the economy (labor and expenses related to afforestation) and from the environment (average local rainfall, soil nutrients, and biomass of the analyzed trees) were estimated. Thus, the emergy value per tree was obtained. The average value 5.54E +15 seJ per tree was found. Use of the *emdollar*, which is obtained from the emergy analysis of the local economy, is recommended. Therefore, the average value of $1 240.00 per tree was obtained, which takes into account the average contribution per tree to the economy and to the environment. With the emergy environmental valuation, it can be seen that the work of nature is recognized, and that environmental and urban planning—in this case, urban forestry in Ponta Grossa—can be better conducted.

Blue carbon of selected natural and plantation stands of mangrove forests in the Philippines. Castillo, J. (*Ecosystem Research and Development Bureau, the Philippines; allan536@yahoo.com*).

This study estimated the carbon stored in the biomass and sediment in selected natural and plantation stands of mangrove forests in the Philippines. For natural stands, the total carbon stock in biomass and sediment combined was 262.66 metric tons C/ha, on

average, and ranged from 178.41 to 369.70 metric tons C/ha. The carbon sequestered during the 2 years of the study based on biomass accumulation in the four natural mangrove stands studied was 3.83 t C/ha/yr, on average, and ranged from 1.90 to 5 t C/ha/year. For mangrove plantations, all of the plantations studied were *Rhizophora* plantations, mostly mixed *Rhizophora apiculata* and *Rhizophora mucronata* stands with trees 12–27 yr old or 18.5 yr on average. The combined carbon held by the biomass and upper 30 cm of sediment in the mangrove plantations was on average 190.59 metric tons C/ha and ranged from 117.56 to 262.45 metric tons C/ha. The yearly rate of carbon accumulation in the biomass of the four mangrove plantations based on carbon stock and plantation age was 4.01 t C/ha on the average and ranged from 2.75 to 5.15 t C/ha/year. The study demonstrated the potential of mangrove forests in the Philippines, both in natural stands and in plantations, as an option for climate change mitigation.

National assessment of non-timber forest products: prospects for improving the reporting of volumes and values of these products. Chamberlain, J., Patel-Weynand, T., Haan, T. (*U.S. Forest Service, USA; jchamberlain@fs.fed.us; tpatelweynand@fs.fed.us; tjhaan@fs.fed.us*).

Non-timber forest products (NTFPs) have been significant contributors to the forest products industry in the United States (Chamberlain *et al*., 1998) since this country was established. The United States has been a major supplier of herbal forest products used for their medicinal value, though the economic contribution has not been fully accounted for in valuing the forest products industry. For more than 60 years, the U.S. Forest Service has been tracking wood production through the timber products output (TPO) assessments and can estimate production by product and county of origin. In addition, the Forest Service's Forest Inventory and Analysis (FIA) group can estimate growing stock, tree removals, and forest condition and age, as well as land ownership patterns. These estimates provide a comprehensive assessment of the trees and timber products that make up the forests and related industries. But that assessment capability is lacking for the non-tree resources or the non-timber products that are harvested from the forests. Through a series of interviews, conversations, a workshop, and reviews of policies, regulations, and literature, the Forest Service has undertaken a national assessment to examine the potential and pitfalls of improving the reporting of NTFPs. This presentation examined the status of non-timber forest products and identified gaps in the knowledge and ways to improve conservation, management, and reporting of these valuable products.

Assessment of aboveground biomass and soil carbon storage of the fallow forests after swidden cultivation in the Bago Mountains, Myanmar. Chan, N. (*Kyoto University, Japan; nchan08@gmail.com*), Takeda, S. (Kyoto University*, Japan; takeda@asafas.kyoto-u.ac.jp*), Suzuki, R. (*Kyoto Gakuen University, Japan; suzuki@kyotogakuen.ac.jp*), Yamamoto, S. (*Kagoshima University, Japan; sotayama@cpi.kagoshima-u.ac.jp*).

This study was conducted to assess the aboveground biomass (AGB) accumulation and soil carbon (SC) storage in the swidden cultivated fallows of the Bago Mountains, Myanmar, by using a chronosequential approach. The 34 sample plots were randomly set up in 1-, 5-, 10-, 15-, 20-, 25-, and 30-year-old fallows, as well as in nearby old forests. The AGB in the fallows was estimated by the allometries established through destructive sampling. Similarly, the 213 soil samples were taken at 0–10 cm, 10–20 cm and 20–30 cm layers from the fallows to analyze soil carbon storage by using an NC analyzer. The average total AGB (including trees, bamboo, understory vegetation, and vines) in 1-, 5-, 10-, 15-, 20-, 25-, 30-year-old fallows and in the nearby old forests were 13.91, 31.31, 52.96, 66.52, 103.12, 88.45, 92.42 and112.48 Mg/ha, respectively. The average total SC was 23.31, 18.31, and 15.01 Mg ha^{-1} in the 0–10 cm, 10–20 cm and 20–30 cm layer, respectively. The results show that the AGB increased with fallow age, with the largest contribution by bamboo biomass in the fallows. However, the average SC accumulation in the fallows was about 58.14 Mg/ha with the fluctuation trend along the fallow age.

The contribution of historical vegetational database recovery to the study of forest biodiversity in Trentino (Italy). Ciolli, M. (*University of Trento, Italy; Marco.Ciolli@unitn.it*), La Porta, N., Zottele, F. (*Edmund Mach Foundation, Italy; nicola.laporta@fmach.it; fabio.zottele@fmach.it*), Geri, F. (*University of Trento, Italy; geri.francesco@gmail.com*).

Multi-temporal biodiversity data for a forest ecosystem can provide useful information about the evolution of biodiversity in that area. The Edmund Mach Foundation owns an archive used to determine the main Schmid's vegetational belts in the Trento province of Italy. The archive contains data collected over 20 years, from the 1970s until the 1990s. The database was developed with tools and technologies that are now obsolete, making it unusable. As part of the FORCING project, a comprehensive process of database recovery was carried out: an analysis of the data structure was performed to reverse-engineer the database structure, and missing data were digitized from historical maps and other preserved documents. All the maps of the 16 forest districts and the related 8,000 detected transects have been georeferenced to geographically enable the whole database and to evaluate the possibility of performing comparative samplings on up-to-date data sets. Raw data for vegetation (about 200,000 specific identifications including frequency indices) remain an important and irreplaceable source of information not only for their historical value, but also for many other applications. Provided here are examples of how this kind of data can be used in different multitemporal comparisons. The potential and the limits of the specific data set and of the historical data base in general are highlighted.

An historically consistent and broadly applicable MRV system based on LiDAR sampling and Landsat time-series. Cohen, W., Andersen, H., Healey, S. Moisen, G., Schroeder, T., Woodall, C., Domke, G. (*U.S. Forest Service, USA; wcohen@fs.fed.us; handersen@fs.fed.us; seanhealey@fs.fed.us; gmoisen@fs.fed.us; tschroeder@fs.fed.us; cwoodall@fs.fed.us; gmdomke@fs.fed.us*), Yang, Z. (*Oregon State University, USA; zhiqiang.yang@oregonstate.edu*), Stehman, S. (*State University of New York, USA; svstehma@syr.edu*), Kennedy, R., Woodcock, C., Zhu, Z. (*Boston University, USA; kennedyr@bu.edu*), *curtis@bu.edu; zhuzhe@bu.edu*), Vogelmann, J., Steinwand, D. (*U.S. Geological Survey, USA; vogel@usgs.gov*), *steinwand@usgs.gov*), Huang, C. (*University of Maryland, USA; cqhuang@umd.edu*).

The authors are developing a REDD+ MRV system that tests different biomass estimation frameworks and components. Design-based inference from a costly field plot network was compared to sampling with LiDAR strips and a smaller set of plots in combination with Landsat for disturbance monitoring. Biomass estimation uncertainties associated with these different data sets

in a design-based inference framework was examined. The authors are also testing estimators that rely primarily on Landsat within a model-based inference framework. Contributions from Landsat are current (e.g., 2013) spectral response and metrics describing disturbance history derived from a time-series leading up to the current date. An advantage of the model-based framework is its extension back in time (e.g., to 1990) using a consistent approach based on disturbance history as an indicator of biomass density. This requires use of the older, MSS archive to be fully effective in estimating biomass for the 1990 baseline. The United States, though not a REDD country, is party to the UNFCCC and has a need for similar NGHGI baseline information. The various components of the authors' MRV system will be tested in the United States, where sufficient data are available for parsing the uncertainty contributions of the several system components being tested.

Longitudinal and radial variation of the wood density in an unmanaged stand of *Araucaria angustifolia.* Curto, R. (*Federal University of Paraná, Brazil; rafaellacurto@yahoo.com.br*), Mattos, P., Muñoz-Braz, E. (*EMBRAPA, Brazil; patricia.mattos@embrapa.br; evaldo.braz@embrapa.br*), Pellico Netto, S. (*Federal University of Paraná, Brazil; sylviopelliconetto@gmail.com*), Zachow, R. (*Brazilian Forest Service, Brazil; randolfzachow@hotmail.com*).

The objective was to evaluate the wood density variation of *Araucaria angustifolia* in a 66-year-old stand. Thinning was carried out only between 1970 and 1980, without records after this period. Nine trees in three diameter classes (suppressed, intermediate, and dominant) were selected randomly. Wood density was determined at six different heights (0, 20, 40, 60, 80, and 100% of commercial stem) and in the radial direction in five samples, for each height. The average wood density along the stem presented no statistical difference among the three diameter classes, when comparing similar height percentages. Average wood density differed significantly, decreasing in the longitudinal direction. However, it was observed that the average wood density at 60% was greater than at 40%, suggesting that this is an effect related to the thinning carried out in the past. Management of *Araucaria angustifolia* stands, aiming at balanced tree competition with periodic thinning, will enable the production of wood with lower density variability, and will reduce problems in mechanical processing.

Forest carbon storage and tree biomass dynamics under the Natural Forest Protection Project in the northeastern forest region of China. Dai, L. (*Chinese Academy of Sciences, China; lmdai@iae.ac.cn*).

The role of forest ecosystem carbon storage and biomass dynamics under the Natural Forest Protection Project (NFPP) in China's forests remains unknown. This study collected forest inventory data and used plot databases in northeastern China to calculate forest ecosystem carbon storage in the region. Results showed that under the NFPP trees in the northeastern region functioned as a carbon sink from 1998 to 2008, with a carbon storage accumulation of 6.3 Tg C/yr. Most of the C storage was in natural forests (5.1 Tg C/yr), but simultaneously, planted forests also acted as a carbon sink, with accumulation of 1.2 Tg C/yr. In addition, the existing total ecosystem carbon storage in the region was 4 603.8 Tg C, of which 4 393.3 Tg C was stored in natural forests and 210.5 Tg C in planted forests. Tree carbon density of natural forests was also higher than in planted forests. Soil contained the largest carbon storage and contributed 69.5–77.8% of total carbon storage. Tree and forest floor carbon pools accounted for 16.3–23.0% and 5.0–6.5%, respectively. Understory pools, which ranged from 1.9 to 42.9 Tg C, accounted for only 0.9% of total carbon storage under the NFPP in northeastern China.

Using inventory-based tree-ring data as a proxy for historical climate: investigating the Pacific decadal oscillation and teleconnections. DeRose, R. (*U.S. Forest Service, USA; rjderose@gmail.com*), Wang, S. (*Utah State University, USA; simon.wang@usu.edu*), Shaw, J. (*U.S. Forest Service, USA; jdshaw@fs.fed.us*).

In 2009, the Interior West Forest Inventory and Analysis (FIA) program of the U.S. Forest Service started to archive approximately 11 000 increment cores collected in the Interior West states during the periodic inventories of the 1980s and 1990s. The two primary goals for use of the data were to provide a plot-linked database of radial growth to be used for growth model development and other biometric analyses, and to develop a gridded dendroecological database that could be used to analyze regional patterns of climate, disturbance, and other ecosystem-scale processes. Early analysis related to the latter goal showed that the finely gridded data could be used to map past climatic patterns with more detail than is possible using traditional chronologies. FIA-based Douglas-fir and pinyon pine chronologies showed high temporal coherence with previously published tree-ring chronologies, and the spatial and temporal coherence between the FIA data and water year precipitation was strong. FIA data also captured the El Niño-Southern Oscillation (ENSO) dipole and revealed considerable latitudinal fluctuation over the past three centuries. Finally, the FIA data confirmed the coupling between wet/dry cycles and Pacific decadal variability known to exist for the Intermountain West. These results highlight the further potential for high-spatial-resolution climate proxy data sets for the western United States.

Adaptability of ecosystem-based management to climate-induced increase in fire frequency and growth anomalies in an eastern Canadian boreal forest. Dhital, N., Raulier, F. (*Laval University, Canada; narayan-prasad.dhital.1@ulaval.ca; Frederic.Raulier@sbf.ulaval.ca*), Bernier, P. (*Natural Resources Canada; pbernier@nrcan-rncan.gc.ca*), Lapoint-Garant, M. (*Université du Québec à Montréal, Canada; lapointe-garant.marie-pierre@courrier.uqam.ca*), Bergeron, Y. (*Université du Québec en Abitibi-Témiscamingue, Canada; yves.bergeron@uqat.ca*), Rodriguez, G. (*Laval University, Canada; gereroba@gmail.com*).

Adaptability of ecosystem-based management (EBM) to the potential impact of climate change was evaluated with attention to the role of climate on forest growth and fire regime in a boreal forest of eastern Canada. A climate-sensitive growth index model was calibrated for three commercial species (black spruce (*Picea mariana* (Mill) B.S.P.), jack pine (*Pinus banksiana* Lamb.), and trembling aspen (*Populus tremuloides* Michx.). The model was used to project the evolution of merchantable volume over time under conventional sustained yield timber production and EBM under two climate scenarios. Current burn rate and burn rates under future climate scenarios were also considered. Under the projected climate scenarios, the periodic timber supply responded with long-term reduction by up to 79%. An interaction between the response of growth and fire to the projected climate scenarios was also revealed. EBM emerged a better management strategy in the context of projected climate. It maintained a higher mean standing inventory age, a lower proportion of area under younger age, and a higher level of periodic timber supply. However, further adaptation strategies are needed to deal with the projected climate scenarios and their potential impact on growth and disturbance dynamics.

Methodological proposal for the assessment of the sustainability of *Eucalyptus* spp. plantations in Spain. Diaz Balteiro, L. (*Technical University of Madrid, Spain; luis.diaz.balteiro@upm.es*), Alfranca, O. (*Polytechnic University of Catalonia, Spain; oscar.alfranca@upc.edu*), Bertomeu, M., Gimenez, J. (*University of Extremadura, Spain; bertomeu@unex.es; jcfernan@unex.es*), Romero, C. (*Technical University of Madrid, Spain; carlos.romero@upm.es*).

This paper shows a method based upon multi-criteria analysis for deriving a ranking of eucalyptus plantations in terms of sustainability. Sustainability was characterized by considering 11 indicators of different types (e.g., ecological, economic, social). These indicators were applied to 30 private forest systems (plantations) in which stands are dominated by *Eucalyptus* spp. but contain other species. In this way, a 30 × 11 pay-off matrix was initially obtained. After the elements of the matrix were normalized, and one indicator had been dropped due to correlation issues, several models based on compromise programming and goal programming were formulated. By solving these models a ranking of the 30 forest systems was obtained. In addition, possible links between the certification of the plantations and their sustainability were established. The analysis could be extended by introducing the preferences of different stakeholders, which in practical terms would involve attaching different preferential weights to the indicators used.

Exploring options for the estimation of forest carbon stocks from 1990 to the present using the national forest inventory of the United States. Domke, G., Woodall, C., McRoberts, R., Walters, B. (*U.S. Forest Service, USA; gmdomke@fs.fed.us, cwoodall@fs.fed.us, rmcroberts@fs.fed.us, bfwalters@fs.fed.us*).

The Forest Inventory and Analysis (FIA) program of the U.S. Forest Service is responsible for compiling estimates of forest carbon stocks and stock changes as part of the National Greenhouse Gas Inventory report produced annually by the U.S. Environmental Protection Agency. In 1999, the FIA program made a transition from state-by-state periodic inventories largely tailored to regional requirements to nationally consistent, annual inventories designed for large-scale strategic requirements. Lack of measurements on all forest land during the periodic inventories, along with plot access difficulties and misidentification of forest plots as nonforest due to poor aerial imagery, has resulted in missing data throughout the FIA database. These data gaps contribute to differences in estimates of forest C stocks and stock change due to the procedural transition from periodic to annual inventories. This study builds on recent work examining strategies to compensate for nonresponse in annual inventories by evaluating imputation and model-based approaches to update forest carbon data throughout the periodic inventories using plots measured previously in the periodic inventories. The precision and uncertainty of annual estimates throughout the periodic inventories will be evaluated for each updating approach and forest carbon stocks and stock changes obtained using current methods will be compared with estimates obtained from approaches proposed in this study.

The effect of varying estimation procedures on downed dead wood carbon stock estimates using the national forest inventory of the United States. Domke, G. (*U.S. Forest Service, USA; gmdomke@fs.fed.us*), Harmon, M. (*Oregon State University, USA; mark.harmon@oregonstate.edu*), Woodall, C. (*U.S. Forest Service, USA; cwoodall@fs.fed.us*), Fasth, B. (*Oregon State University, USA; becky.fasth@oregonstate.edu*), Walters, B. (*U.S. Forest Service, USA; bfwalters@fs.fed.us*).

Over the last several decades, downed dead wood (DDW) in forests has emerged as an important component in ecosystem structure and function. Renewed interest in utilizing forest biomass for energy has further elevated the profile of DDW and the contribution of this component to the carbon cycle. In the United States, the national forest inventory conducted by the U.S. Forest Service, Forest Inventory and Analysis (FIA) program has been consistently measuring DDW since 2001. Recently, modeled estimates of DDW carbon stocks were replaced in the FIA inventory with estimates developed from field measurements. The nationally consistent FIA inventory data were used as a mechanism to evaluate alternative volume models, density reduction factors, and carbon concentration constants used to estimate DDW carbon. The results illustrate the complexities in measuring and modeling DDW dynamics in forest ecosystems and estimating DDW biomass and carbon across multiple spatial scales. Using FIA data to compare alternative estimation methods and inputs was a convenient mechanism for assessing the implications of emerging research on DDW and should prove useful in the evaluation of other forest and tree attributes.

Effects of different harvesting scenarios in a Brazilian eucalyptus catchment. Faria, V.G., Garcia, L., Ferraz, S., Rodrigues, C.B., Lima, W.P. (*University of São Paulo, Brazil; viniciusgf@usp.br; larajangada@gmail.com; silvio.ferraz@usp.br; cabreuva@gmail.com; wplima@usp.br*), Mingoti, R. (*EMBRAPA, Brazil; rafael.mingoti@embrapa.br*).

Eucalyptus plantations cover more than 5 million ha in Brazil and have an important role in the economy, environment, and society of that nation. This paper focused on the environmental issues concerning forestry logging practices, especially those regarding soil conservation. For this purpose the physics-based hydrological model, gridded surface subsurface hydrologic analysis (GSSHA), will be applied to an experimental catchment (85 ha) located in southeastern Brazil. GSSHA will be run with a 2011 year-round data set, which was both collected on site and based on literature, taking into account the main hydrological processes and soil erosion-sediment routing. Methods for calibrating and validating the model will also be discussed. Simulations with long-term scenarios will consider different harvesting intensities (0%, 25%, 50%, and 100% of clearcutting) and will be performed by modifications on land-use input parameters. The event-based variables considered for statistical purposes will be (1) surface erosion (m^3), (2) sediment wash-load discharge (m^3), maximum rate of wash-load discharge (m^3/s), and (4) stream peak discharge (m^3/s). With this paper the authors expect to demonstrate the importance of patch cutting methods to ensure sustainable forest management and conservation of land resources in a Brazilian Eucalyptus production site.

Combining LiDAR structure and ecology data in predictive ecosystem mapping models for improved estimates of landscape-scale forest carbon. Fedrigo, M. (*University of Melbourne, Australia; mel.fed@gmail.com*), Roxburgh, S. (*Commonwealth Scientific and Industrial Research Organization (CSIRO, Australia; Stephen.Roxburgh@csiro.au*), Bennett, L., Kasel, S., Nitschke, C. (*University of Melbourne, Australia; ltb@unimelb.edu.au*, *skasel@unimelb.edu.au, craign@unimelb.edu.au*).

Predictive ecosystem mapping models (PEMMs) can identify the potential spatial distribution of individual species or larger forest types based on input variables from a variety of sources. The two most common PEMMs are those solely based on field ecology

and those using remote sensing and GIS data, but few PEMMs incorporate significant elements of both data types. PEMMs are increasingly being developed for landscape-scale forest management and monitoring due to the availability of landscape-level data sets, the improvement in landscape-scale data acquisition, and the ability to improve these models as new data become available. In this study, a PEMM was developed that uses both airborne LiDAR data, which characterised forest structure, and ecological plot data to quantify the geographic extent and biomass/C content of cool temperate rain forest across the Central Highlands region of south-eastern Victoria, Australia. The authors demonstrate how field-based measures of this forest type combined with LiDAR structural information can give better predictions of spatial distribution and biomass and carbon content at the landscape scale within this region. They also demonstrate how this PEMM approach can be used for determining the impact of forest harvesting and management on the distribution and structure of cool temperate rain forest.

Western Africa tropical Sudanian riparian forest contribution to ecosystem carbon balance performance in Togo. Folega, F. (*Beijing Forestry University, China; ffolega@yahoo.fr*), Wala, K. (*Université de Lomé, Togo; kpwala75@yahoo.fr*), Zhang, C. (*Beijing Forestry University, China; zcy_0520@163.com*), Batawila, K. (*Université de Lomé, Togo; batawilakomlan@yahoo.com*), Zhao, X. (*Beijing Forestry University, China; bfuz@163.com*), Akpagana, K. (*Université de Lomé, Togo; koffi2100@gmail.com*).

Research was conducted to determine available biomass in a riparian ecosystem in the Sudanian area of northern Togo by analyzing land cover types and estimating biomass productivity of vegetation on the site. Diameter and height of trees of DBH $\geq$10 cm in rectangular 500-m^2 plots located adjacent to rivers were recorded. An allometric equation was used to compute aboveground and belowground biomass. Landsat ETM+ imagery was then used to assess the major land cover types, and net primary productivity (NPP) was calculated. Across the 5.4 ha sampled, total biomass density was 196.77 metric tons/ha. Tree species such as *Daniellia oliveri* contribute much of the total biomass. Four major land cover types (permanent woody vegetation, fallows-farmlands, barren land, and permanent moist areas) were defined. The NPP for the investigated site was estimated at $8.99x10^9$±11 738.13 g C/m^2/yr, and the map of NPP distribution matches well with the land cover map. This research could be useful for researchers, planners, and administrators within the clean development mechanism (CDM) framework.

Random forests and stochastic gradient boosting for predicting tree canopy cover: comparing tuning processes and model performance. Freeman, E., Moisen, G., Coulston, J., Wilson, B. (*U.S. Forest Service, USA; eafreeman@fs.fed.us, gmoisen@fs.fed.us*), *jcoulston@fs.fed.us; barrywilson@fs.fed.us*).

Random forests (RF) and stochastic gradient boosting (SGB), both involving an ensemble of classification and regression trees, are compared for modeling tree canopy cover for the 2011 National Land Cover Database (NLCD). The objectives of this study were twofold. First, sensitivity of RF and SGB to choices in tuning parameters was explored. Second, performance of the two final models was compared by assessing the importance of, and interaction between, predictor variables, the global accuracy metrics derived from an independent test set, and the visual quality of the resultant maps of tree canopy cover. Examination of relative variable importance elucidated the differences in how RF and SGB make use of correlated predictor variables. SGB had a tendency to concentrate variable importance in fewer variables, whereas RF tended to spread importance out amongst more variables. The predictive accuracy of RF and SGB was remarkably similar on all four of the pilot regions, by all the accuracy measures examined. RF is simpler to implement than SGB, as RF both has fewer parameters needing tuning, and also was less sensitive to these parameters.

Small-area estimation of forest attributes within fire boundaries. Frescino, T., Moisen, G. (*U.S. Forest Service, USA; tfrescino@fs.fed.us; gmoisen@fs.fed.us*), Adachi, K., Breidt, J. (*Colorado State University, USA; kristenkadachi@gmail.com; jbreidt@stat.colostate.edu*).

Wildfires are gaining more attention every year as they burn more frequently, more intensely, and across larger landscapes. Generating timely estimates of forest resources within fire perimeters is important for land managers to quickly determine the impact of fires on U.S. forests. The U.S. Forest Service's Forest Inventory and Analysis (FIA) program needs tools to produce these estimates in a timely matter. Small-area estimation methods were recently developed and applied to previous wildfires in Colorado. This paper illustrates how these methods were assimilated into an automated R-based programming environment, FIESTA, to produce estimates of forest resources affected by a specified fire perimeter. This small-area estimation approach uses a modified composite estimator, which is a weighted average of two estimators: a synthetic estimator built from model-based predictions, and a direct estimator built from the FIA plot data that fall within the small area. The synthetic estimator is generated from FIA sample data and Landsat geospatial layers (www.landfire.gov) that fall within a larger area encompassing the small area, delineated by the Forest Service EcoMap Subsections.

Austrian forest biodiversity index (AFBI) – concept and results. Geburek, T., Richard, B., Michael, E., Frank, G., Hauk, E., Liebmann, S., Neumann, M., Starlinger, F. (*Federal Research Centre for Forests, Austria; thomas.geburek@bfw.gv.at; richard.buechsenmacher@bfw.gv.at*), *michael.englisch@bfw.gv.at georg.frank@bfw.gv.at; elmar.hauk@bfw.gv.at; sylvia.liebmann@bfw.gv.at; markus.neumann@bfw.gv.at; franz.starlinger@bfw.gv.at*).

Forest biodiversity cannot be measured and monitored directly. Indicators referring to different biodiversity levels (genes, species, ecosystems) are needed to tackle this task. In addition, indicators must provide an appropriate basis for tangible goals in forest and environmental policy. In this paper a single aggregated measure is proposed: the Austrian forest biodiversity index (AFBI). This index is composed of different indicators that are weighted depending on their putative significance for the maintenance of forest species richness and genetic diversity. The AFBI consists of nine state and four response indicators. Selection of state indicators was based on the general hypothesis that forests which mimic natural conditions or are characterized by structural elements of old-growth forests maintain a high number of forest-dependent species and a high genetic richness therein. Among the response indicators, the establishment of natural forest reserves and of genetic reserve forests, and utilization of seed stands and seed orchards were considered the most relevant. Each indicator is referenced and the sum of all weighted indicator measures is rescaled as a total score that may vary from 0 to 100, so that the AFBI is simple to communicate and straightforward to apply. Data of the AFBI are presented and discussed.

Local and general above-stump biomass functions for loblolly pine and slash pine trees. Gonzalez-Benecke, C., Gezan, S. (*University of Florida, USA; cgonzabe@ufl.edu; sgezan@ufl.edu*), Albaugh, T., Burkhart, H. (*Virginia Polytechnic Institute and State Universityt, USA; tim_albaugh@vt.edu; burkhart@vt.edu*), Jokela, E. (*University of Florida, USA; ejokela@ufl.edu*), Maier, C. (*U.S. Forest Service, USA; cmaier@fs.fed.us*), Martin, T. (*University of Florida, USA; tamartin@ufl.edu*), Rubilar, R. (*Universidad de Concepción, Chile; rrubilar@ncsfnc.cfr.ncsu.edu*), Samuelson, L. (*Auburn University, USA; samuelj@auburn.edu*).

Currently, there is an increasing interest in estimating biomass for loblolly pine and slash pine trees, the two most commercially important tree species of the southeastern United States. Most of the available individual-tree allometric models are local, relying on stem diameter outside bark at breast height and, in some cases, total tree height. Only a few include stand age or other covariates. In this research, a large data set collected from five forestry research institutions in the southeastern United States, consisting of biomass measurements from 744 loblolly pine and 259 slash pine trees, was used to develop a set of individual-tree equations to estimate above-stump biomass of all tree components (foliage, bole, bark, and branch). Specific equations that can be used in the physiological process-based model 3PG were also developed. Local and general models are presented for each tree attribute. Local models included DBH or DBH and height as predicting variables. General models included stand-level parameters such as age, quadratic mean diameter, basal area, and stand density. The inclusion of stand parameters greatly improved the accuracy of predictions of above-stump biomass. The first set of local and general allometric equations are reported for both species. The models can be applied to trees growing over a large geographical area and across a wide range of ages and stand characteristics.

Wood volume estimation for eucalyptus plantations using ALS metrics and stand age. Görgens, E., Silva, A., Oliveira, J., Rodriguez, L. (*University of São Paulo, Brazil; gorgens@usp.br; andregracioso@gmail.com; juliannecoliveira@usp.br; lcr@usp.br*).

This study compared traditional and ALS-based yield models adjusted to estimate stand volume in fast-growing eucalyptus plantations in Brazil. The plantation stands are located in the state of São Paulo and are managed to produce logs for pulp mills. The LiDAR campaign occurred at the end of the rainy season, and covered stands ranging from 2 to 8 years old. The field data came from one hundred and twelve 400-m^2 circular plots measured during the same flight mission period. The traditional model estimated volume as a function of age, site index, and basal area; the alternative estimated volume as a function of age, metric cubic mean height, and metric 95th percentile. The plots were randomly divided into training (60%) and validation (40%) data. The comparison was guided by an evaluation of the RMSE and a graphical analysis of the residuals. The model based on LiDAR metrics resulted in RMSE of 32.5 m³/ha (13.3%) and the traditional in RMSE of 11.2 m/ha (5%). The lower performance of the model with ALS metrics is due to the larger variance of the cubic mean height metric. The work shows good potential for large-scale ALS forest monitoring.

Application of the carbon budget model to estimate Europe's current and future forest carbon sequestration. Grassi, G., Pilli, R. (*Joint Research Centre Institute for Environment and Sustainability, Italy; giacomo.grassi@jrc.ec.europa.eu; roberto.pilli@ext.jrc.ec.europa.eu*), Kurz, W. (*Natural Resources Canada; wkurz@nrcan.gc.ca*).

The estimation of forest carbon sequestration potential in Europe is a challenging task due to complex and varying silvicultural systems, including uneven-aged forest management, and incomplete inventory data time-series. In this study, the carbon budget model of the Canadian Forest Sector (CBM-CFS3) was used to develop estimates of carbon stock changes in various forest pools (including links with the harvested wood product pool, HWP, in line with the new IPCC methodological guidance) in 25 EU countries. Estimates cover the historical period (since 2000, including major past natural disturbances) and simulations of different harvest rate scenarios to 2030. A number of methodological challenges required modifications to the default model implementation, that is, to include uneven-aged forest management and to reconstruct past carbon dynamics. This study demonstrated the utility of the CBM-CFS3 for country-scale estimation of past and future carbon sequestration from forests, potentially supporting the verification of greenhouse gas inventories and the design and monitoring of forest and climate-related policies.

Stand canopy cover prediction from individual tree measurements: stocking, crown width, and overlap functions. Gray, A. (*U.S. Forest Service, USA; agray01@fs.fed.us*), McIntosh, A. (*University of Alberta, Canada; amcintos@ualberta.ca*), Garman, S. (*U.S. Geological Survey, USA; slgarman@usgs.gov*).

The goals for a wide range of forest management objectives are often stated in terms of the amount and layering of canopy cover. However, measuring canopy cover is labor intensive and different techniques provide widely different estimates. Several approaches have been developed to predict cover from common tree- or stand-level density attributes, with varying results. This study used line-intercept measured tree cover from 1 800 U.S. Forest Service, Forest Inventory and Analysis (FIA) plots across the state of Oregon to build predictive models from estimates of tree stocking, crown width, and other stand attributes (e.g., mean diameter, stand height, stand density index). A variety of adjustments were applied to adjust for tree social status and account for tree crown overlap. Stocking was a better predictor of cover than was crown width, although much of the error in the latter was due to estimates of crown overlap. The random crown overlap function that is standard in the Forest Vegetation Simulator (FVS) resulted in biased predictions in mesic forest types, but not in dry forest types. New model predictions based on stocking for mesic forest types were within 15% of measured cover for >82% of the observations. Although there are some additional options for improving estimated cover from tree and stand attributes, ground-based measurements will probably be required for precise estimates.

Novel automated terrestrial LiDAR sensor decreases forest measurement uncertainties when used in a multi-method approach. Griebel, A., Arndt, S., Bennett, L., Lane, P. (*University of Melbourne, Australia; agriebel@student.unimelb.edu.au; sarndt@unimelb.edu.au;ltb@unimelb.edu.au; patrickl@unimelb.edu.au*), Culvenor, D. (*Environmental Sensing Systems, Australia; darius.culvenor@sensingsystems.com.au*), Newnham, G. (*Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia; glenn.newnham@csiro.au*).

Natural eucalypt forests are extensive ecosystems in Australia and important carbon stores on a national level. Established methods for measuring eucalypt growth dynamics, especially crown dynamics, are manually intensive and have high uncertainties. A recently developed ground-based LiDAR sensor (VEGNET™) produces automated and daily measures of leaf area index (LAI) and vertical foliage profiles. For this study, three sensors were deployed continuously for 2 years in a dry sclerophyll eucalypt forest in combination with a number of well-established growth measurement methods like eddy covariance flux tower, hemispherical images, litter fall, and micro-dendrometers. The authors studied the potential of VEGNET™ alone and in combination with other methods (1) to accurately represent LAI and vertical structure dynamics, (2) to partition carbon allocation between root, stem, and crown biomass pools, and (3) to decrease uncertainties associated with stand growth dynamics. Data indicate that the VEGNET™ sensors agree well with established methods, but greatly improve the accuracy and feasibility of quantifying dynamics of biomass vertical distribution. Net primary production can be partitioned more easily between each pool, and the seasonal dynamics of each can be continuously monitored. Thus, this automated multiple-method approach including the novel VEGNET™ sensors clearly demonstrates the potential to decrease uncertainties associated with forest growth measurements.

Modeling forest biomass baselines in miombo forests of southern Africa: approaches and uncertainties. Halperin, J., LeMay, V., Marshall, P., Coops, N., Verchot, L. (*University of British Columbia, Canada; j.halperin@alumni.ubc.ca; Valerie.LeMay@ubc.ca; peter.marshall@ubc.ca; nicholas.coos@ubc.ca*), Verchot, L. (*Center for International Forestry Research (CIFOR), Indonesia; l.verchot@cgiar.org*).

Obtaining forest biomass baseline estimates and associated uncertainties continues to elude forest monitoring practitioners in tropical forests. These baselines are fundamentally needed as a critical step in moving forward with REDD+ MRV systems. Without this critical information, countries lack the information needed to plan and implement climate change mitigation and adaptation strategies. Further, methods to estimate these baselines must be sensitive to anticipated changes within forests and must be flexible to allow for monitoring at spatial and temporal scales consistent with the drivers of these changes. Combining forest inventory and remotely sensed data to develop forest biomass estimates that can be obtained for multiple scales would contribute to obtaining these necessary baseline estimates. In this study models were developed to estimate biomass using imputation or spatial interpolation, or a combination thereof. Data for this study included high resolution imagery from the RapidEye satellite and a 10 km × 10 km network of ground-measured permanent sample plots established within the Zambian National Forest Inventory framework. This paper discusses the accuracy of each approach and its relevance for monitoring changes. The potential for repeatability of these same methods using lower resolution satellite imagery, such as Landsat, is highlighted.

Simulating effects of forest management on European forest carbon stocks and carbon balance. Härkönen, S., Mäkelä-Carter, A., Berninger, F. (*University of Helsinki, Finland; sanna.harkonen@metla.fi; annikki.makela@helsinki.fi*), Aachen, W. (*Université Libre de Bruxelles, Belgium; wouter.achten@ulb.ac.be*), Chirici, G. (Italian Academy of Forest Sciences*, Italy; gherardo.chirici@unimol.it*), Hasenauer, H. (*University of Natural Resources and Life Sciences (BOKU), Austria; hubert.hasenauer@boku.ac.at*), Marchetti, M. (*Italian Academy of Forest Sciences, Italy; marchettimarco@unimol.it*), Merganic, J., Merganicova, K. (*Czech University of Life Sciences, Czech Republic; merganic@fld.czu.cz; merganicova@fld.czu.cz*), Mohren, G. (*Wageningen University, the Netherlands; frits.mohren@wur.nl*), Moreno, A. (*University of Natural Resources and Life Sciences, Austria; adam.moreno@boku.ac.at*), Mues, V. (*University of Hamburg, Germany; volker.mues@uni-hamburg.de*), Mura, M. (*University of Sassari, Italy; mrmura@uniss.it*), Mura, M. (*University of Molise, Italy; mur.teo@gmail.com*), Neumann, M. (*University of Natural Resources and Life Sciences, Austria; mathias.neumann@boku.ac.at*), Svoboda, M. (*Czech University of Life Sciences, Czech Republic; svobodam@fld.czu.cz*).

This paper introduces the new FORMIT forest growth simulator, which is a climate-sensitive summary model framework developed for estimating forest gross primary productivity, net primary productivity (NPP), and net ecosystem exchange for different regions in Europe. The simulator consists of several sub-models which are either based on earlier modeling studies or new regional models fitted with National Forest Inventory NFI) data from different parts of Europe. The simulator can be run based on basic forest inventory data (dominant species, mean height, mean diameter, mean crown base height, basal area) and daily weather data. The FORMIT simulator includes the most typical management systems (thinnings + clear-cut) practiced currently in different parts of Europe and it is capable of simulating development of either managed or natural even-aged forests. In this paper the simulator will be tested in different ecological regions from Northern, Western, Southern, and Middle-Europe, and will be evaluated against NPP estimates derived from measurements of two NFI rounds between 2000 and 2010. The test areas are in Finland, Czech Republic, Germany, Austria, Belgium, and Italy. The simulator allows users to examine long-term development of carbon stocks and carbon balance in European forests with business-as-usual management. It also allows examination of effects of adjusted management regimes, such as longer rotation lengths or lighter thinnings, to the long-term carbon balance.

An idea of things to come: using satellite observations for assessing site-specific sensitivities of European beech to excessive drought conditions. Hill, J., Stellmes, M., Stoffels, J. (*Trier University, Germany, Germany; hillj@uni-trier.de*), *stellmes@uni-trier.de; Stoffels@uni-trier.de*), Langshausen, J. (*Rhineland-Palatinate State Forest Administration, Germany; Joachim.Langshausen@wald-rlp.de*).

The recently published IPCC report states that temperatures and length, frequency, and intensity of warm spells or heat waves might increase over all of Europe. Reliable information about the sensitivity of important tree species to climate is therefore of utmost importance for maintaining forest productivity. The climate sensitivity and drought tolerance of European beech (one of the economically most important species in Germany) have already been the subject of various empirical studies and modeling approaches. Although revealing potential adaptation abilities and site limitations on a large spatial scale, results do not necessarily support site-specific decision-making. In the federal state of Rhineland-Palatinate (Germany), as in most of Europe, the summer of 2003 was one of the hottest and driest on record; climatologists suggest it provided a realistic idea of future climate scenarios. The authors used calibrated satellite observations collected during the drought progression to examine stands occupied by European beech which were suffering from water shortage. By mapping the decreasing forest canopy water content across

regional environmental gradients, site-specific stress levels for European beech were identified with respect to spatially explicit evapotranspiration and solar radiation estimates. Results indicate substantial differences within the range of sites and might be used to support site-specific forest management decisions.

Using forest land cover disturbance detection as a proxy for monitoring water quality in the Lake Michigan and Lake Superior Basins, USA. Housman, I., Seilheimer, T., Perry, C.H., Nelson, M., Stueve, K. (*U.S. Forest Service, USA; ihousman@fs.fed.us; tseilheimer@aqua.wisc.edu;charleshperry@fs.fed.us; mdnelson@fs.fed.us*), *kstueve@biogeography.us*).

As part of the Great Lakes Restoration Initiative, the capability of remote sensing-based forest land cover disturbance products to monitor water quality was tested. An enhanced version of the Vegetation Change Tracker (VCT) was applied to quantify landscape-level patterns of forest land cover disturbance across the Lake Superior and Lake Michigan basins. The enhanced version of VCT integrated snow-covered winter imagery to enhance product accuracy. Disturbance data were then related to water quality metrics. Results indicate that areas identified as undergoing forest land cover disturbance showed a decrease in water quality. Based on this study, forest land cover disturbance products from VCT can provide an alternative method for monitoring water quality as it relates to forest land cover disturbances.

Comparison of point clouds from 3D airborne image matching and airborne LiDAR in mapping carbon or tropical rain forest in Indonesia. Hussin, Y., Sumarah, A. (*University of Twente, the Netherlands; hussin@itc.nl; a.dwisumarah@student.utwente.nl*).

Various methods for the derivation of forest stand parameters such as biomass and carbon in the fields of pre-processing, digital surface model (DSM) generation, tree extraction, and classification already exist, but few of them are targeted or even tested on the most recent point cloud based on digital aerial imagery. The high cost of LiDAR operation makes it difficult to get recent and up-to-date LiDAR data. An accurate and up-to-date DSM can be generated from photogrammetric image matching. Thus, a DSM from image matching and a digital terrain model (DTM) from LiDAR can be used for mapping carbon in forest cover. LiDAR can map only in 3D, but photogrammetry can produce 2D and 3D maps. LiDAR is capable of estimating tree height with reasonable accuracy but not tree species and tree density. Aerial 3D photogrammetry can produce more point density than LiDAR at the same height and flight speed, which is more useful for assessing biomass and mapping carbon. The objective of this research was to compare the use of LiDAR airborne data and 3D photogrammetric image matching to estimate and map carbon in the tropical rain forest in Indonesia.

Modeling woody biomass utilization for energy feedstock in the northwest United States. Jacobson, R., Keefe, R. (*University of Idaho, USA; jaco0707@vandals.uidaho.edu; robk@uidaho.edu*).

Woody biomass is a significant potential source of biofuel feedstock. Woody biomass is commonly burned in the inland northwest United States, as opposed to being removed for energy generation, primarily due to a lack of viable markets to utilize the biomass. In order to better understand the potential impacts of woody biofuels development on communities in the northern Rocky Mountains, the authors are using simulation modeling linked with GIS data to evaluate potential local, regional, and international market scenarios representing different biomass development options for the region. Analysis of the production, transportation, and energy generation of woody biomass in the region is separated into three scenarios: a localized scenario using a mobile liquid conversion reactor, a regional scenario in which a large liquid fuel conversion facility (>700,000 bone dry tons/yr) for domestic production is considered, and a third scenario in which a centralized pellet mill exporting to foreign markets is considered. Detailed cost analysis of each scenario will provide inputs to broader economic models used to analyze the economic impacts of each scenario in Washington, Oregon, northern Idaho, and western Montana.

Spatio-temporal assessment of forest cover changes in Mongolia using remotely sensed data. Jamsran, T. (*Institute of GeoEcology, Mongolia; tsogtbaatarj@magicnet.mn*), Sodov, K. (*Environment Information Centre of Mongolia, Mongolia; mtt@magicnet.mn*), Nyamtseren, M. Sumya, A. (*Institute of GeoEcology, Mongolia; maaggi@yahoo.com; khatuusamar@yahoo.com*).

The forests of Mongolia are mainly located in the north-central parts of the country, forming a transition zone between the Great Siberian boreal forest and the Central Asian steppe desert. The geography and ecology of forest ecosystems differ from ecoregions due to bioclimatic conditions in the country, which vary with latitude and longitude. The pressure on Mongolia's forests is high because of the dry climate, high frequency of forest fire, and high ecological risks from forest insect outbreaks. Rapid economic growth in the country over the last two decades has put additional demands on forests for construction and infrastructure development. This study tests the hypothesis of a spatial relationship between land surface temperature (LST) and different vegetation indices (normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and soil adjusted vegetation index (SAVI)) derived by remotely sensed data to define forest cover extent. To survey temporal changes in forest ecosystems the change detection analysis was done for 2000, 2005, and 2013. Results show that the LST and NDVI are highly correlated within the selected Landsat scene and gave a similar spatial pattern. The spatial homogeneity of NDVI suggested as an indicator to map tree cover and the LST temporal characteristics may indicate a certain level of damage to the forest ecosystem.

Carbon storage, floristic composition, and species diversity in charcoal and agriculture fallows and management implications in miombo woodlands of Zambia. Kalaba, F. (*Copperbelt University, Zambia; kanungwe@gmail.com*).

This paper provides an integrated understanding of aboveground (AG) carbon storage and floristic composition in charcoal and agriculture fallows in miombo woodland systems of Zambia. Tree diameters were measured and species composition was recorded on twenty-four 0.25-ha plots in undisturbed woodlands, and fifty-eight plots re-growing after agriculture (5–58 yr) and charcoal production (5–44 yr). Undisturbed miombo stored 39.6 Mg AG C/ha. After clearing, C stocks accumulated at annual rates of 0.98 and 1.42 Mg C/ha in agriculture and charcoal fallows, respectively. No significant differences were observed in C stocks between woodlands and fallows ≥20 years old, implying that in terms of AG C storage, woodlands sufficiently recover after 20 years. Importance values of tree species show low presence of less fire-resistant tree species in the initial regrowth of

post-agriculture fallows. The study observed low species similarities between mature woodlands and fallows, suggesting that though C storage in miombo systems recovers relatively fast, species composition takes longer to recover. Agriculture and charcoal fallows hold enormous management potential for restoring carbon and biodiversity in degraded forest ecosystems and therefore should be considered under the REDD+ mechanism.

Monitoring and evaluation of impacts of FSC forest management certification. Karmann, M. (*Forest Stewardship Council – FSC International, Germany; m.karmann@fsc.org*).

Within in the Forest Stewardship Council (FSC) system and in the public domain a large amount of information is generated about the outcomes and impacts of certification requirements at the level of each certified forest management operation. To evaluate more systematically the outcomes and impacts that FSC certification triggers in terms of social, environmental, and economic aspects of forest management, the organization set up a monitoring and evaluation (M&E) program. This M&E framework could allow some level of generalization about the complex effects of forest management interventions, the different commodities and services forest management provides in different parts of the world, and FSC's stakeholder engagement. After consultations with stakeholders, a theory of change was developed for the FSC system and intended impacts were identified. Related quantitative and qualitative impact indicators will be monitored regularly at the forest management level. Some indicators will be monitored on case-specific levels only. In addition, the modular approach of FSC's new program allows baseline data to be identified before certification interventions so that forest management interventions can be more clearly attributed to certification requirements. This paper presents the FSC's M&E framework, including research partners, preliminary results, and invitations to further cooperative research.

Comparative assessment of riparian forests based on remote sensing in a Hungarian-Slovakian cross-border area. Király, G., Brolly, G. (*University of West Hungary, kiraly.geza@emk.nyme.hu; gbrolly@emk.nyme.hu*), Sačkov, I., Bucha, T. (*National Forest Center Zvolen, Slovakia; sackov@nlcsk.org; bucha@nlcsk.org*).

High density airborne laser scanning (ALS) along with aerial photography has been carried out over the "Szigetköz" Hungarian-Slovakian cross-border area, as part of a cross-border cooperative project called INMEIN. The area, which is the floodplain of the Danube River, has a very high percentage of cover (75%) in forest, which is endangered by lowering the water level by the Gabčíkovo hydroelectric power station. The dominant forests are poplar plantations, interspersed with patches of natural softwood and hardwood forests along the streams and oxbows. The plantations and close-to-natural forests were compared using remotely sensed data. The basis for these assessments was raw point-cloud data, but additional derived data sets, such as digital surface models (DSM) and canopy height model (CHM) were also included. This objective of this research was to develop methods for deriving dendrometric characteristics of forest stands and single trees. The very high resolution imagery data were used as complementary reference data. Some Hungarian and Slovakian test areas were selected and compared in this investigation. Results of this work will be used to establish a remote sensing- based and harmonised procedure for forest inventory and monitoring in this ecologically very sensitive area.

Estimating aboveground tree biomass in three different miombo woodlands and associated land use systems in Malawi. Kuyah, S., Sileshi, G, Njoloma, J., Mng'omba, S., Neufeldt, H. (*World Agroforestry Centre (ICRAF), Kenya; s.kuyah@cgiar.org; S.Weldesemayat@cgiar.org; j.njoloma@cgiar.org; s.Mng'omba@cgiar.org; H.Neufeldt@cgiar.org*).

Trees outside forests support smallholder farmers' livelihoods and play a critical role in the global carbon cycle. However, their relative contribution to climate change mitigation through carbon storage is not obvious because of limited information regarding their extent, and inadequate methods for quantification. This study evaluated the distribution of aboveground tree biomass in three 100-km^2 sentinel sites, Kasungu, Salima, and Neno in Malawi. More than 100 species and a total of 2 481 trees were inventoried at 67 sample plots covering 37 cultivated fields and 30 woodland plots. The three most dominant species in terms of biomass were *Faidherbia albida* (47.8%)*, Piliostigma thonningii* (10.5%), and *Mangifera indica* (8.9%). High biomass trees (i.e., those with DBH >40 cm), formed less than 1% of the total population inventoried in Salima, but held >60% of the biomass. Smaller trees (DBH <10 cm) dominated all the sites, representing 92.9% of all the trees measured. Biomass was disproportionally distributed, with high biomass estimated in Salima and low biomass estimated in Kasungu and Neno. The biomass estimates established in this study provide a useful benchmark against which future estimates can be compared, and sets a baseline for calculating changes in carbon stocks over time.

Carbon stores in Ukrainian forests: current stock and midterm forecast. Lakyda, P., Vasylyshyn, R., Bilous, A., Zibtsev, S. (*National University of Life and Environmental Sciences of Ukraine, Ukraine; lakyda@nubip.edu.ua; rvasylys@ukr.net; abels@ukr.net; sergiy.zibtsev@nubip.edu.ua*).

Forests cover 9.6 million ha or 15.9% of Ukraine with a total growing stock of about 2.1 billion m^3 and an average of 220 m^3/ha, according to 2011 government data. Current total stock of deposited carbon in Ukrainian forests is estimated as 758 Tg or 9.3 metric tons C/ha. Almost 48% of carbon is stored in hardwoods, and the balance is in conifers. More than 26 Tg of carbon are deposited in dead wood (92.6 million m^3). Total net primary productivity (NPP) in Ukrainian forests is 49.0 Tg C/yr or 512 g C/m^2/yr on average. It is almost 67% higher than the average NPP for Russian forests (317 g C/m^2/yr) (Shvidenko *et al*., 2012). Based on an analysis of data from the past two decades and recent trends in social-economic development (current and expected funding of forestry, current levels of reforestation and afforestation, conservative forecast of harvesting), carbon stores in Ukrainian forests are projected to reach 860 Tg by 2030. This estimate represents a 12% increase by midterm.

An object-based analysis of high resolution imagery to map canopy cover across semi-Mediterranean stands in western Iran. Latifi, H. (*University of Wuerzburg, Germany; hooman.latifi@uni-wuerzburg.de*), Naghavi, H. (*University of Lorestan, Iran; hm.naghavi@gmail.com*), Fallah, A. (*Sari Agricultural Sciences and Natural Resources University, Iran; a.fallah@sanru.ac.ir*), Shataee, S. (*Gorgan University of Agricultural Sciences and Natural Resources, Iran; shataee@yahoo.com*), Conrad, C. (*University of Wuerzburg, Germany; christopher.conrad@uni-wuerzburg.de*), Soosani, J. (*University of Lorestan, Iran; javad.soosani@yahoo.com*), Ramezani, H. (*Swedish University of Agricultural Sciences, Sweden; habib.ramezani@slu.se*).

The Zagros forests cover approximately 5 million ha of mountainous areas in semi-Mediterranean western Iran, forming a crucial source of ecosystem services such as genetic diversity, erosion control, and non-timber forest products. Yet the sites are severely threatened by overgrazing, cultivation in understory, wildfire, and erosion. Thus, a sufficient inventory of existing tree cover is highly essential for protection purposes. The authors pursued a hybrid method to combine ground samples and high resolution Quickbird imagery for mapping canopy cover in an area encompassing 1 200 ha of unmanaged *Quercus brantii* stands. The focus was on defining an optimum sampling design by testing various approaches within a 100-ha 100%-inventoried subarea. The entire site was then sampled by 0.1-ha circular plots. The plot data were associated with the original and synthetically derived spectral metrics from Quickbird imagery using nonparametric classification of image segments. Results indicated that the applied metrics have a medium to high potential for producing canopy cover maps at the plot as well as segment level. The authors concluded that their methodology could help with inventories of highly fragmented, unmanaged stands in similar areas. Care should be taken when deriving soil-adjusted vegetation indices, where a strong background soil reflectance generally exists.

Change analysis of Myanmar dryland land cover and vegetation temperature condition index. Lee, E., Lee, W., Choi, S., Yu, H., (*Korea University, Republic of Korea; leeej1212@korea.ac.kr; leewk@korea.ac.kr; saymi0630@nate.com; willpower0129@gmail.com*), Kang, H. (*Dongguk University, Republic of Korea; ccdasa@naver.com*).

Myanmar is one of the developing countries affected by land degradation mainly resulting from inappropriate land use practices. Dryland of Myanmar is the most problematic region because of low productivity of agricultural crops, forest degradation, and adverse soil and climate conditions. The main causes of land degradation are demographic pressure on agricultural land, over-grazing, shifting cultivation, and illegal logging. To begin to address land degradation in the dryland of Myanmar, this study investigated land cover change as a first step. Then the vegetation temperature condition index (VTCI), which was derived from the normalized difference vegetation index (NDVI) and land surface temperature (LST), was used to observe changes in the distribution of vegetation. The VTCI can be used to monitor drought occurrences at a regional level over a given period, and to study the spatial distribution of drought within the region. The VTCI and land cover change map were used to explore relationships between human impacts and climatic variables. This study was carried out with the support of "Forest Science Technologies Development Project (Project Number: S211213L030320)" provided by the Korea Forest Service.

Zoning productivity and growth constraints for eucalyptus forest plantations in southeastern of Brazil
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In a competitive market for land with other crops, zoning productivity can help forest managers to make decisions about land choice and occupation, based on technical information of forest productivity. The objectives of this study were to map the actual productivity of eucalyptus forest plantations in southeastern Brazil and to determine the constraints of forest growth. The estimation of productivity was made by integrating the 3PG model modified by soil water content with GIS tools. For this purpose, maps of monthly rainfall, maximum temperature, and minimum temperature, and soil maps were used. To evaluate model performance, the mean annual increment at 7 years (MAI7) estimated by 3PG was compared with projections based on inventory measurements (1 884 plots dispersed in 58 000 ha). Average eucalyptus productivity from 3PG estimation and inventory projection was similar, 42 m^3/ha/yr. However, the comparison of the MAI7 between measured and predicted stratified by soil type and farm, presented a high data dispersion, probably because of the average climate data used as model input, soil type detailing, genetic material adaptation, and silviculture management, or the interaction of those factors. Nonetheless, it was possible to zone eucalyptus productivity, and the main growth constraints were vapor pressure deficit and soil water content.

Forest cover dynamics of the Dxing'anling Forest Zone over the last four decades. Li, S. (*Institute of Forest Resources Information Techniques, CAF, China; lism@caf.ac.cn*).

Spatial information inherent within imageries presents opportunities to generate unique and ecologically important forest cover maps. Over the last 40 years, the focus of forest management policy in China has changed from wood production, to wood harvesting, protection and utilization, and most recently to ecological services and functions. This study investigated forest cover dynamics in the Dxinganling Forest Zone over the last three decades using time-series of Landsat TM/ETM+ imagery. Time-series of forest cover maps were produced by supervised classification of Landsat images acquired in the 1980s, 1990s, 2000s, and 2010s. The dynamics of forest cover were analyzed by using time-series of forest cover map and supplementary data including digital elevation models, forest inventory data, and social-economic and policy factors to identify the reasons of forest cover change.

Using MODIS data to estimate the leaf area index of different forest types in Taiwan. Lin, T., Chen, J. (*National Pingtung University of Science and Technology, China-Taipei; ybf90905@hotmail.com; zzz.john@msa.hinet.net*), Hsu, L. (*Chinese Culture University, China-Taipei; lita@faculty.pccu.edu.tw*), Chen, C. (*National Pingtung University of Science and Technology Pingtung, China-Taipei; cct@gisfore.npust.edu.tw*).

Leaf Area Index (LAI) is one of the most important factors in forest ecosystems for evaluating energy fluxes. Traditional direct measurements of LAI are usually costly and time-consuming, and are unable to cover large areas. In recent years, there has been a tendency to estimate large-scale LAI based on the multiple spectral characteristics of satellite images. The NASA Website continually provides free MODIS time- series data for monitoring forest ecosystems. In this study, the relationships between field- measured LAI data and the vegetation indices derived from FS2 satellite images were examined. The result showed that the normalized difference vegetation index (NDVI) was a good indicator of LAI. The regression equation, LAI = 8.8997(NDVI)1.4937 (R^2=0.74), was used to estimate the spatial distribution of LAI, and was subsequently applied to the MODIS imagery to analyze spatial patterns and temporal trends. The results showed that the LAI of all forest types decreased as the temperature rose between 0.2 and 0.6 °C from 2001 to 2009. In terms of precipitation, the drought in 2002 significantly decreased the LAI of forests except for alpine forests. The results of time-series analysis showed a long-term trend of decreasing LAI for all forest types.

The U.S. Government's SilvaCarbon Program: technology transfer for MRV development. Lister, A. (*U.S. Forest Service, USA; alister@fs.fed.us*).

SilvaCarbon is a multi-agency program of the U.S. government that aims to provide technical support to developing countries seeking to participate in the United Nations' REDD+ program. SilvaCarbon works in the Andean Amazon region (Colombia, Ecuador, and Peru), South East Asia region (Indonesia, Philippines, Thailand, Vietnam, Cambodia, Lao PDR, and Nepal), and Africa region (Cameroon, Gabon, Democratic Republic of Congo, and Central Africa Republic). The goal of the program is to provide assistance in the implementation of monitoring, reporting, and verification systems (MRV) for REDD+ by developing and delivering good practice guides, manuals, training, and tools; facilitating learning exchanges, regional forums, and networks to enhance sharing among countries; providing technical advice and assistance to governments, including Global Forest Observation Initiatives (GFOI) countries; and partnering with other donors and with international organizations to multiply impact and reach. This presentation provides an opportunity to show some of the outcomes from the capacity building in these regions, and how a coordinated program can multiply the impact of international cooperation.

The variations analysis of forest canopy closure estimated from airborne LiDAR data. Liu, Q., Li, S., Li, Z., Chen, E., Pang, Y. (*Chinese Academy of Forestry, China; liuqw@ifrit.ac.cn; lism@caf.ac.cn*; *lizy@caf.acn.cn; chenerx@caf.ac.cn; pangy@caf.ac.cn*).

The 3D structure of forest canopies can be characterized using airborne LiDAR data, and forest biophysical parameters can be obtained by allometric equations. Forest canopy closure is one of the important features of forest stand structure, and can be used as an indicator of the redistribution of environmental parameters such as light and water in forest stands. It could be expressed as the ratio of different return points. The estimation accuracy of forest canopy closure was affected considerably by flight platform parameters, LiDAR system configurations, data processing algorithms, and other factors. The test site is located in the Gansu Qilian Mountains National Nature Reserve of China. Airborne LiDAR data were acquired in June 2008. The study demonstrated the variability of forest canopy closure estimates derived from laser cloud point data under different conditions. Results can be used to facilitate planning of flight campaigns that reflect the accuracy requirements of different tasks.

Evaluation of permanent sites for monitoring and modeling biomass and CO_2 in Mexico's mixed forests. Lopez-Ochoa, L., Treviño Garza, E., Aguirre Calderón, O., Jimenez, J., Alanis, E. (*Universidad Autónoma de Nuevo León, Mexico; lopezochoa.luis@gmail.com; eduardo.trevinogr@uanl.edu.mx; oscar.aguirrecl@uanl.edu.mx*, *jjimenez20@gmail.com; alanis_eduardo@yahoo.com.mx*).

There is worldwide concern about climate change, which has mainly been attributed to increased concentrations of greenhouse gases. As a response to this problem, mechanisms have been created to reduce emissions from deforestation and forest degradation, attributing a monetary value based on their ability to store carbon. The aim of this study was to calculate the aerial biomass and CO_2 of individual trees in 11 research plots using allometric models. With these estimates it is possible to calculate stored carbon, which indicates the attenuator effect (sink) of a species as it removes excess greenhouse gases. The research plots are located in the Sierra Madre Oriental south of the state of Nuevo León, Mexico. Analysis of reported data showed that the main species found on these plots were *Pinus pseudostrobus*, *P. teocote*, *P. cembroides*, *Abies* spp., *Quercus laeta*, *Q. polymorpha*, and *Arbutus xalapensis*. Being reported that only in 2.75 corresponding surface of the 11 plots, there is a total of 758 Mg of aerial biomass equivalent to 1 437 Mg of CO_2 stored. The models adequately estimate biomass and CO_2 and have good statistical adjustments.

Geospatial biomass estimation in the Sierra Madre Occidental in Durango (Mexico). Lopez Serrano, P., López-Sánchez, C., Corral Rivas, J. (*Universidad Juárez del Estado de Durango, Mexico; inglopez_13@hotmail.com; calopez@ujed.mx; jcorral@ujed.mx*, Vargas-Larreta, B. (*Instituto Tecnológico de El Salto, Mexico; bvargas@itelsalto.edu.mx*).

The Sierra Madre Occidental is the largest mountain range in Mexico. It has great environmental complexity and is of major ecological, biological, and economic importance because it provides habitat to many tree species, mainly *Pinus*, *Quercus*, and *Arbutus* spp. Because of the extent and economic value of its forest resources, the Durango is considered the most important state in Mexico. Combining geospatial tools and non-parametric multivariate statistical analysis such as classification and regression tree analysis (CART) has proved to be a useful technique for estimating forest biomass in tree plantations. The goal of this study was to estimate the amount of biomass in two mixed, uneven-aged forest regions in Durango using Landsat TM5 spectral data. Multispectral images from April 2011 were used, along with data from permanent sample plots collected during the same year. Sites are 50 m × 50 m in size and were placed using systematic sampling throughout the study areas. The digital levels were transformed into reflectance values (%) and the normalized difference vegetation index (NDVI). Biomass estimation was obtained using the CART approach. Pixels reflected 81.25 Mg/ha of forest biomass on average (R^2 = 0.63, RMSE = 36.5). Study findings indicate that combining remote sensing imagery and non-parametric multivariate statistical techniques allows the estimation of forest biomass with a good overall accuracy in the mixed and unmanaged forest stands studied in Durango.

The effect of changing forests on seasonal patterns of the albedo in boreal forests. Lukeš, P., Rautiainen, M., Stenberg, T., Mõttus, M. (*University of Helsinki, Finland; petr.lukes@helsinki.fi; miina.rautiainen@helsinki.fi; pauline.stenberg@helsinki.fi; matti.mottus@helsinki.fi*), Manninen, T. (*Finnish Meteorological Institute, Finland; Terhikki.Manninen@fmi.fi*).

Forests play an important role in global change. The area and density of the world's forests influence global climate via feedback mechanisms such as the land surface albedo. Globally, the area of forests is decreasing, but in the boreal forest zone both area and biomass stored in the forests continue to increase. However, there is an acknowledged need for more reliable quantitative assessments of how changes in forest biomass and structure affect the land surface albedo. This need applies in particular to boreal forests, which are characterized by a very heterogeneous structure, combined with snow-covered ground in winter. A physically based albedo model was parameterized for the boreal region using forest inventory data and measured spectral data on forest elements, understory, and snow. The model was validated using global satellite and land cover data. Model simulations

were made to derive generic relationships between forest structure and biomass and shortwave albedo. The results were applied to predict the effect of changing forests on the albedo throughout the season.

RapidEye object-based image classification and landscape ecology analysis to support the geospatial component of the Brazilian National Forest Inventory. Luz, N. (*Fundação de Amparo à Pesquisa do Estado de Goiás (FAPEG), Brazil; naissa@gmail.com*), Oliveira, Y.M., Rosot, M., Garrastazu, M., Mattos, P., Franciscon, L. (*EMBRAPA, Brazil; yeda.oliveira@embrapa.br; augusta_rosot@hotmail.com; marilice.garrastazu@embrapa.br; patricia.mattos@embrapa.br; luziane.franciscon@embrapa.br*), Freitas, J., Piotto, D., Gomide, G., Souza, G. (*Brazilian Forest Service, Brazil; joberto.freitas@florestal.gov.br; daniel.piotto@florestal.gov.br; guilherme.gomide@florestal.gov.br; gilson.souza@florestal.gov.br*).

In response to the growing demand for reliable information on forest and tree resources as well as for land use/land cover (LULC) maps at larger scales, the Brazilian National Forest Inventory (NFI-BR) is now being conducted. Besides the traditional approaches related to forest assessment, the NFI-BR includes a geospatial component to provide such information at landscape scale. Using a sampling grid of 20 km × 20 km, field registry sample units were established, and 100-km^2 landscape sample units were located on a 40 km × 40 km grid. LULC maps at 1:50000 scale are being prepared for each LSU using RapidEye imagery. The mapping approach uses object-based image classification and newly developed vegetation indices. Attributes from image objects such as spectral characteristics, texture, and context are also involved in process tree classification. A special feature of the LULC map legend is the inclusion of trees outside forests (TOFs), which are isolated trees or small groups of trees not classified as forests. LULC maps are the basis for analyzing landscape-scale forest fragmentation analysis as well as for evaluating compliance of permanent preservation areas under recently approved environmental legislation.

Remote sensing, GIS, and successive inventory for forest resource assessment in the Blue Nile region, Sudan. Mahmoud El-Abbas, M. (*Dresden University of Technology, Germany; mmelabbas@hotmail.com*), A. Elsiddig, E. (*University of Khartoum, Sudan; elnour-elsiddig@yahoo.com*).

Well-designed information systems and management plans are needed as the forest sector in Sudan faces many challenges. One of these challenges is land use/land cover (LULC) changes, particularly deforestation and land degradation. To cope with this issue, the efficiency of successive forest inventory was tested in vast areas of the Blue Nile region. In order to estimate the change, a field mission was conducted in 2005 to revisit the same plots determined within the framework of an AFRICOVER project in 1996. Earth observation data were used to assess the estimates from field inventories. The study showed a high correlation for LULC data obtained by the two methods. Meanwhile, data collected from successive inventory provide detailed information about the vegetation cover. In the area under investigation, results showed the forest land was drastically decreased and degraded. The agrarian structure in conversion of forest into agricultural fields and grassland was considered to be the main cause of deforestation. To conclude, remote sensing and GIS are efficient tools and have been effectively used to estimate large-scale LULC and its dynamics in a timely and cost-effective manner.

Developing modular methods for predicting forest growth responses to environmental change. Mäkelä-Carter, A., Nikinmaa, E., Härkönen, S. Kalliokoski, T., Kolari, P. (*University of Helsinki, Finland; annikki.makela@helsinki.fi; eero.nikinmaa@helsinki.fi; sanna.harkonen@helsinki.fi; tuomo.kalliokoski@helsinki.fi; pais.kolari@helsinki.fi*), Linkosalo, T., Mäkipää, R., Peltoniemi, M. (*Finnish Forest Research Institute (METLA), Finland; tapio.linkosalo@metla.fi; raisa.makipaa@metla.fi; mikko.peltoniemi@metla.fi*), Valsta, L. (*University of Helsinki, Finland; lauri.valsta@helsinki.fi*).

Prediction of forest growth under climate change involves quantification of a multitude of impacts at different spatial and temporal scales. Few ecosystem models incorporate all the essential impacts simultaneously, and single models easily become too complex to parameterise for larger areas or longer time spans. Much information about forest ecosystem functioning is quantified in different models. The Helsinki Integrated Forest Impact Model System (HIFI-MS) approach is to combine models in a modular system for estimating climate change impacts at a regional scale. The method is applied to adaptation of forest management under climate change in southern Finland. Process models were used to predict daily net primary productivity and C and N release from the soil. The results were expressed as parameters of a stand growth model and mapped over the region. A growth model with optimal C:N allocation was applied to derive the climate-sensitive parameters to carbon allocation. These were translated into changes in volume growth and used as input to an empirical growth model to estimate regional forest growth changes. The authors' models predict that despite increasing growth potential with climate change, the initial age distribution of stands will largely determine the total growth in the region for 40–50 years. After this period, climate scenarios and management options start to influence the outcome.

Intra-annual xylem formation of Norway spruce and Scots pine across a latitudinal gradient in Finland. Mäkinen, H., Jyske, T., Kalliokoski, T., Nöjd, P. (*Finnish Forest Research Institute (METLA), Finland; harri.makinen@metla.fi; tuula.jyske@metla.fi; tuomo.kalliokoski@metla.fi; pekka.nojd@metla.fi*).

The expected changes of climate call for better insight into the growth responses of trees to varying environmental conditions over large geographical regions. The authors analysed the intra-annual xylem formation of Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus sylvestris* L.) across a latitudinal gradient in Finland (60–68°N). The number of tracheids and the onset, highest rate, and cessation of xylem formation were determined in nine stands during growing seasons of 2001–2009. Tracheid formation initiated earlier and ceased later for Scots pine than for Norway spruce. In northern Finland, xylem formation started later and ceased earlier than in the south. The temperature sum (TS) at growth cessation was lower in the north. In the northernmost stand, the length of the growing season was less than 2 months and the onset of xylem formation required lower TS than elsewhere. The highest tracheid formation rate occurred slightly after the summer solstice, but differences between sites and variation by year were high. The results imply that year-to-year weather variation has a marked impact on the timing of xylem formation. However, the results support the hypothesis that the provenances have adapted genetically and adjust their wood formation to local conditions.

Industrial forest mapping with satellite data. Marini, L., Boschetti, L., Smith, A., Keef, R. (*University of Idaho, United States; mari3635@vandals.uidaho.edu; luigi@uidaho.edu; alistair@uidaho.edu; robk@uidaho.edu*), Hudak, A. (*U.S. Forest Service, USA; ahudak@fs.fed.us*).

Remote sensing has been widely used for mapping and characterizing changes in forest cover. A change in land cover highly amenable to remote sensing is deforestation. The available remote sensing forest change products are suitable for estimating total change in forest cover but are not discriminating between deforestation and industrial forest management. Current estimates of carbon-equivalent emissions report the contribution of deforestation as 12% of total anthropogenic carbon emissions (van der Werf *et al*., 2009), but accurate monitoring of forest carbon balance should discriminate between land use change related to forest natural disturbances, and forest management. The total change in forest cover (Gross Forest Cover Loss, GFLC) needs to be characterized based on the cause (natural or human) and on the outcome of the change (regeneration to forest, or transition to non-forest). Industrial forestry today is highly optimized: economic profitability forces the adoption of standard practices that result in very clear spatial patterns evident to human interpreters, but hardly detectable with traditional satellite mapping approaches. To overcome these challenges, the authors propose a methodology for distinguishing between deforestation and forest management practices that combines the use of multitemporal Landsat data time-series, and object-oriented analysis of shapes, textures, and spatial relationships of the areas of deforestation/afforestation.

Modeling the uncertainty of climate change impacts on *Eucalyptus fastigata* productivity in New Zealand. Meason, D. (*Scion, New Zealand; dean.meason@scionresearch.com*), Palma, J. (*University of Lisbon, Portugal; joaopalma@isa.ulisboa.pt*), Harrison, D. (*Scion, New Zealand; duncan.harrison@scionresearch.com*).

Eucalyptus fastigata is a fast-growing eucalypt that is suitable to a wide range of New Zealand environments. It has good wood properties and is well suited for carbon sequestration. Process-based modeling would suggest that under climate change, its growth will increase to rival *Pinus radiata,* the dominant forest species. However, modeling future productivity is fraught with uncertainties: variability of a future climate, including extreme weather events, and its impact on productivity. The uncertainties of site environmental data further complicate such an analysis. Detailed information on soil type and depth are very sparse in forest areas. This information is difficult and expensive to obtain, but could have a major impact on modeling. To provide better certainty of the potential productivity of *E. fastigata*, a series of climate change scenarios (global temperature rise of 2 °C) was made with the process-based model 3PG. To address uncertainties with soil characteristics, a series of available soil water and depth scenarios was investigated. This study provides spatial information about climate change impacts to decision-makers. Results include mean potential productivity under climate change scenarios and a quantification of uncertainty. Regions where *E. fastigata* would be most vulnerable to climate change are identified.

Land use and land cover change estimation – a sample strategy for monitoring. Megown, K., Brewer, K., (*U.S. Forest Service, USA; kamegown@fs.fed.us*), Brewer, K. (*U.S. Forest Service (retired), USA; ckbrewer01@gmail.com*), Webb, J., Lister, A., Finco, M. (*U.S. Forest Service, USA; jwebb@fs.fed.us; alister@fs.fed.us; mfinco@fs.fed.us*).

This submission offers a means to independently monitor information regarding land use and land cover, over space and time. This strategy provides a way to evaluate the complex interactions between human and biophysical systems, to project future conditions absent policy changes, and to design mitigation and adaptive management strategies. This work is supported by photointerpretation methods developed in conjunction with the U.S. Forest Service, Forest Inventory and Analysis program and remote sensing data. Concepts of interpretation, methods of interpretation, an estimation strategy, and finally land use and land cover changes will be shown for the states of Colorado, Georgia, and Washington.

Landsat-MODIS data fusion for automatic mapping of fire disturbances in a forest environment. Melchiorre, A., Boschetti, L. (*University of Idaho, USA; melc2617@vandals.uidaho.edu; luigi@uidaho.edu*), Roy, D. (*South Dakota University, USA; david.roy@sdstate.edu*), Baraldi, A., Humber, M. (*University of Maryland, USA; andrea6311umd@gmail.com; mhumber@umd.edu*).

Satellite data have been used to monitor forest fire for more than three decades using automatic algorithms that detect the location of fire at the time of satellite pass and the spatial extent of the areas affected by fire. MODIS sensors have dedicated fire monitoring capabilities, and their data are used to systematically generate daily global 1-km active fire and monthly 500-m burned area products. Neither MODIS product can detect the incidence or extent of fire reliably at the scale of tens of meters. The free Landsat data policy now provides the opportunity for continental- to global-scale Landsat 30-m resolution processing. The authors present a multi-temporal methodology to fuse the MODIS active fire and burned area products with Landsat data to map burned forest areas at 30 m on a temporally rolling basis. To demonstrate the methodology, 30-m burned area maps of the western United States were generated using the free Web Enabled Landsat (WELD) mosaics (http://landsat.usgs.gov/WELD.php). Validation was conducted by systematic comparison with fire perimeter vectors provided by the U.S. Geological Survey Monitoring Trends in Burn Severity project. Prospects for future development and continental application are discussed. The methodology demonstrates the potential use of the Landsat archive to generate a long-term 30-m fire data record.

Can detailed physiological measurements be efficiently used in forest modeling? Merganicova, K., Merganic, J., Strelcova, K., Fabrika, M. (*Technical University Zvolen, Slovakia; merganicova@tuzvo.sk; j.merganic@forim.sk; strelcova@tuzvo.sk); fabrika@tuzvo.sk*), Sitkova, Z. (*National Forest Centre, Slovakia; sitkova@nlcsk.org*), Lestianska, A., Nalevankova, P., Kurjak, D. (*Technical University Zvolen; lestianska@tuzvo.sk; nalevankova@tuzvo.sk;kurjak@tuzvo.sk*).

The performance of forest growth models is usually examined by comparing model output with data collected in the field. Such tests require comparability of the modeled and the measured parameters to ensure that results of the validation studies are plausible. The presented study addressed the quality of continual measurements of tree circumference, sap flow, and soil water content in European beech forests in central Slovakia, and the possibility of using them in process-based forest ecosystem modeling. Diurnal measurements of stem circumferences include the changes caused by two different processes: changes due to tree growth and changes caused by fluctuations in water balance of tree tissues. Hence, if such data are to be used for modeling

diurnal tree increment, the changes due to stem contraction or expansion need to be eliminated. On the other hand, allocation algorithms used to distribute the assimilated carbon to individual tree components are crucial parts of the models that can affect the comparison of modeled and measured values representing diameter increment at a certain tree height. This study examined the possibilities of eliminating these sources of uncertainty and the potential for using continual experimental measurements for model validation.

Considerations for using a plot-based approach to model forest biomass and canopy structure at the landscape level using LiDAR technology. Mitchell, B., Schrader-Patton, C. (*U.S. Forest Service, USA; brentmitchell@fs.fed.us; cschrader@fs.fed.us*).

The U.S. Forest Service views the inventory and monitoring of forest biomass and canopy structure as a critical part of managing its natural resources. Within the last decade LiDAR technology has been used by the Forest Service to create landscape GIS layers for inventory parameters such as biomass, basal area, and timber volume. For the models to be logical and conform to trends known to occur on the landscape, strong agreement between field plot measurements and corresponding LiDAR metrics must be observed. This relatively new approach to modeling forest structure across the landscape brings with it new challenges and considerations when compared to traditional forestry practices. This presentation highlights the appropriate field data collection protocols and data integration techniques when the goal is combining field and LiDAR data to create forest biomass and canopy structure GIS models.

A proposed coastal pine reforestation model on the Great East Japan Earthquake. Mizutani, K. (*Forestry and Forest Products Research Institute, Japan; mizutani@ffpri.affrc.go.jp*), Kodani, J. (*Ishikawa Agricultural and Forestry Research Center, Japan; kodani@pref.ishikawa.lg.jp*).

Coastal pine forests suffered severe damage from the Great East Japan Earthquake in 2011, demonstrating the need to regenerate strong forests capable of withstanding great tsunami. An experiment involving pine reforestation with direct seeding of devastated coastal land has been conducted since 2007. Suitable stem density was achieved by plowing, burying to a depth of about 4 cm, and mulching using dried pine branches. The method appears feasible as growth is likely to be satisfactory even without weeding. The pine forest withstood the Great East Japan Earthquake relatively well. Coastal banks housing pine forests growing naturally through crevices did not collapse. Such coastal banks, where banks and pine forest come together, are strong and have become a model for regeneration. It is recommended that the regeneration of coastal pine forests shift from traditional planting to natural or direct seeding. Accordingly, the authors propose a regeneration model which covers the bank from the sea side to the land side. Regenerating the coastal forest via this method will protect the bank and allow it to withstand disasters like the great tsunami.

Urban forest identification with high resolution remote sensing. Monteiro, M.M.G., Batista, D.B., Martini, A. (*Federal University of Paraná, Brazil; mayssamonteiro@gmail.com; dbiondi@ufpr.br; martini.angeline@gmail.com*).

Urban forests are increasingly recognized as an important component in improving a city's environmental condition. The high spatial resolution in remote sensing can provide a large amount of spatial data in a short time, from which urban forests can be identified, quantified, and analyzed for spatial distribution within a city. The aim of this research was to verify the applicability of high spatial resolution remote sensing techniques to identify urban forests. The "Jardim Botanico" district, Curitiba/Paraná, Brazil, was selected as the study area because of the presence of different types of green areas. A GeoEye1 image sensor was used and classified by the ECHO (extraction and classification of homogeneous objects) method of automatic supervised classification using ENVI software. Vegetation covered 49% of the total area of the district. It was possible to identify the green areas (a park, five squares, and three *Jardinetes*) and street trees. The green areas represented 9% of the district's total area; 86% of the green areas was covered by vegetation and 14% by impermeable areas (buildings and pavement). It was estimated that the street trees occupied 9% of the district's total area. The results indicate that identification and quantification of urban forests through high spatial resolution digital images are possible.

Towards an understanding of shifting cultivation systems as a form of forest degradation. Morales, L. (*Bangor University, Costa Rica; moralesluciacr@gmail.com*).

There is an important debate on how to deal with land cleared for shifting cultivation (from the REDD+ perspective), particularly regarding whether it should be considered deforestation or forest degradation. Land cover change detection analysis is usually carried out based on satellite data from two different dates several decades apart, which does not allow detection of land-cover dynamics of shorter time periods, or it is done with coarse resolution data. This work aims to quantify carbon stocks in a system of forest clearance and re-growth caused by shifting cultivation, using the Ayuquila Basin in Jalisco as a case study. Multi-date analysis of SPOT 5 satellite imagery was used to estimate the magnitude of the area under shifting cultivation for three years (2004, 2007, 2010). Aboveground biomass was spatially modeled based on the combination of spectral indexes and 106 field data plots, and this relation was used to estimate gain and loss of carbon stocks. Preliminary results indicated that shifting cultivation represents a temporal loss of stocks, which should be monitored according to its temporal and spatial dimensions.

A new European climate data set. Moreno, A., Hasenauer, H. (*University of Natural Resources and Life Sciences (BOKU), Austria; adammoreno@live.com; hubert.hasenauer@boku.ac.at*).

Climate data are essential for performing a wide variety of modeling exercises. Even with the formation of the European Union there still does not exist a cohesive weather station network throughout all of Europe. Individual interpolation over the entire continent is consequently difficult. The European Climate Assessment and Dataset team has compiled data from many of the weather stations throughout Europe to create a gridded daily meteorological data set called E-OBS. This data set, however, is at 0.25 degrees (about 30 km) at its finest grain. A 900-km^2 resolution is not low enough to perform many local, regional, or even landscape-level modeling studies. The authors are using E-OBS along with the climate surface map WorldClim and the algorithm MtClim to produce a daily 1-km^2 resolution data set that covers all of Europe for the time period 1950–2013. Precipitation, maximum temperature, minimum temperature, mean daily temperature, vapor pressure deficit, and solar radiation will be

included. Scientists will now have access to finer-scale meteorological data that are consistent across all of Europe. This data set will eventually be used to create continental-scale modeling simulations on a fine resolution that should improve estimates of European net primary productivity and carbon dynamics.

Comparison of height-diameter mathematical models for three subtropical forest types in southern Brazil. Moser, P., Piazza, G., Vibrans, A., de Maçaneiro, J., Oliveira, L., Lingner, D. (*Regional University of Blumenau, Brazil; paolo.moser@gmail.com; guinuzaum@gmail.com; acv@furb.br; jpmacaneiro@gmail.com; laiozoliveira@gmail.com; deboravanessa.ef@gmail.com*).

Generic height-diameter models were calibrated to predict the total height of tree species in three forest types in Santa Catarina state (southern Brazil), as well as specific models for the species *Nectandra megapotamica* (Spreng.) Mez, *Ocotea puberula* (Rich.) Nees, *Cedrela fissilis* Vell., *Clethra scabra* pers., *Hieronyma alchorneoides* Allemão, *Miconia cinnamomifolia* (DC.) Naudin, *Nectandra oppositifolia* Nees, *Pera glabrata* (Schott) Poepp. ex Baill., and *Tapirira guianensis* Aulb. The data set was collected by the Santa Catarina Forest and Floristic Inventory (IFFSC) in 418 permanent sample plots. The models were calibrated for two databases, one containing the tree heights measured with a hypsometer and the other estimated by field crews. In order to compare these data sets the F test for model identity ("extra sum of squares") was conducted, revealing that the differences between the two data sets are insignificant. Differences in height-diameter relationships between forest types were investigated through the construction of simultaneous confidence intervals using dummy variables and confidence bands generated by the Working-Hotelling method. All inferences were conducted at the level of $\alpha = 0.05$. Differences could be explained by structural and floristic variations, as well as different climatic and geomorphological conditions.

Detectable differences in carbon stocks of forest soils in Japan: Boosted regression tree analysis can identify stratifying factors. Nanko, K., Miura, S. (*Forestry and Forest Products Research Institute, Japan; knanko@affrc.go.jp; miura@ffpri.affrc.go.jp*), Ugawa, S. (*Kagoshima University, Japan; ushin@agri.kagoshima-u.ac.jp*), Hashimoto, S., Osone, Y., Ishizuka, S., Sakai, Y., Tanaka, N., Takahashi, M., Kaneko, S. (*Forestry and Forest Products Research Institute, Japan; shojih@ffpri.affrc.go.jp; osone@affrc.go.jp; ishiz03@ffpri.affrc.go.jp; yoshimis@ffpri.affrc.go.jp; nagaharu@ffpri.affrc.go.jp; masamiti@affrc.go.jp; kanekos@affrc.go.jp*).

Determining changes in soil carbon stocks is an important aspect of global warming countermeasures, but the spatial heterogeneity of forest soils makes them difficult to describe with confidence. Soil C pools were sampled in 2 500 systematically located forested locations in Japan in 2006–2010. Soil C to a depth of 30 cm averaged 6.94 kg C/m^2; dead wood and litter accounted for 0.42 and 0.49 kg C/m^2. Based on a power analysis, the detectable difference in a future remeasurement for this sample size was 3.0, 8.9, and 4.6%, respectively. The number of samples required to detect a 5% change was 875, 7 734, and 2 092. Environmental factors determining soil organic C stocks were analyzed using boosted regression trees. The most important factors were mean annual temperature, slope, and forest type. Sites with colder temperatures and lower slopes had higher soil C contents. Steep slopes were associated with greater rock volume. Stratifying the data set based on these factors will reduce the detectable differences in the 5-year re-survey of these sites. Power analysis can save labor and time in detecting changes in carbon stocks in forest soils with known confidence.

Site quality and climate factors in stand level modeling of biomass growth of hybrid poplar in southern Scandinavia Nielsen, A., Nord-Larsen, T., Stupak, I. (*University of Copenhagen, Denmark; atn@life.ku.dk; tnl@life.ku.dk; ism@ign.ku.dk*), Raulund-Rasmussen, K. (*Forest and Landscape Denmark, Denmark; krr@life.ku.dk*).

The interest in the potential role of poplar biomass production for renewable bioenergy is increasing in southern Scandinavia. The production potential of the OP42 hybrid poplar clone (*Populus tricocarpa x P. maximowiczii)* might be as high as 15 oven-dried tons/ha/yr under south Scandinavian conditions, and the clone has great flexibility under the applied management regime. However, precise knowledge about its growth is required to compare production potential with that of other tree species. This study established a single-tree biomass growth model for the OP42 clone, based on sampling of 50 trees in 7 stands in Denmark and southern Sweden. The model predicts the total aboveground biomass and the distribution of biomass to different tree components, with tree diameters and heights as independent variables. Twelve stands representing a wide range of growth conditions were measured to establish diameter distributions and diameter-height relationships for scaling up the model to stand level. The effect of soil water and nutrient regimes and climatic parameters on stand-level growth was studied. The modeling concept was discussed as a generic approach for inclusion of site factors in biomass growth models.

Long-term forest planning with consideration of fragmentation. Öhman, K., Korosuo, A. (*Swedish University of Agricultural Sciences, Sweden; karin.ohman@slu.se; Anu.Korosuo@slu.se*).

Forest planning is no longer planning for only timber production. Other aspects, such as forest fragmentation, are now included in the planning process. One way to take fragmentation into consideration in forest planning models is to use the core area concept. A core area can be defined as the portion of a stand that is not influenced by effects from surrounding areas, and it is a function of the size, shape, and condition of the stand and the state of the surrounding areas. The objective of this study was to present a new formulation for including core area demands in a traditional forest planning problem where the problem still could be solved with exact solution methods. The formulation includes options for varying the edge effect. The model was applied in a case study for a landscape in northern Sweden in the context of reindeer husbandry. In the study the core area concept was used to increase the connectivity between reindeer grazing areas. Preliminary results from the case study show that it is possible to increase connectivity at a relatively low cost. However, the cost largely depends on how the reindeer grazing areas are defined.

Geoprocessing in creating maps for the purpose of conservation areas in a state park in Brazil. Oliveira, F.B., Oliveira, C. R., Lima, J., Miranda, M.R., Filho, R.B.R. (*Espírito Santo State University, Brazil; fabriciabenda@gmail.com; engcarloshenrique@yahoo.com.br; juliao.lima@ufes.br; maiararm123@gmail.com; reinaldobrfilho@gmail.com*), Ferraz, F. (*Faculdades Integradas de Aracruz, Brazil; fillipe.ferraz7@gmail.com*), Turbay, E.R.M.G. (Capixaba Institute of Research, Technical Assistance and Rural Extension*; emunaro@hotmail.com*).

The Cachoeira da Fumaça State Park in the state of Espírito Santo, Brazil, has an approximate area of 162.50 ha. This study developed a procedure to assist managers in making decisions about the allocation of conservation areas, using multiple criteria analysis and GIS techniques to generate thematic maps that define areas suitable for conservation. Seven factors relevant to conservation suitability were prioritized using the Analytic Hierarchy Process. After these factors were combined, a map was generated showing areas that ranged in suitability from less to more in need of conservation. Through analysis of the map, strategies for conservation of the park can be developed in order to concentrate efforts on more vulnerable areas, thus guiding the work of managers and saving resources. It was observed that the areas most in need of conservation measures are mainly close to the waterfall and park structures because of increased anthropogenic pressure exerted at these locations. Other vulnerable areas were grazing areas in the regeneration stage.

Comparison of methodologies for quantifying deforestation: a case study in Chico Mendes Resex, Brazilian Amazon. Oliveira, K. (*University of Viçosa, Brazil; kamillarbr@gmail.com*), Bomfim, B. (*University of California Davis, USA; bdbomfim@ucdavis.edu*), Soares-Filho, B.S. (*Federal University of Minas Gerais, Brazil; britaldo@csr.ufmg.br*), Emiliano, P.C. (*Federal University of Viçosa, Brazil; paulo.emiliano@ufv.br*), Pereira, R.S., Matricardi, E.T. (*University of Brasília, Brazil; reginaldosp@unb.br; ematricardi@gmail.com*).

The Chico Mendes Extractive Reserve (RESEX), historically known for environmental disputes with regard to its preservation, was used as a case study for comparing methodologies in quantifying deforestation in Acre State, Brazil. Two methods were used to quantify deforestation between 1989 and 2010: PRODES, developed by the Brazilian National Space Institute (INPE), and a method developed by the Geoprocessing Unit (UCEGEO) in Acre. According to the longest temporal series (mapped by UCEGEO) for the study area, the accumulated gross deforestation was 7 174.14 ha in 1988. Between 1989 and 2010, the mean deforested area increased by 2 295.67 ha/yr, from 0.077% of the total area in 1988 to 0.5% of the total area by the end of 2010. This represented an increase of 57 672 ha in deforested areas, accounting for 0.33% of the deforestation in Acre. Results of the accuracy analysis showed that UCEGEO overestimated by nearly 4.9% (87.34 ha) the value classified and validated by the high-resolution Formosat image, and PRODES underestimated it by 16.8% (–297.9 ha). Analysis of classification accuracy found that PRODES showed lower ability to distinguish between classes, whereas the UCEGEO method was more accurate in classification.

Research Infrastructure & Network for Monitoring and Adapting European Atlantic Forests under Climate Change (REINFFORCE). Orazio, C. (*European Forest Institute, France; christophe.orazio@efi.int*), Carnus, J. (*Institut National de la Recherche Agronomique, France; carnus@pierroton.inra.fr*), Cordero-Debets, R. (*European Forest Institute, France; rebeca.cordero-debets@efi.int*).

As climate change is a global and long-term issue, there is a need to coordinate and develop transnational research infrastructures to investigate adaptive forest management options and to provide harmonised monitoring data on effects of rapidly changing climates on forest ecosystems. Approaches through ecophysiological studies or bioclimatic envelopes have their limitations. Therefore, planting the same tree genetic materials under a wide range of climates and continuously monitoring climatic impact on those trees seems a relevant tool to study species' responses to future climates. Such an infrastructure of "climate change arboreta" has been established in Atlantic Europe over a large climatic gradient (Mediterranean to boreal) and will offer opportunities for identifying specific climatic parameters affecting selected tree species, and for screening of variability of various provenances. This network of arboreta mainly addresses selection of reproductive material for planting, but the infrastructure also includes large-scale forest demonstration sites where different adaptive management options are tested in the field and compared to business-as-usual management. The research infrastructure (REINFFORCE) provided the opportunity to launch a European database on long-term monitoring trials with a map and species tested that can be consulted at http://www.efiatlantic.efi.int/portal/databases/forestrials/.

Effects of climate change on suitable habitat of trees; analysis in two ecoregions. Osorio, C. (*Independent, Peru; marcela.mosorio@gmail.com*), Gunter, S. (*Thünen Institute of International Forestry and Forest Economics, Germany; sgunter@catie.ac.cr*).

The main objective of this research was to evaluate the effect of climate change scenarios on changes in suitable habitat of 26 tree species of priority conservation or timber value, at the regional level with an emphasis on Costa Rica. Climatic and physiographic variables were considered, data came from herbal botanicals, and current and future projection (to 2020) was performed with the program MaxEnt. The results show loss of suitable habitat from 24% for trees with timber value to 44% for species with conservation value. Effect of climate change differs by ecoregion; loss of suitable habitat is less severe in the north than in the south. Furthermore, suitable habitat loss within protected areas and biological corridors is very similar to the total, suggesting that establishment of these areas will not effectively mitigate habitat reduction. The main conclusion is that conservation strategies should consider specific effects within each ecoregion and also should consider a set of biological corridors as a possible approach to potential migration routes. The method can be a useful tool for other adaptation measures such as selecting seed sources and planning for forest plantations.

Estimating aboveground biomass using airborne LiDAR in tropical seasonal forests for REDD+ implementation. Ota, T., Kajisa, T., Mizoue, N., Yoshida, S., (Kyushu University, *Japan; chochoji1983@gmail.com; kajisa@agr.kyushu-u.ac.jp; mizouenn@gmail.com*, *gm.syoshida@gmail.com*), Takao, G., Hirata, Y., Furuya, N. (*Forestry and Forest Products Research Institute, Japan; takaogen@ffpri.affrc.go.jp; hirat09@affrc.go.jp; nfuruya@affrc.go.jp*), Sano, T. (*Asia Air Survey Co., Ltd, Japan; tk.sano@ajiko.co.jp*).

The objectives of this research were to: (1) develop an empirical model to estimate aboveground carbon density with variables derived from airborne LiDAR in tropical seasonal forests in Cambodia, and (2) assess the effect of pulse density of airborne LiDAR on the estimation accuracy of aboveground carbon density. First, the relevance of variables to estimate aboveground carbon density from original pulse density data was checked. Aboveground carbon density was regressed against eight variables

derived from airborne LiDAR. Then, the relationship between pulse density and estimation accuracy was investigated using the best regression model. The accuracy of the model from eight LiDAR point densities consisting of 0.25, 1, 2 3, 4, 5, and 10 pulses/m^2 was compared. Mean canopy height (MCH) derived from airborne LiDAR was highly correlated with aboveground carbon density. The best model was the single MCH model (R^2 = 0.97). Additionally, the differences in RMSE between each pulse density were less than 1 Mg/ha. The main conclusion is that aboveground carbon density can be estimated from MCH derived from airborne LiDAR in tropical seasonal forests in Cambodia even when using data from a pulse density of 0.25 pulses/m^2.

Using species distribution models to select climate change-resistant species for ecological restoration of bowé in West Africa. Padonou, E. (*University of Abomey-Calavi, Benin; padonouelie@yahoo.fr*), Bachmann, Y. (*J.W. Goethe University, Germany; bachmann@bio.uni-frankfurt.de*), Sinsin, B. (*University of Abomey-Calavi, Benin; bsinsin@gmail.com*).

Bowalization is a particular form of land degradation and leads to lateral expansion of ferricrete horizons. The process occurs only in tropical regions. In this study the species most adapted and resistant to climate change were identified on *bowé.* The 15 most common *bowé* species of the sub-humid and semiarid climate zones of Benin were submitted together with significant environmental variables (elevation, current bioclimatic variables, soil types) to the ecological niche modeling program Maxent (version 3.3.3). For future prediction (2050) IPCC4 climate data from the International Center for Tropical Agriculture were applied. *Asparagus africanus, Andropogon pseudapricus*, and *Combretum nigricans* were identified as the most resistant species for ecological restoration of *bowé* in the semiarid climate zone and *Asparagus africanus, Detarium microcarpum*, and *Lannea microcarpa* in the sub-humid climate zone.

The impact of climate change on *Eucalyptus globulus* plantation productivity: Bayesian model averaging of two process-based models. Palma, J., Minunno, F. (*Technical University of Lisbon, Portugal; joaopalma@isa.ulisboa.pt; francescom@isa.utl.pt*).

Both 3PG and YIELDSAFE are forest process-based models. While 3PG is being used worldwide due to its simplicity, YieldSAFE, being even more parameter sparse, is more specific to agroforestry systems, and includes water and light competition algorithms between the tree component and the understory (e.g., pasture, agricultural crops). It has been suggested that 3PG could include competition from the understory. This work explored the possibility of taking advantage of having a previously developed model with understory competition algorithms. By means of Bayesian statistics, the two models were calibrated for *Eucalyptus globulus* stands in Portugal, using a comprehensive data set that consisted of eddy-covariance fluxes, experimental plots, and permanent sample plots. Independent data were used for the Bayesian model comparison of the two models. Taking into account the uncertainty in model selection, the Bayesian model averaging was used to make predictions about the impact of climate change on *E. globulus* productivity. Results showed how the most productive regions of the country are more vulnerable to changes in climatic conditions.

Integrating a forest ecosystem services finder in WEFES, a Web-based explorer for forest ecosystem services. Palma, J. (*Technical University of Lisbon, Portugal; joaopalma@isa.ulisboa.pt*), Payn, T. (*Scion, New Zealand; tim.payn@scionresearch.com*).

Central to any land use decision-making is the need for information, data, models, and knowledge. As long as the complexity of need expands, the difficulty of providing, managing, and manipulating such knowledge expands with it. Web 2.0 developments—Web applications that facilitate participation, information sharing, interoperability, and collaboration, and that are user-centered—opens up the opportunity to use data in ways previously impossible and to develop systems and approaches that will allow users to work in different ways. In 2009 an international collaborative project 'TRANZFOR' (www.tranzfor.eu) developed the Web Explorer of Forest Ecosystems Services under climate change (WEFES) to identify forest productivity and ecosystem services at a forest location and evaluate the impact of climate change. A recent development, Forest Ecosystems Services Finder (FESF), uses a reverse approach in WEFES. Users can now search for specific levels of ecosystem services and productivity mixes on the map, allowing the identification of locations with higher combined benefits, such as erosion control and reduction of nitrate leaching. Identification of priority areas for afforestation is thereby facilitated. Web 2.0 approaches have helped users avoid the need to access large and complex software systems, thus increasing the accessibility of complex information. The WEFES tool is available at http://home.isa.utl.pt/~joaopalma/projects/tranzfor/wefes.

Biodiversity monitoring for sustainable conservation of Mt. Makiling Forest Reserve and Mt. Banahaw to support regional food security and monitor climate change impacts. Pampolina, N. (*University of the Philippines, the Philippines; nelsonmanguiatpampolina@yahoo.com*).

Establishment of permanent biodiversity monitoring areas (PBMA) is essential to generate research useful in coding genes of plants that show potential as food and to indicate local climate change. This paper presents a GIS based of data management to monitor biodiversity in plots set from ASEAN Heritage Mt. Makiling Forest Reserve and Mt. Banahaw, a home to several new species. The main objective was to characterize and identify potential biodiversity resources from these mountains that will address food security and provide ecophysiological evidence of climate change. A 2-ha PBMA was permanently gridded following international standards. Composition, biometrics, and structure of floristic taxa, wildlife vertebrates and invertebrates, and fungal resources are being surveyed for geospatial data and identification, and, in the case of plants, for a herbarium collection. Plant species exhibiting food qualities will be sampled via microtechniques to determine fiber biometrics and other measurements. Chemical analysis for protein, sugar, and anti-oxidant properties will be obtained using gas chromatography and other techniques. Diversity parameters in relation to climate change will include allelic richness, private alleles, observed heterozygosity, unbiased heterozygosity, and inbreeding depression coefficient. All parameters will be statistically tested and considered as a basis for food production in a suitable ecosystem while conserving the natural genetic pool.

Forest management and carbon regulation: an integrated economic perspective based on sequestration, storage, and substitution. Peyron, J. (Ecosystèmes Forestiers (*ECOFOR), France; jean-luc.peyron@gip-ecofor.org*).

Carbon issues play a major role among the challenges that forestry faces. They depend on many phenomena such as the sequestration of CO_2 in stands and soils by growing forests, the residence time of carbon in forests and wood products, land use changes, the substitution of wood for materials that release large carbon emissions when they are processed, and the use of wood fuel instead of fossil fuel. Due to these various aspects, carbon issues cannot be addressed easily from a management point of view and are highly controversial. There is probably a need for a reference: an integrated carbon indicator that takes into account forest management and forest-based products. The framework of economics allows the comparison of different alternatives based on multiple phenomena considered at different periods. This presentation clarifies the main phenomena determining carbon management in forests. It then aims to discuss each of them separately in order to determine how they should be accounted for and to identify which assumptions should be stated. It finally tells how an integrated indicator could be a reference for carbon management and complement the reference used for roundwood production over time.

Monitoring trends and burn severity for the United States. Quayle, B., Megown, K., Finco, M., Schwind, B., Lecker, J. (*U.S. Forest Service, USA; bquayle@fs.fed.us; kamegown@fs.fed.us; mfinco@fs.fed.us; bschwind@fs.fed.us; jlecker@fs.fed.us*).

The Monitoring Trends in Burn Severity (MTBS, www.mtbs.gov) project is mapping the extent, size, and severity of all large fires greater than 1 000 acres in the West and 500 acres in the east over the conterminous United States (CONUS), Alaska, and Hawaii. In 2012 the project reached a milestone, completing the mapping for all fires between 1984 and 2010. The MTBS project produces geospatial and tabular data using a consistent protocol for fire trend analysis at a range of spatial, temporal, and thematic scales. This paper reviews the objectives of the MTBS project, describes the data sets and information provided, and presents results of the analysis of the 1984–2010 MTBS data set for the United States.

In situ conservation of an urban forest fragment in the Botanical Garden of Salvador, Brazil. Queiroz, E., Souza dos Santos, L. (*Botanical Garden of Salvador, Brazil; eripqueiroz@yahoo.com.brlusozah@yahoo.com.br*), Andrade, P.M. (*Federal University of Bahia, Brazil; pedroematos@hotmail.com*), Kucharski, C., Teixeira, L. (*Botanical Garden of Salvador, Brazil; chenriquegaspar@hotmail.com; lucineide-teixeira@ibest.com.br*).

Urban forests have an essential function in the well-being of cities because of their environmental services and maintenance of biodiversity. The Brazilian Atlantic Rainforest in Bahia is recognized worldwide as a hotspot of biodiversity. Botanical gardens play a fundamental role in the conservation of biodiversity, environmental research, and education. Located in a rapidly developing coastal city, the Botanical Garden of Salvador (BGS) has a special urban forest fragment (17 ha), locally known as Mata-dos-Oitis, because of the presence of an endemic species, *Licania salzmannii*. BGS harbors many endemic and threatened species, such as *Hirtella insignis, Cattylea* spp., and *Dalbergia nigra*, some of which are rare and are indicators for preserved areas. Since its establishment in 2002, BGS has contributed to the conservation of the rain forest by studying floristic composition, phytosociology, and plant development; applying specific management methodologies; monitoring pilot areas; containing the edge effect; adding tree species; assessing forest health; surveying and gradually replacing exotic species with native species; identifying and controlling invasive species; producing forest seedlings; and raising the surrounding population's awareness about conservation of native forest species. Through this conservation activity, there have been a significant enrichment of species and an increase in vegetation cover in edge-effect areas.

Forest aboveground biomass estimates in Madagascar: new insights from the use of wood specific gravity data. Rafidimanantsoa, H., Ramanakoto, M., Ramananantoandro, T. (*Université d'Antananarivo, Madagascar; rafidimanantsoa.patrick@gmail.com; miorra_mi@hotmail.fr; ramananantoandro@gmail.com*).

To generate carbon credits under REDD+, accurate estimates of forest carbon stocks are needed. Carbon accounting efforts have focused on carbon stocks in aboveground biomass (AGB). Although wood specific gravity (WSG) is known to be an important variable in AGB estimates, there is currently a lack of data on WSG for Malagasy tree species. This study aims to determine whether estimates of carbon stocks calculated from literature-based WSG values and WSG values measured from wood core samples differ. Carbon stocks in forest AGB were assessed using two WSG data sets: (1) WSG values measured from 3 250 wood core samples extracted in the study area, and (2) WSG values derived from two existing databases (Zanne *et al*., 2009, Vieilledent *et al*., 2012). Results suggest that carbon stocks calculated from the two data sets do not significantly differ at the level of $\alpha = 0.05$ level despite the significant difference between the field and literature-based WSG values. Such findings could be attributed to the form of the allometric equation used. The choice of data set should depend on the level of accuracy (TIER II or III) desired within REDD+. As higher levels of accuracy are rewarded at a higher price, species-specific AGB and WSG data would be highly desirable.

Estimation of tree radial growth in the South Western bushes of Madagascar by growth ring analysis. Ramananantoandro, T. (*Université d'Antananarivo, Madagascar; ramananantoandro@gmail.com*), Beeckman, H. (*Royal Museum for Central Africa, Belgium; hans.beeckman@africamuseum.be*), Heriniaina, R. (*Université d'Antananarivo; vonenina@gmail.com*), Josoa, R.R. (*Université d'Antananarivo, Madagascar; rramarolanonana@yahoo.fr*).

There are few data on the growth of Malagasy native species, especially drought-resistant bushes in the bush ecosystem, which is rich in biodiversity. Yet these ecosystems are subject to high pressures from slash and burn agriculture and charcoal production. Deforestation is estimated at more than 1% per year. The absence of reliable data on forest productivity implies that the development of management plans is currently based on unverified assumptions of growth in diameter estimated as 2–3.3 mm/yr. This work aimed to estimate the annual radial growth of the most abundant species in the bush ecosystem in South Western Madagascar by growth ring analysis. The study focused on seven common species: *Alluaudia comosa, Cedrelopsis grevei, Gyrocarpus americanus, Poupartia caffra, Rhigozum madagascariense, Sclerocarpa birrea*, and *Terminalia gracilipes*. Five trees per species were harvested. The growth rings of disks taken at 30 cm from the ground level were analyzed anatomically, then counted and

compared with rainfall data. Results showed that it is possible to identify growth rings on these seven species. The annual diameter growth rate ranges between 0.58 and 1.81 mm/yr, which is lower than the hypothesis. These data are crucial to estimate accurately woody biomass productivity of this ecosystem to be compared with the wood extraction rate.

Research strategies for genecological zonation of teak in India. Ramasamy, Y. (*Institute of Forest Genetics and Tree Breeding, India; yasodharaja@yahoo.com*).

India is one of the world's largest consumers of timber products and a major importer of timber. The demand for timber in India is expected to grow to 153.0 million m^3 by 2020. Although India is recognized as one of the main centers of diversity for teak, all the logs consumed in India are now imported and it remains the biggest market. Genetic resources for teak are shrinking in the country because of illegal felling and habitat destruction. Further, climate change projections show that 30% of the teak growing area in India is vulnerable. Assessment of morphological, genetic, and ecological characteristics of teak should be considered to address more complex demographic questions, such as the sizes of subpopulations, their degree of substructure, and rates of gene flow. Identification of a deficit of rare genetic variants may suggest population contraction, which would be the result of recent illegal harvesting of the best phenotypes. Identification of substructure if any within populations may influence breeding strategies. In addition, such data can play an important role in the management and conservation of species. These efforts are particularly important in light of the distribution status of teak and the increasing isolation of teak populations caused by habitat fragmentation and decline.

Effect of field plot location on estimating tropical forest attributes of Nepal using airborne laser scanning (ALS) data. Rana, M., Tokola, T., Korhonen, L. (*University of Eastern Finland, Finland; parvez.rana@uef.fi; timo.tokola@uef.fi; lauri.korhonen@uef.fi*).

Prediction of tropical forest attributes using airborne laser scanning (ALS) is becoming attractive as an alternative to traditional field measurements for providing accurate estimates. Area-based ALS inventories require a set of representative field sample plots from the study area, which may be difficult to obtain in tropical forests with limited accessibility. The study investigates the effect of sample-plot selection based on accessibility factors in mountainous Nepal. The authors assumed that the estimation error increases if the plots are placed in sloping areas or farther away from the road. The optimal number of training plots was also tested. The sparse Bayesian regression method was used in the model to estimate forest variables with a leave-one-out cross validation procedure for model validation. Study findings showed that the estimation error of stem volume and aboveground biomass increased with increasing field plot distances from the road. The paired-sample Wilcoxon signed-rank test proved that the reduced number of sample plots provided statistically similar performance compared with the full data set. The one way analysis of variance test confirmed that sample-plot distances had significant correlation with stem density. These outputs strengthen the authors' assumption that the field plots farther away from road had low accuracy, which could be related to the high stem density.

A new concept for biomass estimation of conifer-dominated boreal forest using remote sensing data. Rana, M., Tokola, T., Korhonen, L., Xu, Q., Kumpula, T. (*University of Eastern Finland, Finland; parvez.rana@uef.fi; timo.tokola@uef.fi; lauri.korhonen@uef.fi; Qing.xu@uef.fi; timo.kumpula@uef.fi*), Vihervaara, P., Mononen, L. (*Finnish Environment Institute, Finland; petteri.vihervaara@ymparisto.fi; laura.mononen@ymparisto.fi*).

This study evaluated the accuracy of boreal forest aboveground biomass (AGB) estimates obtained using airborne laser scanning (ALS) and RapidEye data in a two-phase sampling method. Linear regression-based estimation was tested using an independent validation data set and the performance was evaluated by assessing the bias and RMSE. In phase I, ALS data from 50 field plots were used to predict AGB for the 200 surrogate plots. In phase II, the ALS-simulated surrogate plots were used as a ground-truth to estimate AGB from the RapidEye data for the study area. The resulting RapidEye models were validated against a separate set of 28 plots. The RapidEye models showed a promising accuracy with a relative RMSE of 19–20% for AGB. The evaluated concept of biomass inventory would be useful to support future forest monitoring and decision-making for sustainable use of forest resources.

Terra-i: an initiative to monitor forests and other natural covers based on the use of geospatial tools. Reymondin, L., Coca Castro, A., Tello, J., Paz, P., Navarrete, C., Jarvis, A. (*International Center of Tropical Agriculture, Colombia; terra.i.ciat@gmail.com; a.coca@cgiar.org; J.J.TELLO@cgiar.org; paulapaz1101@gmail.com; c.navarrete@cgiar.org; a.jarvis@cgiar.org*), Mulligan, M. (*King's College London, United Kingdom; drmarkmulligan@gmail.com*), Perez-Uribe, A. (*University of Applied Sciences Western Switzerland, Switzerland; Andres.Perez-uribe@heig-vd.ch*).

"Terra-i: An eye on habitat change" is a monitoring system in near real time that detects habitat changes over Latin America and the Caribbean with a spatial resolution of 250 m and temporal resolution of 16 days. The tool, which generates predictive models supported by the use of neural networks and satellite data, is able to detect, from 2004 to the current year, anomalies from the typical natural cycle of vegetation that can be associated mostly with anthropogenic impacts. The data generated allow the determination of when, where, and how often the region is experiencing the most common events of change, especially deforestation and the loss of other natural covers. Comparison of data with other regional systems such as PRODES-Brazil and GUYRA-Paraguay provides evidence that Terra-i approximates the values reported by those models for tropical and subtropical habitats. Additionally, Terra-i data have been integrated into decision support systems such as WaterWorld and Co$ting Nature to understand the impact of coverage change on hydrology as well as on the production and delivery of ecosystem services. Finally, the tool, with its flexible and automated methodology, has the potential and is projected to extend its monitoring throughout the entire Tropics.

Impacts of biomass operations on soil erosion. Rhee, H. (*University of Montana, USA; hakjun.rhee@gmail.com*), Elliot, W., Miller, I. (*U.S. Forest Service, USA; welliot@fs.fed.us; suemiller@fs.fed.us*).

This study aimed to investigate the impacts of different biomass operations on water resources. Three field sites were selected that used different biomass operation methods: the Payette National Forest (in the state of Idaho, USA) using forwarder, the Colville

National Forest (state of Washington) using tractor and skidder, and the Flathead National Forest (state of Montana) using skyline. A total of 47 silt fences (5 m × 10 m) were installed to monitor soil loss from biomass operations during the first few years after the operations; 28 silt fences were on the disturbed plots, and 19 on the control plots. No soil loss was observed except on the forwarder trails in the Payette National Forest, where animal disturbances (deer, elk, and gopher) were responsible for the soil losses. Infiltration rates measured using an onsite infiltrometer showed that rates on the on-trail plots for the ground-base operations were lower than on the control plots. Vegetation cover increased on the disturbed plots, but it remained the same on the control plots. Current data indicate no direct impacts on water resources attributable to biomass operations. However, pulverized road conditions, a potential source for soil erosion, were observed in the Payette National Forest, due to an increase in traffic volume for transporting biomass feedstock.

Characterization of fire regimes in Utah's subalpine forests using remotely sensed data. Rhodes, A., Horn, K., St. Clair, S. (*Brigham Young University, USA; aaron.rhodes0@gmail.com; 3horns@byu.net; samuel_stclair@byu.edu*).

Fire drives ecological processes on a global scale, defines plant community composition, and delineates regional biomes. Fire is what has driven the functionality of many ecosystems across geological time; it gives rise to spatial and biologic patterns on the landscape. The variability in fire regime characteristics has important consequences for regeneration of flora and fauna across landscapes. Despite the recognized importance of fire regimes, it remains uncharacterized in much of the world. The authors' objective was to develop a clear understanding of regional fire regimes in the subalpine forests of the state of Utah, USA. Landsat imagery from 1974 to present was used to derive normalized burn ratios to estimate severity, extent, and frequency of fire. The following themes were explored: (1) The fire regimes of the dominant vegetation types (aspen dominant, aspen-conifer mixed, and conifer dominant) were examined differentially based on classification under the Gap Analysis Program (GAP) from 1995. (2) In order to examine the effects of climate, topography, and human land use, those parameters were modeled using GIS as explanatory variables of fire regimes. (3) In order to characterize fire regimes as a function of topography, digital elevation models were used to extract slope, aspect, and elevation. Those variables were then modeled as explanatory parameters for a region-wide fire model.

Using financial indicators to manage risk in timber supply modeling. Rodriguez, G., Raulier, F. (*Laval University, Canada; gereroba@gmail.com; Frederic.Raulier@sbf.ulaval.ca*).

Risk analysis entails systematic use of historical information to determine frequency of unexpected events such as wildfires and the magnitude of their consequences. Currently forest management is based on long-term sustained timber yield, predicted with deterministic planning models. This study used financial indicators to manage risk in timber supply models. These indicators are based on the cumulative probability distributions of potential supplies: upside potential or opportunity value and the risk area ratio. The methodology was applied to a 1.08 million-ha forest management unit in the eastern Canadian boreal forest in the context of supply planning and harvest scheduling. The Spatially Explicit Landscape Event Simulator (SELES) was used to simulate the interaction between harvest planning and stochastic processes such as fire over time. The authors explored the effects of accounting for fire risk under the ecosystem-based management strategy and made comparisons with the business-as-usual strategy. Decision-making was improved with the use of this methodology, which accounts for uncertainties.

Comparing probability-proportional-to-size and simple random sampling designs in model-assisted estimation of growing stock in a boreal forest area in Finland. Saarela, S. (*University of Helsinki, Finland; svetlana.saarela@helsinki.fi*), Grafström, A., Staahl, G. (*Swedish University of Agricultural Sciences, Sweden; Anton.Grafstrom@slu.se; goran.stahl@slu.se*), Kangas, A., Holopainen, M. (*University of Helsinki, Finland; annika.kangas@helsinki.fi; markus.holopainen@helsinki.fi*), Tuominen, S. (*Finnish Forest Research Institute (METLA), Finland; sakari.tuominen@metla.fi*), Nordkvist, K. (*Swedish University of Agricultural Sciences, Sweden; Karin.Nordkvist@slu.se*), Hyyppä, J. (*Finnish Geodetic Institute, Finland; juha.hyyppa@fgi.fi*).

Airborne laser scanning (ALS) and satellite optical data for use in large-area forest inventories were evaluated with the intent to increase estimation accuracy and decrease costs. The aim of the study was to efficiently use both wall-to-wall satellite optical data and a sample of laser scanning data using model-assisted sampling to estimate the volume of growing stock. Variables derived from the Landsat ETM satellite image were spectral values of blue, green, and red lights, near infra-red (IR), and two shortwave IR channels. From the laser scanning data 26 laser scanning height- and density-based features were extracted. The study was performed in a 30 000-ha area of Kuortane, western Finland. Sample plots, measured using a modification of the 10th National Forest Inventory, were used as field data. Three nonlinear regression models were developed and analyzed. Different sample sizes and uses of auxiliary information in connection with the model-assisted estimation were compared. Results showed that Landsat-based wall-to-wall auxiliary data improve the estimation accuracy compared to using only ALS sample data. Probability-proportional-to-size sampling of ALS strips in the first phase (and simple random sampling in the second) was shown to be more efficient than using simple random sampling in both phases.

Forest carbon stocks in longleaf pine forests in the southern United States. Samuelson, L., Stokes, T. (*Auburn University, USA; samuelj@auburn.edu stoketa@auburn.edu*), Butnor, J., Johnsen, K. (*U.S. Forest Service, USA; jbutnor@fs.fed.us); kjohnsen@fs.fed.us*), Gonzalez-Benecke, C. (*University of Florida, USA; cgonzabe@ufl.edu*), Anderson, P., Jackson, J. (*U.S. Forest Service, USA; phanderson@fs.fed.us; jajackson@fs.fed.us*), Ferrari, L. (*Auburn University, USA; lzf0012@auburn.edu*), Martin, T., Cropper, W. (*University of Florida, USA; tamartin@ufl.edu; wcropper@ufl.edu*).

Longleaf pine (*Pinus palustris* Mill.) ecosystems in the southern United States offer opportunities to sequester carbon and mitigate CO_2 emissions, because longleaf pine is a long-lived tree species and there is a renewed focus on restoration and protection of longleaf pine ecosystems for a variety of ecosystem services. The authors are developing and linking two longleaf pine forest carbon cycle models: an even-aged plantation model that can simulate scenarios for young (0–50 yr) planted longleaf pine stands and a single-tree-based model which will enable simulation of older (40 to >200 yr) uneven-aged stands. This work will: (1) model the forest carbon cycle of longleaf pine ecosystems based on measurements on three military installations (Georgia, Louisiana, and North Carolina) representing the historical range of the species, (2) elucidate sources and sinks of

carbon and changes through time, and (3) determine the contribution of ecologically based forest management to carbon offsets. To support model calibration and validation, carbon stocks in aboveground and belowground biomass, shrubs, the herbaceous layer, soils, forest floor litter, and detritus were measured in 10 stands (5–87 yr of age). Allometric relationships were developed. Forest carbon stocks were dependent on stand age and structure.

Testing alternative response designs for training forest disturbance and attribution models. Schroeder, T., Moisen, G., Schleeweis, K. (*U.S. Forest Service, USA; tschroeder@fs.fed.us; gmoisen@fs.fed.us; kgschleeweis@fs.fed.us*).

Understanding and modeling land cover and land use change is evolving into a foundational element of climate, environmental, and sustainability science. Land cover and land use data are core to applications such as carbon accounting, greenhouse gas emissions reporting, biomass and bioenergy assessments, hydrologic function assessments, fire and fuels planning and management, and forest and rangeland health assessments. Remote sensing-based monitoring efforts like the North American Forest Dynamics (NAFD) project, and the newly launched Landscape Change Monitoring System (LCMS), will provide land cover and land use change data on all U.S. lands for the longest possible historical period. Empirical models driving disturbance and causal maps rely on large quantities of high quality data. Many decisions need to be made about the size, shape, quantity, quality, and other details about the training plots themselves, i.e., the response design. Here, the authors explored best practices for collecting training data for these empirical models on 10 pilot scenes in the United States. Alternative designs were evaluated in terms of their costs and benefits for national mapping applications.

Global Forest Information Service (GFIS) in Russia. Shalaev, V., Chumachenko, S., Kulakova, O. (*Moscow State Forest University, Russian Federation; shalaev@mgul.ac.ru; chumachenko@mgul.ac.ru; koololka@gmail.com*).

The mission of the Global Forest Information Service (GFIS) in Russia is to disseminate information and knowledge among members of the global forest community. The goal is to give all people whose activities are related to forests and the forest sector, an opportunity to obtain and share information. The GFIS was established in 1998 and began operation in Russia in 2005. In recent years, the Internet portal GFIS.ru for the Russian part of the Global Forest Information Service was developed by Moscow State Forest University as a project within the International Partnership on Forests. Currently the authors are working on filling up the site. News about forests, both in the forestry and broader scientific spheres, is published daily on the Website. Information on upcoming conferences, training, workshops, exhibitions, and other forestry-related events is published regularly by site administrators. Future development of the Website will include efforts to increase the amount of information published and to enhance the features of the digital library. Books, scientific papers, articles, and abstracts will be available in the digital library, and improvements are planned for easier access to and sale of the resources in this depository.

Comparison of land cover classification using medium resolution and high resolution imageries. Shrestha, H. (*Kathmandu University, Nepal; hlshrestha@gmail.com*).

Information about land cover is a fundamental geospatial component that informs the preparation and implementation of land use plans and other decisions about development issues. Remote sensing technology makes an important contribution to the study of land cover and land use change dynamics as past records are lacking in many locations. Remotely sensed images of historical land cover can be compared with data on current land use status. However, as remote sensing technology advances, some technological issues arise when comparing past and present status of land use and land cover. Thus, the aim of this study was to compare the methodological performance of land cover classification by using medium resolution and high resolution imageries from the same date. This comparison gave an opportunity to understand limitations, differences in processing methodologies, and effects on product results. The study showed that land use and land cover can be interpreted in greater detail from high resolution images and at a more generalized level with medium resolution imagery.

MODIS-based forest fire burned area assessment in the Hind-Kush-Himalayan (HKH) region. Shrestha, H. (*Kathmandu University, Nepal; hlshrestha@gmail.com*).

Forest fire is considered to be a major driver of forest degradation through the burning of trees and production of ash and smoke. Burning of forest trees also emits carbon to the atmosphere. Rate of spread of a forest fire depends, in part, on forest type. A forest fire can be described in spatio-temporal terms: when it occurred, rate and degree of spread, and location and extent of burning scars on ground. A geospatial approach can better present the current scenario, assess the damage and losses, and support planning for fire management. MODIS products have the capability to support regular monitoring of forest fire occurrence and losses. This study tried to determine current trends in forest fire occurrence and burned areas in the Hind-Kush-Himalayan (HKH) region from 2000 to the present using MODIS. The study also tried to assess the seasonality and spatiality of the forest. The MODIS MCD45A1 products of burn area and burn date were analyzed by writing the routine code in Python scripting. The HKH region does not have a proper damage assessment and recording system for forest fires. The assessment of active forest fires and burned areas provides the information needed for forest fire management in the region.

A system for assessing live biomass of northern Eurasian forests: methodology, models, results, and uncertainties. Shvidenko, A. (*International Institute for Applied Systems Analysis (IIASA), Austria; shvidenk@iiasa.ac.at*), Usoltsev, V. (*Russian Academy of Sciences, Russian Federation; usoltsev50@mail.ru*), Shchepashchenko, D. (*International Institute for Applied Systems Analysis (IIASA), Austria; schepd@iiasa.ac.at*), Lakyda, P. (*National University of Life and Environmental Sciences of Ukraine, Ukraine; lakyda@nubip.edu.ua*).

This paper presents systems analysis of current methods and models used for assessing live biomass (LB) of temperate and boreal forests. Methods that are based on forest inventory data generate an empirical background for reliable estimation of uncertainties. Grouped by ecoregion, two unified sets of biomass extension factors (BEF) for northern Eurasia forests are presented in forms of multiple regressions: (1) for data aggregated by forest enterprises [BEF = f (DS, A, SI, RS)] and (2) for biometric characteristics of individual stands [BEF = F(TS, A, D, H, N, H100)], where DS = dominant species, A = age, SI = site index, RS = relative

stocking, TS = species composition, D = average diameter, H = average height, N = number of trees, and H100 = expected height at 100 yr. BEF are defined for seven LB components: stems, branches, foliage, coarse roots, fine roots, understory+undergrowth, and green forest floor based on measurements at approximately 8 000 sample plots. At a country level, the system has been applied for forests of Russia and Ukraine. Results were presented in a spatially explicit form. "Within method" uncertainties depend on quality of inventory data and regional accuracy of BEF and are estimated at 5–7% (CI 0.9). The modeling system can be used in integrated observation systems, e.g., for apportioning remotely sensed forest biomass.

Assessing the climate change mitigation potential of residue-based bioenergy in Canada's forest sector. Smyth, C., Rampley, G., Lemprière, T., Kurz, W., Schwab, O. (*Natural Resources Canada, Canada; carolyn.smyth@nrcan.gc.ca; greg.rampley@nrcan.gc.ca; tony.lempriere@nrcan.gc.ca*, *wkurz@nrcan.gc.ca; olaf.schwab@nrcan.gc.ca*).

The potential of the forest sector to mitigate greenhouse gas (GHG) emissions is widely recognized, but challenging to quantify at the national scale. This study determined the mitigation potential of harvest residue-based bioenergy derived from the 230 million ha of Canada's managed forest using a dynamic systems approach. The authors took into account forest carbon stocks, C stored in harvested wood products including landfills, expected bioenergy use and facility types, and the likely alternative energy system displaced by the bioenergy to calculate how net GHG emissions vary over time and across the country. Two indicators of mitigation potential are presented: break-even points, the time required for bioenergy system emissions to be equal to those of the alternative energy system; and the cost effectiveness of using bioenergy to reduce GHG emissions. The authors concluded that (1) forest sector mitigation options need to be assessed rigorously from a systems perspective to avoid the development of policies that deliver no net benefits or substantially delayed benefits to the atmosphere, (2) alternative uses of the harvest residues need to be considered in the analysis, and (3) displaced emissions result in mitigation benefits that continue to accumulate, thereby increasing their importance over time.

Inclusion of carbon cycle and albedo in life cycle assessment for bioenergy. Soldal, E., Rørstad, P. (*Norwegian University of Life Sciences, Norway; ellen.soldal@nmbu.no; per.kristian.rorstad@umb.no*).

Bioenergy is promoted as part of the solution for climate change. Comprehensive and thorough methods are needed to evaluate the effect of climate change mitigation measures. Four different methods for accounting of biogenic CO_2 and two methods for inclusion of albedo were addressed in this paper. The methods were applied to two case studies in Norway: bioethanol used for heavy-duty transport and chips-fired district heating. Global warming potential (GWP) was used as a metric. A method was developed which includes carbon emissions and sequestration in the forest. In the boreal forest, which is snow-covered part of the year, albedo is an important climatic driver. As the forest is harvested and re-grown, the albedo changes. Both factors were included in this method and converted to the GWP metric, which can be used for life cycle assessment. Results show that the accounting of biogenic CO_2 is important. When addressing bioenergy from forests as slow growing as the boreal forest, the time horizon for analysis is particularly important. Over the short term (20 years), the albedo has an important cooling effect and the carbon has a warming effect. Over the longest time horizon (500 years) the GWP of the bioenergy (excluding fossil emissions tied to production) approaches zero.

Comparing methodologies for assessing forest ecosystem services in South Korea. Song, C., Lee, W., Choi, H., Moonil, K. (*Korea University, Republic of Korea; cholhosong@korea.ac.kr; leewk@korea.ac.kr*; *sosobut@korea.ac.kr*, *windy7up@naver.com*).

The ecosystem services that forests provide are indispensable for maintaining human activities. Many studies have attempted to evaluate ecosystem services in South Korean forests. However, the validity of early evaluation methodologies needs to be verified. For example, the most used indicator for valuing the water purification function of forests relies on precipitation, so the value of forests fluctuates yearly. To solve this problem, previously widely used methods should be functionally compared with other models that could potentially be adopted for South Korean forests. By comparing results, the authors will be able to suggest more accurate approaches for valuing forest ecosystem services. In addition, mapping ecosystem services is one of the key elements for improving decision-making and implementing ecosystem services, but it has not yet been done. Therefore, the results of the comparisons in this study will be described spatially. Using these comparisons and GIS, the applicability of models to South Korea at the national and local level can be analyzed. Furthermore, links are suggested between economic valuation and the quantification of results of ecosystem functions, and additional direction is provided based on the applicability of models.

Growth dynamics of silvertop ash regrowth forests in East Gippsland in response to contrasting thinning and fertiliser applications: A twenty-year evaluation. Soraya, E. (*Australian National University, Australia; emma.soraya@anu.edu.au*).

Various silvicultural treatments have been applied for more than two decades in East Gippsland, Australia, to increase silvertop ash's wood productivity and value by shortening sawlog rotation. However, reports published mainly short-term results. This study aimed to update the report of the growth dynamics of silvertop ash regrowth forests in East Gippsland in response to different thinning and fertiliser applications 20 yr after treatment. Data for this study came from experiments established by CSIRO and the Victorian Department of Sustainability and Environment. All stands are almost pure and were naturally regenerated following harvesting and burning. There were 13 treatment combinations between thinning and dosage of N and P fertilizer application. Results showed that 20 yr since treatment, mean basal area (BA) of individual trees in thinned plots was relatively bigger than that of the unthinned plots. However, because there were more trees in unthinned plots than in thinned plots, total BA/ha in unthinned plots was higher. Trees in thinned and fertilised plots showed increased BA/ha. About 13–20% of all retained stems in thinned plots were in the sawlog size class compared to only 4% in unthinned plots.

Carbon stock and dynamics of pioneer and non-pioneer forest species in an undisturbed forest in the Brazilian Amazon. Souza, C.R., Azevedo, C., Rossi, L.B. (*EMBRAPA, Brazil; cintia.souza@embrapa.br; celso.azevedo@embrapa.br; marcelo.rossi@embrapa.br*).

Great attention has been given to the effects of global climate change, and it is known that tropical forests play an important role in this issue. However, most research has considered the forest as a whole, with no distinction between the different ecological

groups and their influence on carbon dynamics. This study was conducted in an area of primary forest belonging to EMBRAPA Western Amazon, using data from three forest inventories conducted in 2005, 2007, and 2010, which measured all trees with DBH ≥10 cm. The aim of this study was to evaluate carbon dynamics in pioneer and non-pioneer forest species in an area of unmanaged forest, between 2005 and 2010, in order to determine the contribution of pioneer species (which have fast growth, and therefore absorb more carbon from the atmosphere) to the carbon balance of the area. Results showed that the pioneer species did not contribute significantly to the volume or to the carbon stock in the forest studied; only 13% of the local carbon stock was related to the pioneer species.

Contribution of Sapotaceae, Burseraceae, and Lecythidaceae families to carbon sequestration in an unmanaged forest in the Brazilian Amazon. Souza, C.R., Azevedo, C., Rossi, L.B. (*EMBRAPA, Brazil; cintia.souza@embrapa.br; celso.azevedo@embrapa.br; marcelo.rossi@embrapa.br*).

Tropical forests play an important role in the issue of global climate change. This study was conducted in an area of primary forest belonging to EMBRAPA Western Amazon, in Manaus/Amazonas. In this area, most species (approximately 40%) belong to the Lecythidaceae, Sapotaceae, and Burseraceae families. Data were used from three forest inventories that measured all trees with DBH ≥10 cm in 2005, 2007, and 2010. Considering the large representation of individuals of these families in the study area, the goal of this project was to evaluate the contribution of species in these three families to the carbon balance of the area between 2005 and 2010. The results showed that 31.3% of the timber volume of forest species studied was related to the selected families. The same can be observed in the case of carbon stock: 32% of the total carbon stock of the unmanaged area came from the three families studied. This contribution is significant but was expected, given that these families account for a large proportion of the forest species on the site.

Contribution of forest management to carbon sequestration in the Brazilian Amazon. Souza, C.R., Azevedo, C., Rossi, L.B. (*EMBRAPA, Brazil; cintia.souza@embrapa.br; celso.azevedo@embrapa.br; marcelo.rossi@embrapa.br*), Santos, J., Higuchi, N. (*National Institute of Amazonian Research (INPA), Brazil; joca@inpa.gov.br; niro@inpa.gov.br*).

The Amazon forest has received increased attention as global discussions consider the role of forests in global climate change. Burning or thinning forests can increase greenhouse gas emissions. On the other hand, carbon can be absorbed from the atmosphere through the growth of the stand. This study analyzed data from three forest inventories to evaluate the contribution of forest management to carbon sequestration, by quantifying carbon stocks and dynamics in a Central Amazon forest. No difference was found between logging treatments after 23 years of application. The control treatment (without logging) showed the highest carbon stocks. The carbon stocks in the forest equaled the existing stocks in 1986, prior to the experimental logging, indicating total recovery of the forest in terms of biomass. Nevertheless, the area may not be ready for harvest again, mainly due to the high number of pioneer species still existing in the managed area. In other words, the forest has recovered in terms of biomass but not in terms of species composition.

Modeling bark thickness and volume for Norway spruce (*Picea abies* [L.] Karst) in southwest Germany. Stängle, S., Brüchert, F, Nakou, A., Sauter, U. (*Forest Research Institute Baden-Wuerttemberg, Germany; stefan.staengle@forst.bwl.de; franka.bruechert@forst.bwl.de; Aikaterini.Nakou@Forst.bwl.de; udo.sauter@forst.bwl.de*).

Precise bark thickness estimates are important to calculate log diameters inside bark from measurements outside bark and to assess the availability of bark biomass. National forest inventories usually are based on diameter measurements outside bark, so wood volume can only be calculated with precise bark thickness estimates that should reflect regional conditions. In Central Europe the wood volume that is relevant for trade agreements between forest owner and wood buyer, can be calculated with modeled inside bark diameters using outside bark measurements. Another use for bark models is in bucking optimisation software for harvesters. Bark has become a valuable fuel, and bark components can be extracted for high-value biomaterial production. Thus, the assessment of available bark biomass is important to estimate the potential of such technologies for generating additional income for the forestry sector. Existing bark models have shown that bark thickness is strongly influenced by site conditions. Changing climate and increased nitrogen deposition, as well as changing silvicultural practices, might therefore have influenced relative bark thickness in the study area. This paper presents the results of modeling bark thickness for Norway spruce based on easy-to-measure tree variables, such as stem height, as well as seasonal changes, regional variation, and genetics.

Perspectives on integrating multi-phenological and multi-sensory remote sensing data into operational forest management. Stoffels, J., Hill, J., Mader, S., Sachtleber, T. (*Trier University, Germany; Stoffels@uni-trier.de; hillj@uni-trier.de; mader@uni-trier.de; sachtl@uni-trier.de*), Langshausen, J. (*Rhineland-Palatinate State Forest Administration, Germany; Joachim.Langshausen@wald-rlp.de*).

In the Federal State of Rhineland-Palatinate (Germany), local forest management plans are currently based on databases comprising attributes of various forest stand characteristics. Due to the prohibitive costs of traditional inventory concepts, there is a strong interest in exploring remote sensing as a replacement or complementary strategy. Emphasis is placed on detailed forest cover maps that, beyond their direct information content, can be used as stratification layers for reducing or optimizing field sampling efforts. Remote sensing-based forest inventory methods have to meet high quality requirements because of the high variation in forest communities and forest structure and the fragmentation of the Central European forested area. The aim of this study was to classify the main tree species and development stages of the total forest area in Rhineland-Palatinate (>800 000 ha) using multi-temporal ASTER, SPOT-5, and RapidEye data. To overcome current limitations in achieving acceptable mapping results within topographically heterogeneous and structurally complex forest systems, a spatially adaptive classification approach has been developed. The quality of the derived maps complies with the requirements of the state forest service. Further work will be focused on complete integration into forest management operations. Additionally, a conceptual framework will be presented for using Sentinel-2 data to support an optimized integrated inventory design.

Relationships between ground cover biomass and prescribed fire in longleaf pine forests in the southeastern United States. Stokes, T., Samuelson, L. (*Auburn University, USA; stoketa@auburn.edu; samuelj@auburn.edu*), Gonzalez-Benecke, C., Martin, T. (*University of Florida, USA; cgonzab@ufl.edu, tamartin@ufl.edu*).

Longleaf pine (*Pinus palustris* Mill.) ecosystems in the southeastern United States have high levels of plant diversity. Prescribed fire is important for longleaf pine ecosystem management, but we have a limited understanding of relationships between ground cover biomass and time since a burn. The objective of this research was to quantify relationships between ground cover biomass and time since prescribed fire in longleaf pine forests varying in age and forest structure and located throughout the range. Ground cover (all plants <1 m in height) biomass was examined in 19 longleaf pine stands ranging in age from 5 to 90 years in Georgia and Louisiana. Significant relationships between ground cover biomass and basal area and time since burn were observed and are discussed. Results from this study provide data needed to model the dynamics of forest growth after prescribed fire and to parameterize a carbon cycle model being developed for longleaf pine carbon management.

New approach for extracting growth trends and climate information from radial increment of Scots pine and Norway spruce. Suty, N. (*Swedish University of Agricultural Sciences, Sweden; nicole.suty@slu.se*), Grudd, H. (*Stockholm University, Sweden; hakan.grudd@natgeo.su.se*).

Climate-corrected estimates of forest growth are part of the official annual statistics produced by the National Forest Inventory in Sweden. Tree-ring indices are used as a proxy for climatic factors. A new approach can be based on statistical methods that are commonly used in the field of dendroclimatology and contribute to a better understanding of the effect of climate on volume growth estimates in forestry applications. Climatologists use tree rings to reconstruct climate patterns that go further back than on-the-ground temperature and precipitation records. Foresters use the same ring widths to calculate biomass and carbon budgets within a much shorter time frame. In this study the methods for producing tree-ring indices developed by Swedish foresters were evaluated and methods like regional curve standardization and the signal-free detrending concept were tested on the same data. There is potential for improving the measurements. For example, short series produce a biased chronology that fails to preserve recent climatic trends. Inventory data are collected annually over large areas and allow for studies of complex growth responses and spatial diversity. Regional climate-growth relationships become increasingly interesting in a global context, and large climate networks and tree-ring databases can benefit from forestry data.

Historical investigation of forest landscapes and their various uses in the early 20th century, based on national forest management plans. Suzuki, A., Matsuura, T. (*Forestry and Forest Products Research Institute, Japan; asakom@ffpri.affrc.go.jp; matsuu50@ffpri.affrc.go.jp*), Sano, M. (*Forestry Agency, Japan; masakoto@affrc.go.jp*)

Various natural and socio-economic forest-related data has been periodically recorded for nearly one century in Japan, in the form of national forest management plans (NFMPs) and their ancillary forest-type maps. These are precious data for investigating forest landscape history, particularly in the early 20th century, when aerial photographs and satellite imagery were unavailable. The present study examined the use of these historical national forest data to estimate past forest landscapes and their uses in a protected forest in the Tadami district of western Fukushima, Japan, where these data were fully available. There, we found rich information on forest types, forest age, logging methods, and their local uses, some of which had not been recorded in current NFMPs. In addition, we were also able to clarify the locations of past anthropogenic disturbances of timber and charcoal production for harvesting various edible wild plants and household woodwork industry by local inhabitants. Such information could be particularly useful to investigate the historical background of forest landscapes in detail, which could be the basis for conserving various ecosystem services related to cultural/biological diversity.

Risk analysis and forest scenario modeling. Tewari, V. (*Institute of Wood Science and Technology, India; vptewari@yahoo.com*).

Due to the long-term planning horizons and the great variety of natural, economic, and operational hazards affecting forest ecosystems, uncertainty and multiple risk are typical aspects of forest management. Applications of risk analysis are surprisingly rare, in spite of the rich assortment of sophisticated forest planning tools that are available today. Forest scenario models evaluate multiple management options and answer "what if" questions about a particular development path of a given forest. Forest scenario planning may reduce uncertainty in management outcomes by anticipating the future in a systematic way, thus reducing the likelihood of unexpected events. It can also improve the chance that future developments will agree with specified objectives. Numerous techniques are available for generating and evaluating scenarios of forest development. Some of them are limited to applications in simple forest production systems; others are suitable for any type of forest management. Risk analysis, risk evaluation, and risk management are formal procedures for quantifying, evaluating, and managing risk within a given hazard domain. Applications of risk analysis in forest scenario planning are scanty and greater emphasis needs to be placed on hazard prediction. This article discusses some aspects of risk analysis.

Comparing spatially and non-spatially explicit algorithms to implement thinnings in an individual tree growth model for cork oak stands. Tomé, M. (*Technical University of Lisbon, Portugal; magatome@isa.utl.pt*), Amaral Paulo, J., Soares, P. (*Technical University of Lisbon, Portugal; joanaap@isa.utl.pt; paulasoares@isa.utl.pt*).

Incorporation of thinning into individual tree models requires: (1) the selection of an index/variable to represent thinning intensity or residual stand density (such as removed or residual basal area or relative spacing), here designated by thinning index; and (2) implementation of some rule to select the trees to be thinned (thinning algorithm). Two thinning algorithms are compared for cork oak stands. The first is a spatially explicit algorithm based on the Hegyi competition index. The tree with the highest competition index value is the first thinned. After a tree is thinned, the competition indices of the trees in the neighbourhood of the thinned tree are re-computed and the tree with the highest competition index value is again selected to be thinned. This process is repeated until the intended value of the thinning index is achieved. The second is a non-spatially explicit algorithm based on a model that estimates the probability of a tree to be thinned. A thinning probability is estimated for each tree, the trees are randomly sorted, and the decision as to whether to thin each tree is taken by comparing its thinning probability with a random number (Monte-Carlo simulation). Trees are sequentially thinned until the intended thinning index is achieved.

Genomics-assisted selection of white spruce benefits from SilviScanTM: advanced phenotyping technology for measuring industrially relevant wood traits. Tong, T. (*FPInnovations, Canada; Tessie.Tong@FPInnovations.ca*), Beaulieu, J. (*Natural Resources Canada; jean.beaulieu@NRCan.gc.ca*), Sherson, G. (*FPInnovations, Canada; gail.sherson@fpinnovations.ca*).

With the rapid advancement in genotyping technologies, genotyping is becoming more affordable and will no longer be a limiting factor in forest genetics research. To keep pace with these developments, there is an increasing need for precise, high-throughput, and cost-effective phenotyping for wood and fibre traits in genomics research. Advanced phenotyping technologies such as SilviScan can facilitate the acquisition of wood traits accurately and efficiently for large sample sets. SilviScan rapidly and cost-effectively determines multiple wood traits on the same increment core or wood disc sample. It offers high resolution pith-to-bark measurements of fibre diameter, wood density, microfibril angle, modulus of elasticity, cell wall thickness, ring width and area, fibre coarseness, and cell population. The data have applications in many fields, such as resource characterization, forest inventory enhancement, forest management decision-making, forest genetics research, tree improvement, and adaptation to climate change. This poster illustrates the benefits of SilviScan in forest genetics research and describes a pilot study to test for association between single nucleotide polymorphisms (SNPs) of candidate genes and wood traits in white spruce. Genomic selection in boreal conifers appears particularly promising for traits that must be assessed at a more mature stage, such as wood quality traits.

Green public areas as an increase to the connectivity between forest remnants in urban landscapes. Toppa, R.H., Correia, S.G., Moraes, M.P. (*Federal University of São Carlos, Brazil; toppa@ufscar.br; silvania.goularte@gmail.com;na_moraesrp@hotmail.com*).

The average distance between the Brazilian Atlantic Forest fragments is 1 440 m, making it essential to ensure that these remnants are not isolated in the landscape. This study investigated if green public areas (GPA) improve the connectivity between patches of native vegetation and a Protected Area in the city of São Vicente, in the coastal zone of São Paulo state, Brazil. The connectivity index for 100 m and the nearest neighbor distance were used as landscape measurements to compare two scenarios in the city: one containing only natural vegetation fragments, and another, in which the regional GPA were included. The average Connectivity Index was found to be 42,010 between natural vegetation fragments and 42,028 in the scenario with the GPA. The average distance between the fragments was 41 m in the scenario with natural vegetation and 17 m in the scenario with the GPA, representing a 59% reduction in the average distance between the fragments. This reduction of the average distance between the natural vegetation remnants in the presence of GPA confirms that these areas can contribute to the connectivity of urban landscapes.

Evaluation of the revegetation process in forest fire areas for the monitoring and modeling of aerial biomass. Treviño Garza, E., González-Tagle, M., Aguirre Calderón, O., Jiménez Pérez, J. (*Universidad Autónoma de Nuevo León, Mexico; eduardo.trevinogr@uanl.edu.mx; Marco.gonzaleztg@uanl.edu.mx; oscar.aguirrecl@uanl.edu.mx; javier.jimenezp@uanl.mx*), Lopez-Ochoa, L. (*Mexico; lopezochoa.luis@gmail.com*).

This work consisted of a multi-temporal assessment of natural vegetation areas in the Sierra Madre Oriental in northeastern Mexico where wildfires occurred in 1998. Biomass was monitored using spectral values of five sets of satellite images acquired as follows: 1998 after the fire (Landsat), 2001 (Landsat), 2004 (SPOT), 2010 (SPOT), and 2012 (RapidEye), all of which were processed digitally. In addition, a stratified random sampling was performed in areas that did not have another fire after 1998. Analysis of vegetation recovery based on reflectance values indicated that after the fire only 9% of the area showed evidence of live vegetation but that 99% of the area did by 2012. Before the fire, imagery showed the area contained mixed forests of pine-oak, oak-pine, and oak. Analysis of field data showed the tree species that have been established in burned areas. With these values biomass volume present in the communities was calculated.

Forest information in Brazil: evolution and strengthening. Trindade, A., Pieruzzi, F. (*Brazilian Forest Service, Brazil; ana.trindade@florestal.gov.br; fernanda.pieruzzi@florestal.gov.br*).

Brazil is a country with vast forests, yet until the early 2000s information on forest resources was widely dispersed. Further, government agencies had little capacity to collect and organize information to meet national demand and respond to requests from the international forestry community. This paper describes the evolution of the organizational capacity of forest information in Brazil, as part of a strategy for creating and consolidating a national forest information system, driven by the need to respond to international questionnaires, such as the Global Forest Resources Assessment (2005, 2010, 2015) by the Food and Agriculture Organization of the United Nations, Joint Forest Sector Questionnaire (2005–2012) organized by the International Tropical Timber Organization (ITTO), and the Criteria and Indicators report of ITTO. Experience in production of these reports over the years highlights the continuing need for data collection and management, helps to identify important variables to assess the condition of forests and the forest sector, and points out the shortcomings of information. It also shows the need for cooperation between the Brazilian Forest Service, research and educational institutions, and governmental and non-governmental organizations, which should work together to establish national procedures, terms, and definitions.

Protected areas adaptation to future climate and land use changes in northern Thailand. Trisurat, Y. (*Kasetsart University, Thailand; fforyyt@ku.ac.th*), Kreft, H. (*University of Goettingen, Germany; hkreft@uni-goettingen.de*), Katzenstiner, K. (*University of Natural Resources and Life Sciences (BOKU), Austria; klaus.katzenteiner@boku.ac.at*).

The objectives of this research were to assess the impacts of future land use and climate change scenarios on the distributions of mammals in northern Thailand and to determine how much additional land should be protected to cope with the projected impacts. Occurrence data of 17 selected mammals were obtained from a nationwide inventory during 2004–2006. Current and predicted future bioclimatic variables in 2050 were extracted from global data sets. In addition, the maximum entropy model was used to generate suitable habitats. The results revealed that future climatic conditions would favor species living in habitats with dense forest cover. However, most species were predicted to lose suitable habitats if the remaining forest cover declines from the current level of 57% to 50% in 2050. When land use and climate changes were combined, the predicted impacts were more

severe. Most species would lose suitable habitats and the average shift in distribution was greater than 40%. Centers of mammal richness currently occur in large and contiguous protected forests, and were predicted to persist in the future although the percentage of moderate to very high concentrations would decrease marginally in the future. If 1 861 km^2 were added to the current protected areas, this minimal conservation effort (from 31.4% under the current plan to 32.5%) will significantly increase coping capacity.

Towards precise estimation of foliar biomass turnover rates in Finland. Tupek, B., Lehtonen, A., Heikkinen, J., Peltoniemi, M., Ukonmaanaho, L., Hokkanen, T., Nöjd, P., Nevalainen, S., Lingren, M., Mäkipää, R. (*Finnish Forest Research Institute (METLA), Finland; boris.tupek@metla.fi; aleksi.lehtonen@metla.fi; juha.heikkinen@metla.fi; mikko.peltoniemi@metla.fi; tatu.hokkanen@metla.fi; pekka.nojd@metla.fi; seppo.nevalainen@metla.fi; martti.lingren@metla.fi; raisa.makipaa@metla.fi*).

Precise litter input estimates are a prerequisite for studying environmental effects on soil carbon stock development. However, if the litter inputs are estimated using regionally averaged turnover rates, then the smaller-scale effects of significantly different litter inputs on soil carbon development may diminish. The authors tested the foliar turnover rates estimated from long-term measurements of the needle-cohort counts used in soil carbon models, such as in the Finnish greenhouse gas inventory, and turnover rate estimates from litterfall measurements. The counts of needle-cohorts were measured across Finland on an extensive network of 1 064 Scots pine and Norway spruce stands between 1995 and 2006. Litterfall measurements were conducted between 1960 and 2010 on 40 Scots pine, Norway spruce, and silver and downy birch stands. Litterfall-based estimates indicated larger litter input rates than those based on needle counts, which means that current turnover rates used in soil carbon models are underestimated. A better understanding of dynamic processes linked with nutrient reabsorption before shedding of foliage may be a key factor for further improvement of litter input estimates.

Biomass and forest carbon accounting in cold-temperate ecosystems in northern Mexico. Vargas-Larreta, B. (*Instituto Tecnológico de El Salto, Mexico; bvargas@itelsalto.edu.mx*), Castedo-Dorado, F. (*Universidad de León, Spain; fcasd@unileon.de*), Corral Rivas, J., López-Sánchez, C. (*Universidad Juárez del Estado de Durango, Mexico; jcorral@ujed.mx, calopez@ujed.mx*).

Forest management can contribute to carbon sources and sinks, and forest managers could benefit from having a scientific tool to evaluate the potential impacts of management activities on the C stocks and stock changes on their forests. Durango is the first forest reserve of Mexico, so it is important to quantify the potential of these forests to mitigate CO_2 emissions. The aim of this study was to quantify forest carbon storage and the carbon sequestration rate in Durango forests. A total of 1 346 trees were sampled across 201 permanent plots (50 m × 50 m) systematically established throughout the study area. Biomass equations for tree components (stem wood, bark, branches, and leaves) and total aboveground biomass for 24 pine and oak species were developed. Parameters of equations were obtained simultaneously to ensure additivity using the generalized method of moments approach (R^2 = 0.87–0.97, RMSE = 18.3–90.5 kg). Results showed that the average biomass in the study area (3 500 000 ha) was 81.25 Mg/ha. Total C stores amounted to 172 550 000 Mg, and the rate of C sequestration was 0.81 Mg/ha, or 2 822 560 Mg C/yr. Forest management emits 2 310 000 Mg CO_2/yr, plus 12 016 000 Mg CO_2/yr, due to deforestation (1.9%). Improvements in forest management practices are seen as an important way to increase the carbon sink strength of Durango forests.

Towards harmonized monitoring of water provisioning, regulating, and purifying services in urban forests. Vilhar, U., Verlič, A, Žlindra, D., Simončič, P., Japelj, A (*Slovenian Forestry Institute, Slovenia; ursa.vilhar@gozdis.si; andrej.verlic@gozdis.si; daniel.zlindra@gozdis.si; primoz.simoncic@gozdis.si; anze.japelj@gozdis.si*).

In recent years there has been increasing focus on ecosystem services provided by urban forests, such as supplying fresh water, purifying water, and regulating water runoff. Researchers have conducted extensive environmental monitoring and collected evaluation data, potentially informing forestry practice, decision-making, and policy. However, information about the extent to which urban forests fulfill their water-related ecosystem services remains limited. In order to better inform public and private entities about the capacity of urban forests to provide water, protect its quality, and regulate runoff, harmonized monitoring of selected core indicators in a network of European cities should be considered. The authors propose and test a set of core indicators for urban forests in the city of Ljubljana, Slovenia. Criteria for these indicators include being necessary, effective, easy to establish, and feasible.

Variation in floristic composition during secondary succession of forests in Cataniapo River Basin, Amazonas state, Venezuela. Villa, P., Infante, J. (*Instituto Nacional de Investigaciónes Agricolas (INIA), Venezuela; villautana@gmail.com; jdinfantet@gmail.com*), Montilla, M. (*Ministerio del Ambiente, Venezuela; mmontilla@gmail.com*), Delgado, L. (*Instituto Nacional de Investigaciónes Agricolas, Venezuela; ldmonsanto@gmail.com*).

The dynamics of secondary succession forests in Amazonas are highly variable and depend largely on the types of disturbances. The aim of this research was to evaluate changes in the floristic composition of secondary forests with regeneration at different successional stages. Plots of 20 m × 50 m were established with different ages of succession, and in primary forest. The relative abundance of species previously identified (DBH 2.5–10 cm, >10 cm) was measured. The evaluation was conducted in five successional stages (3–4 yr, 7–8 yr, 11–12 yr, 15–16 yr, 19–20 yr) and primary forest. As a general trend the floristic composition was highly variable between the early stages of succession, and among pioneer species in relation to later stages and primary forest. Differences were observed in relative abundance among species in each successional stage, and between successional stages. During the first stage, *Aegiphilla* intermediate successional species*, Cecropia sciadophylla, C. ficifolia,* and *Jacaranda copaia* were the dominant species. In advanced stages *Parkia pendula* spp. and *Unonopsis velutina* were the dominant species.

Species richness and forest productivity: a large-scale geospatial analysis. Watson, J., Liang, J. (*West Virginia University, USA; jamesvwatson6@gmail.com; alpenbering@gmail.com*), Tobin, P. (*U.S. Forest Service, USA; ptobin@fs.fed.us*).

Large-scale forest inventory data were used to determine the effects of tree species diversity on the productivity of forested ecosystems. U.S. Forest Inventory and Analysis (FIA) data were compiled from every U.S. state (except Hawaii) to study the relationship between the productivity of the >100,000 permanent sample plots and diversity of trees that are present on these plots. GIS layers of the current basal area, basal area from a previous inventory, site productivity, and the number of species present at a given location were developed. Based on these maps, the relationship between forest productivity and explanatory variables including tree species diversity, total stand basal area, elevation, and slope was analyzed. A positive association was found between tree species diversity and stand productivity consistently across most of the forest types in the United States. This study helps to answer whether an increase in biodiversity improves ecosystem services and what risks are posed by a declining biodiversity to humans and the environment.

Fake forests and quantifying uncertainty in allometric equations for the 'real world'. Wayson, C. (*SilvaCarbon, USA; cwayson.silvacarbon@gmail.com*), Carrillo Negrete, O., Olguín Alvarez, M. (*Proyecto Mexico-Noruega, Comisión Nacional Forestal, Mexico; oswaldisma@gmail.com; olguin.conafor@gmail.com*).

In calculating biomass from allometric equations there are choices of what published equation to use for a particular tree. Often, however, the uncertainty associated with this choice is not included in error estimates. In an effort to examine the impacts of choice of allometric equation on levels of uncertainty, the authors performed a thought experiment by creating a fake forest with characteristics similar to Mexican forests in terms of diameter distribution and a 'known' biomass with 100 000 individuals. An optimal sample size and distribution of diameters for an allometric equation were calculated. From here, the authors analyzed the effects of n, distribution of n, range of n, and equation form on the uncertainty estimates of biomass for the forest as a whole. This work tries to illuminate the effects of allometric equation choice on uncertainty for forest carbon estimates such as those of Mexico. A decision tree algorithm has been created to select the most appropriate equation from the equation database for Mexico, in an effort to reduce overall uncertainty in carbon estimates for Mexican forests.

Detection and quantification of forest carbon in intact tropical rain forests of Brunei Darussalam using remote sensing for REDD+. Yoon, M., Lee, W., Lee, J., Son, Y. (*Korea University, Republic of Korea; lovemihae@gmail.com, leewk@korea.ac.kr; jylee1559@hanmail.net*), *yson@korea.ac.kr*), Kamariah, A. (*University of Brunei Darussalam, Brunei; udhl_2003@yahoo.com*).

Quantification of tropical forest carbon is important for the REDD+ MRV system in climate change science and policy. However, accurately quantifying carbon in intact tropical rain forests has posed challenges because of the complex structure of these forests. This study aimed to estimate carbon storage in tropical rain forests with the next-generation remote sensing (hyperspectral image and synthetic aperture radar (SAR)) technology and to ENHANCE? elaborate remote sensing technology by field measurements for the REDD+ project. The 25-ha forest dynamics research plot in the Heart of Borneo at Kuala Belalong, Brunei, was selected for this study. Within this plot, six 20 m × 20 m sub-plots located along the altitudinal gradients were chosen. Leaf area index and DBH were measured on these sub-plots. The optimal regression equation based on field study, remote sensing data, and various spectral characteristics will be generated. A combination of physical information derived from SAR imagery and optical information derived from the hyperspectral image will be used to estimate carbon storage more accurately. Mapping of forest carbon storage in the extended area will be conducted through cross-validation between remote sensing data and field survey data. This study was carried out with the support of "Forest Science Technologies Development Project (Project Number: S121313L130120)" provided by the Korea Forest Service.

Influence of extreme storm events on forest soil carbon stock changes in Baden-Wuerttemberg, Germany. You, B. (*Albert-Ludwigs-University Freiburg, Germany; Bin.You@Forst.bwl.de*), Hanewinkel, M. (*Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland; marc.hanewinkel@wsl.ch*).

Forest ecosystems play a crucial role in the global carbon cycle, and forest soil carbon stock and fluxes account for a large part of the carbon budget in terrestrial ecosystems. However, the influence of extreme storms on soil carbon stock has not yet been well studied. In this study, a process-based soil carbon model was calibrated by means of Bayes's theorem to update the parameter values of the model (YassoBW) for the state of Baden-Wuerttemberg in Germany. During the process of Bayesian calibration, litter input from living biomass and mortality was estimated based on the National Forestry Inventory (NFI). The repeated measurements of SOC were derived from the soil surveys and then compared with the model outputs. The Markov-Chain-Monte-Carlo (MCMC) method with standard metropolis algorithm was used to explore the parameter space of the YassoBW model. Then it was applied to determine the impact of an extreme storm, Lothar, on the forest soil carbon stock changes in Baden-Wuerttemberg under different climate change scenarios because soil carbon decomposition rate depends greatly on temperature and soil moisture. Sensitivity analysis was implemented to reflect the magnitude of influence of climatic data on soil carbon prediction. Various post-storm management strategies were also integrated to demonstrate their effects on soil carbon stock accumulation in the long-run.

A geostatistical approach to integrate the national forest inventories and monitoring issues within the scope of REDD+. Zamora Lopez, S.Z., Koehl, M. (*University of Hamburg, Germany; szamora.lopez@gmail.com*), *michael.koehl@uni-hamburg.de*), Ramírez, C. (*Food and Agriculture Organization, Peru; carla.ramirez@fao.org*).

The purpose of this research was to evaluate the applicability of geostatistical techniques to national forestry inventories at a national and sub-national scale. The authors used 371 clusters of samples collected in Nicaragua during 2007–2008 by the National Forest Inventory. Tree characteristics such as height, diameter, biomass, volume, and health, as well as soil texture and other variables were analyzed. Methods included exploratory spatial data analysis and geoprocessing such as areal interpolation and empirical Bayesian kriging. Geostatistical techniques show promise for downscaling or upscaling the data samples from forest inventories, and for predicting values and their standard errors. This study highlights the variables suitable for a geostatistical approach. This approach can be used for such purposes as identifying trends, predicting values of key variables, identifying gaps in specific areas, defining indicators of forest inventories, and facilitating cost-effective monitoring. Evidence is provided about how these geostatistical techniques can support decision-making on forest assessments at both a national and a sub-national

scale. In addition, this study stresses the need to use a geostatistical approach for better integration of the national forest inventories and monitoring issues within the context of REDD+.

Forest crown closure retrieval using an inverted geometric-optical model. Zeng, Y., Wu, B., Zhao, D., Zhao, Y. (*Chinese Academy of Sciences, China; yuanz@irsa.ac.cn; wubf@irsa.ac.cn*), *zhaodan@irsa.ac.cn; zhaoyj@irsa.ac.cn*).

The objective of this study was to use an inversion of the Li-Strahler geometric-optical model combined with a scaling-based endmember extraction method to retrieve a forest canopy structural property, crown closure, in the Three Gorges region of China. A space-borne Landsat-8 image covering the whole study area and airborne hyperspectral PHI3 data located in a typical forest nature reserve were acquired at the same time in 2013. First the viewed surface components endmembers were extracted from the Landsat-8 data by the regional scaling-based linear unmixing model using the corresponding PHI3 image. Then crown closure was derived and mapped by inverting the Li-Strahler model based on the extracted endmembers. Finally, the model results were validated using field measurements and regional crown closure estimated from airborne LiDAR data. It can be concluded that the physically based Li-Strahler geometric-optical model could be inverted for estimating forest canopy structure, and the scaling approach may solve the mixture problem, may better extract the input for model inversion, and also could expand forest mapping from a local to a regional scale.

Effects of forest recovery on runoff and river discharge at different scales in a subtropical area of China. Zhou, G. (*Chinese Academy of Sciences, China; gyzhou@scib.ac.cn*), Zhou, P. (*Guangdong Academy of Forestry, China; zhoupinger@sinogaf.cn*).

Information on how forest recovery affects water resources is important as concerns arise over possible shortfalls in water supplies. This study examines the effects of forest recovery on water resources at different scales. At a regional scale, water budget analysis and time-series analysis were used to determine the effects of significant forest recovery on river discharge during 50 years (1960–2009) for the entire Guangdong Province. Contributing variables such as precipitation, potential evapotranspiration, development of impervious areas, human water consumption, and reservoir construction were quantitatively examined. The amount of surface runoff after forest recovery was examined at a hill-slope scale. The results showed that at the slope scale, forest recovery significantly decreased surface runoff ($P < 0.001$). At a large scale, surface water supplies did not decrease significantly as the forest recovered over the last 50 years in this subtropical area ($P > 0.05$), and forest recovery played a positive role in increasing water yield in the dry season.

Estimates of forest biomass carbon storage in Liaoning province in northeastern China: a review and assessment. Zhou, L. (*Chinese Academy of Sciences, China; zhouli930@163.com*).

Accurate estimates of forest carbon storage and stock change is critical for analyzing the effects of forest management on the capacity of forest carbon sinks. Using data from China's Continuous Forest Inventory, this study compared estimates of forest biomass carbon (FBC) storage in Liaoning province derived from different methods. Substantial variation occurred in estimates of FBC storage for young and middle-aged forests. For forests in Liaoning province with high proportions of trees in the young and middle age-classes, the continuous biomass expansion factor (CBM) method by forest type with age class was found to be more accurate for estimating forest biomass. Based on this method, forests in Liaoning province are a carbon sink, and increased from 63.03 Tg C in 1980 to 120.87 Tg C in 2010, with an annual increase of 1.93 Tg C. The average carbon density of forest biomass in the province increased from 26.15 Mg/ha in 1980 to 31.02 Mg/ha in 2010. The largest FBC occurred in middle-aged forests, but the average carbon density decreased in these forests between 1980 and 2010. The increase in forest carbon density resulted mainly from the increased area and carbon storage of mature forests.

Methods for determining the thresholds of forest gaps (treefall gaps) Zhu, J., Zhang, G. (*Chinese Academy of Sciences, China; jiaojunzhu@iae.ac.cn; zgq04713@163.com*), Wang, G. (*Clemson University, USA; gwang@clemson.edu*), Li, X. (*Shenyang Agricultural University, China; lixiufen2009@163.com*), Yan, Q. (*Chinese Academy of Sciences, China; qlyan@iae.ac.cn*).

Forest gaps created by treefall are considered to play an important role in forest ecology because they are the major driving force in maintaining the forest cycle. However, there are inconsistencies in how the upper and lower limits of gaps (from 4 m^2 to 4 ha) are defined. These inconsistencies make it difficult to compare gap research. The authors suggested that the upper limit of the gap be estimated by calculating the mean value of the shade silhouette length (SSL) of the canopy trees surrounding the gap (CTSG) during the growing season, which can reflect the maximum range of impact of CTSG in the gap. The gap lower limit is obtained by estimating the mean value of the minimum SSL of the canopy depth (at 12:00 local time) during the growing season, which can reflect the minimum range of impact of CTSG in the gap. The gap thresholds vary depending on both the location and the height or canopy length of CTSG. The ratio of gap diameter (GD) to canopy height (CH) was used to indicate gap thresholds. For example, at 41°08′53″N, 121°12′6″E, the upper limit of the gap is GD:CH = 3.02 and the lower limit of the gap is GD:CH = 0.29. The authors recommend that the gap size be uniformly determined using the method proposed in this study.

GENERAL POSTER SESSIONS

IUFRO Division 5: Forest Products

Radial variation of wood density and wood anatomy of *Quercus* spp. (Fagaceae) in Japan. Abe, H., Kuroda, K., Yamashita, K., Yazaki, K., Noshiro, S., Fujiwara, T. (*Forestry and Forest Products Research Institute (FFPRI), Japan; abeq@affrc.go.jp; kurodak@affrc.go.jp; zaikana@affrc.go.jp; kyazaki@ffpri.affrc.go.jp; noshiro@affrc.go.jp; fujiwara@ffpri.affrc.go.jp*).

We analyzed the radial variation of the basic density of 35 wood samples from14 species of *Quercus* in the Xylarium of FFPRI which were collected from all over Japan. In addition, in order to investigate the difference in the anatomical features of the inner and outer parts, transverse sections were observed by optical microscopy, and the vessel areas of both parts were measured. In most of the samples of the ring-porous wood, basic densities showed highest values near the pith, becoming lower toward the outer part. For the radial-porous wood, two kinds of patterns were mainly observed in the radial variation of basic densities. One was a slight increase outward from the pith which then decreased, and another was almost constant within a sample. These changing patterns from the inner to the outer in the radial-porous wood could be explained with the changes in vessel area. The average values of the difference between maximum and minimum densities within a radial series of a sample were 0.082 g/cm^3 in ring-porous wood (deciduous species), and 0.041 g/cm^3 in radial-porous wood (evergreen species). In tree species used in this study, *Q. phillyraeoides* had the highest density.

Sustainable utilization and marketing of selected non-timber forest products to support the handicraft industry and the development of rural communities. Aggangan, R., Natividad, R., Tamolang, F., Ella, A., Cortiguerra, E. (*Forest Products Research and Development Institute, Philippines; rtaggangan@gmail.com; ranfprdi@yahoo.com; mt2data@yahoo.com; arsie_ella@yahoo.com; emscortiguerra@yahoo.com.ph*).

This project was conducted to support and promote the sustainable utilization of selected non-timber forest products (NTFPs) to strengthen the production and export capabilities of the handicraft industry and the development of rural communities in Quezon and Camarines Norte, Philippines. Non-timber forest products inventory was done in each project site to generate data on the available NTFPs species, volume, density, and growth of regenerants for the PO information and reference relative to the harvesting, propagation, and plantation development of preferred NTFPs. Moreover, implementation of various capability building activities significantly enhanced the knowledge and skills of the POs on NTFP harvesting, processing, and utilization technologies. The organized handicraft producers' group in the project sites had started selling handicraft products in the local market. Strategies to enhance their product promotion and marketing included installation of product display areas, participation in provincial, regional, and national trade fairs, and preparation of product brochures. Linkages were established with government support agencies to provide further assistance on product development and marketing. The handicraft producers' group in each province was federated to improve production and marketing capability to deliver in case there was a high quantity of orders from exporters or local handicraft traders.

Comparing the potential of black pine essence for use in pharmaceutical industries: case study of Ardebil and Guilan provinces, North Iran. Akbarzadeh, M., Kouhgardi, E., Mikaeili, H. (*Islamic Azad University Iran; mehrdad.ak@gmail.com; kouhgardi@yahoo.com; mikaelih@yahoo.com*).

The goal of this study was to introduce the most important effective material of black pine, and also to introduce the best zone in view of percentage of essence constituents. Sampling was conducted in Ardebil and Guilan Provinces in the north of Iran. In each sampling, a total of 30 trees were selected in three repetitions with 10 trees per repetition. Three leaves were sampled from each tree. The leaves were dried in the shade and their essence was then extracted through a water distillation method by using Clevenger system. After that, the composition of the effective materials of the essence was identified by gas-burning chromatography system connected to the mass spectrophotometer. The results of variance analysis showed that there was a significant difference in the studied zones in view of percentage of evaluated composition. Based on the results, 147 compounds were identified in Ardebil which is 86.61% of total components of the essence. In addition, 137 compounds were identified in Guilan which is 85.96% of total components of the essence. It can be generally concluded that the most important identified components include alfa-pinene, bicycloheptane, camphene, beta-pinene, beta-flandern, alfa-tripinolen, bicycle-heptane, trans caryophyllene, germacrene, delta cadinene, alfa-humulene, and beta-mayerson that have high pharmaceutical values.

Analysis of defects in wood flooring manufactured by Brazilian companie members of a certification quality program. Andrade, A., Milan, M., Takeshita, S., Jankowsky, I. (*University of São Paulo-ESALQ, Brazil; arielandrade@usp.br; macmilan@usp.br; takeshita.sa@gmail.com; jankowsky@usp.br*).

Wood floorings are considered products of higher added value, and the occurrence of defects, especially in the final product, is not desirable as they may cause installation problems that can generate customer dissatisfaction. In Brazil, the National Hardwood Flooring Association (ANPM) has developed a certification program to improve the quality of products. In this sense, this research aimed to analyze the defects of wood flooring that occur in manufacturers. The methodology involved conducting audits in various companies. In total, 120 audits were carried out with companies in the ANPM program and 4 audits were with nonmembers. Audit procedures and classification of defects obeyed Brazilian standards. The results showed that defects considered non-conformities represented 6.1% of analyzed pieces in the wood flooring of the companies participating in the program. For companies that were not members of the program, 28.4% of analyzed pieces presented non-conformities. For companies participating in the program, the most common defects were surface checks, gaps, and pieces with twist. Companies not participating in the program had more failures in the procedures related to the processing, handling, and classification of wood flooring than companies members of the program.

Evolution of quality wood flooring in Brazilian companies members of a certification program. Andrade, A., Milan, M., Takeshita, S., Jankowsky, I. (*University of São Paulo-ESALQ, Brazil; arielandrade@usp.br; macmilan@usp.br; takeshita.sa@gmail.com; jankowsky@usp.br*).

In Brazil there are few initiatives related to quality certifications for wood products. One of the existent quality certifications involves wood flooring and was developed by the National Hardwood Flooring Association (ANPM). However, it is not known if this certification actually generated positive impacts on product quality. In this sense, the goal of this research was to present and analyze the evolution of the quality of wood flooring in Brazilian companies that participate in the program of quality certification developed by ANPM. The methodology involved the collection and analysis of information obtained from six companies and eight complete audit cycles. The results showed that, in general, carrying out the audits increased the quality standard of wood flooring. It was also possible to conclude that the item defects, thickness, and width have better consistency in quality standards, being easier to control, and the item moisture has the worst constancy in quality standard and is more difficult to control.

Combined compression and thermal modification of silver birch and European aspen sawn wood: color changes along the profile. Antikainen, J., Mottonen, V., Heräjärvi, H. (*Finnish Forest Research Institute, Finland; jukka.antikainen@metla.fi; veikko.mottonen@metla.fi; henrik.herajarvi@metla.fi*).

Compression drying combined with thermal modification is a potential method for improving the utilization rate of light-weighted wood species. The density profile through thickness is modified with compression and the thermal modification is used to reduce the set-recovery of the product. Despite the strong discoloration of wood by thermal treatment, a uniform color along the wood profile is desired. Therefore, this study will examine color changes of silver birch (*Betula pendula*) and European aspen (*Populus tremula*) along the sawn wood profile processed with different combinations of degree of compression and temperature. The color changes were measured by 3 mm steps from the surface layer to the core of specimens using a spectrophotometer. Measured spectral information was transformed to the CIELAB color space in order to evaluate the differences between the layers. The results showed that the average color difference (deltaE) along the profile with birch was between 3.81 and 5.49. With aspen the color differences were even lower from 2.44 to 4.47. To conclude, the combined compression and thermal modification do not dramatically affect the color changes along the profile. Therefore, it is a potential method for improving the utilization rate of light-weighted wood species.

Strategies for sustainable dependence on the forest: the case of wood carvers in Ghana. Appiah-Kubi, E. (*Forestry Research Institute of Ghana, Ghana; appiahkemma@yahoo.com*), Agyeman, K. (*Kwame Nkrumah University of Science and Technology, Ghana; kkagyeman.cass@knust.edu.gh*).

The essence of the forest in the socio-cultural and economic life of the people of Ghana cannot be overemphasized. However, there is tremendous imbalance between the forest and its dependents. This is because there is no correspondence between population growth and increase of the forest cover. People who constitute clusters of carvers and the market have increased at the expense of the forest. This is evident in the distances carvers cover these days to attain the rapidly-depleting wood species required for their works. This is coupled with increasing difficulty in meeting the demands of large markets. The causative factors to this situation were investigated both qualitatively and quantitatively through review of salient documents and interviews of stake holders. The data was analyzed cognitively and statistically to paint the real picture of the situation. This situation is related to the forest management strategies, leading to proposed sustainable dependency strategies under the two categories of benefits Ghanaian carvers derive from the forest. These are captured under direct and indirect dependence strategies targeted at curtailing the rapid depletion of the forest notwithstanding sustainable livelihood for the Ghanaian carver.

Promotion and utilization of plantation grown timber species in Ghana: the kiln drying schedule of *Khaya ivorensis*. Appiah-Kubi, E., Opuni Frimpong, E., Essien, C., Tekpetey, S. (*Forestry Research Institute of Ghana, Ghana; appiahkemma@yahoo.com; eopunifr@mtu.edu; caessien@ymail.com; nii9lartey@gmail.com*), Kankam, C. (*Kwame Nkrumah University of Science and Technology, Ghana; ckkankam@hotmail.com*), Mensah, M. (*Forestry Research Institute of Ghana, Ghana; mmensah@csir-forig.org.gh*).

Khaya ivorensis (Mahogany) is ranked as one of the best known and most valuable commercial tropical timbers on the international market. It is acknowledged that these species are becoming scarcer in the wake of dwindling forest cover in Ghana, with illegal logging as the major contributing factor. Since plantation species have not been used much in the past, their kiln schedules had also not been developed, and their drying rates and sensitivity to stain, surface checks, collapse, honeycomb, and warp are unknown. In this study, a kiln drying schedule for plantation grown *Khaya ivorensis* was developed. Results indicated that the mildest drying conditions (that is the lowest initial temperature, smallest initial wet bulb depression, and the lowest final temperature) for the plantation species would be 65 °C and 90 °C for the initial and final temperatures, respectively, and this coincided with the temperature schedule T11. The wet bulb depression (WBD) of 5.5 °C also corresponded with WBD schedule of 5. So for the plantation species, in putting together the mean adopted classes of initial moisture content of B, the WBD class of 5 and the temperature schedule of T11, Madison Drying Schedule T11-B5 is proposed.

Exploring lesser used timber species in Ghana for greener construction: a case of *Cola gigantea* and *Ficus sur*. Appiah-Kubi, E., Wilson Owusu, F. (*Forestry Research Institute of Ghana, Ghana; appiahkemma@yahoo.com; fwowusu3@yahoo.com*).

The sustainable use of lesser-used-species (LUS) has been identified as important for green construction and the sustainable management of forests. In this study, the mechanical properties of two LUS species were determined for efficient utilization in the construction industry. Properties that were determined include static bending strength (MOR), modulus of elasticity (MOE), compressive strength, and hardness and shearing strength. Five trees of *Cola gigantea* and four trees of *Ficus sur* were extracted from two ecological zones in Ghana for the study. The logs were converted to 25 mm and 55 mm thick boards and air dried to about 12% moisture content. The tests were carried out using an Instron universal testing machine. Results revealed that *Cola gigantea* had a mean modulus of rupture (MOR) of 77.5 N/mm^2 with a mean density of 493 kg/m^3 whilst *Ficus sur* had a mean

MOR of 50.85 N/mm^2 with a mean density of 376 kg/m^3. The mean MOE were 9 616 N/mm^2 and 5 707 N/mm^2 for *Cola gigantea* and *Ficus sur,* respectively. Based on the results, both species are generally good for end uses where strength and hardness are not critical requirements.

Profitability analysis of commercial processing of *Vitellaria paradoxa* on livelihood of rural dwellers in savanna area of Oyo State. Arabomen, O., Ayomide, A., Azeez, F., Odediran, F. (*Forestry Research Institute Of Nigeria, Nigeria; arabomenkevwe2009@yahoo.com; adedunmolalala@yahoo.com; abdfataiaranni2002@yahoo.com; festusbukola@yahoo.com*).

The objective of this study was to identify the socio-economic characteristics of processors of *Vitellaria paradoxa* and to examine the different benefits (profitability) that accrue to commercial processing of *V. paradoxa* in the study area. Three local government areas were selected for the study, and random sampling methods were adopted for the selection of respondents. Primary and secondary data were obtained through the use of questionnaires and relevant literature. Data collected were analyzed using descriptive statistical tools, presented in the form of frequency tables, percentages, and charts which were described accordingly. Gross margin analysis and rate of return on investment (RORI) were used to determine the profitability of processing of *V. paradoxa.* The results showed that 90% of *Vitellaria paradoxa* processors were female and 77.1% were within the age range of 21–40 years. They also indicated their primary occupation as farming, with the number of years of experience in processing of *V. paradoxa* (90%) as over 12 years. *V. paradoxa* processors (84.37%) indicated that income was the main economic benefit derived from this business with the RORI as 96% which indicated that the business is highly profitable since the higher the RORI, the higher the profitability.

Promotion and characterization of the mechanical properties of the non-timber forest product *Borassus aethiopum*. Asafu-Adjaye, O., Frimpong-Mensah, K., Darkwa, N. (*Kwame Nkrumah University of Science and Technology, Ghana; asibos@yahoo.com; frimpongmensahk@yahoo.com; nicdarkwa@yahoo.com*).

This study identifies two types of *Borassus aethiopum* (male and female) contrary to Dransfield's findings and discriminates their mechanical properties based on the tree's morphology. Literature on *Borassus aethiopum* tends to be limited to botany. The male is cylindrical and flowers but bears no fruits, while the female bears fruits and has a stem that is comparatively bigger in the middle and tappers towards both ends. Wood samples were collected from the three distinct zones: dermal, sub-dermal, and the central zones at 30%, 60%, and 90% of the trees merchantable height. Mechanical test specimens were prepared and tested in accordance with the British Standard BS 373:1957. The mean strength values at 12% moisture content (MC) at each interval of the male and female *Borassus* were significantly different at ($p < 0.001$) with the male recording the highest strength values. Mechanical properties significantly increased radially from the central zone to the dermal zone and axially decreased from the butt at 30% interval to the 90% interval. The mechanical properties of the dermal and sub-dermal zones can be used in applications requiring higher mechanical strength, whereas the central zone, owing to its low strength values, is not suitable for any application requiring direct load bearing.

Importance of *Pseudocedrela kotschyi* and *Mitragyna inermis* in well being of communities in Sudanian zone of Benin. Assede, E. (*Collaborator through University of Abomey-Calavi, Benin; assedeemeline@gmail.com*), Adomou, A., Sinsin, B. (*University of Abomey-Calavi, Benin; adomouaristide@yahoo.fr*), *bsinsin@gmail.com*).

The main reason for a growing interest in forest species is their increasing contribution to local livelihood. This study aims at assessing the uses and factors affecting the use of two forest species: *Pseudocedrela kotschyi* and *Mitragyna inermis*. Eighty individual interviews were held in the typical Sudanian zones of Benin. Four different tribes were involved: Berba, Waama, Gourma, and Fulani. This study combined quantitative and qualitative ethnobotanical approaches. Overall, 38 different uses were mentioned and 39.5% of uses were common to both species. The most important use is medicine. Even though all organs are used in the treatment of diseases, bark, leaves, and roots are the most important organs included in medicinal treatments. Bark, leaves, and root are respectively involved in 43.4%, 34.2%, and 42% of total uses. The importance of uses depends on species organ and varies between ethnic groups. In the case of *Mitragyna inermis*, Berba use more roots, the Gourma prefer the leaves, while the Fulani and Waama respectively use more bark and stem. All these collections are directly provided by natural forest stands. So, it will be useful to think about the domestication of these forest species.

Beekeeping as a source of livelihood strategy in Oyo State, Nigeria. Ayomide, A., Olugbire, O., Arabomen, O., Abi, E. (*Forestry Research Institute of Nigeria, Nigeria; adedunmolalala@yahoo.com; olugbireolutoyin@gmail.com; arabomenkevwe2009@yahoo.com; eneabi2008@yahoo.com*).

Beekeeping, popularly known as apiculture, is the art and science of raising honey bees for economic benefit. It refers to the practice and management of the bees in the hives, which leads to the production of valuable materials such as honey, beeswax, propolis, bee pollen, bee venom, and royal jelly. This study examined beekeeping as a source of livelihood strategy in Oyo State. The study was carried out in eight local government areas of Oyo State. A structured questionnaire and oral interviews were used to collect information relating to beekeeping housing systems, management techniques, production, marketing, and problems encountered in the business from 70 beekeepers. The result revealed that the majority of the respondents were male (86.11%) while the remaining (13.89%) were female. About 85% of the respondents reported that the purpose for rearing bees was to generate income. The major problem encountered by the beekeepers included lack of financial assistance, bee stings, and disease/insect outbreaks. Since beekeeping was the major income-generating business among the respondents, it was therefore recommended that the government should assist the beekeeper through provision of microfinance credit, processing equipment and encouragement of youth in the art of beekeeping.

Potential of the forest to produce raw material for the wood carving industry in Ghana. Baffo, B. (*Volta River Authority, Ghana; baffoblankson@gmail.com*).

The wood carvers' perceptions on the potential of the forest to produce raw material for the wood carving industry were studied at Enyirisi and Aburi in the eastern part of Ghana. Fifty workshops were selected in both communities using a systematic

sampling method to participate in the survey and two respondents were selected from each workshop. It was realized that out of over 126 different tree species that grow to the size capable of being used for all wood working purposes in Ghana, only 18 species were traditionally preferred for carving. Out of 18 that were being used, 72% were preferred by the carvers based on different perceptions. The majority (75%) of them had to travel distances between 80 km and beyond to get their wood supply, and most of them were (57.5%) from the farmlands. Other sources of supplies include forest (30%) and plantations (18%). The preferred species are now declining at an alarming rate with little or no attempt at replacing them. Recommendations were made to the government to involve all the stakeholders to address the problems associated with wood deficit on the carving industry.

Nanocellulose market volume projections: a derived demand analysis. Bilek, E. (*U.S. Forest Service, USA; tbilek@fs.fed.us*), Shatkin, J. (*Vireo Advisors, USA; jashatkin@gmail.com*), Cowie, J. (*Cowie & Company LLC, USA; john@cowiecompany.com*), Wegner, T. (*U.S. Forest Service, USA; twegner@fs.fed.us*).

Nanotechnology has enormous promise to bring about fundamental changes and significant benefits to society and to the forest products industry. This study created a methodology to estimate the potential volume of nanocellulose that will be used in diverse products and markets in the United States. Published data sources were used to identify research that cites the utility of nanocellulose for particular applications. Eleven potentially high-volume applications were identified along with 12 low-volume applications. In addition, three identified novel applications were considered to be potentially promising, but were not developed enough to make nanocellulose market demand projections. Volume projections were made by estimating nanocellulose market penetrations into representative end-product markets. Middle market-penetration estimates were bracketed by both high and low estimates to establish a plausible volume range for nanocellulose demand. When summed, the annual market potential in high-volume applications in the United States was approximately 12 million tonnes of nanocellulose, with nearly half coming from the combined packaging and paper industries. This estimate was based on current markets and our middle market-penetration estimates. The spread around this middle point is quite wide, ranging from around 45% less to around 55% more, reflecting the early stage of the technology development.

Timber trade and its effectiveness in the context of Slovakia. Brodrechtova, Y., Halaj, D. (*Technical University in Zvolen, Slovakia; brodrechtova@tuzvo.sk); halaj@tuzvo.sk*).

The aim of the study was to identify trade structures and analyze their effectiveness in achieving the economic goals of forest products companies. Coming from new institutional economics, an explanation of decisions for timber trade structures (institutional arrangements) and their influencing factors (transactional characteristics) based on agency and transaction costs was sought. A case study approach with a qualitative methodology was proposed due to the exploratory character of the study. Semi-structured in-person interviews were conducted with 19 experts, 11 forest enterprises, and 9 wood and 5 forest biomass processing companies in Slovakia selected via random stratified sampling. Transcribed interviews were subsequently examined with content analysis. The preliminary results indicate that private forest owners preferred spot market transactions over the short- or long-term contracts favored by state forest owners. The former were influenced mainly by uncertainty, whereas opportunistic behavior and transaction atmosphere also factored in the decisions of the latter. The timber processing companies primarily sought (long-term) contracts with state forest owners. Overall, effective achievement of economic goals for forest products companies was affected primarily by asset specificity and transaction atmosphere as competition for timber resources has considerably increased in Europe in general and Slovakia specifically.

Small enterprises and the U.S. secondary wood industry. Buehlmann, U. (*Virginia Polytechnica Institute and State University, USA; buehlmann@gmail.com*), Espinoza, O. (*University of Minnesota, USA; oaespino@umn.edu*), Bumgardner, M. (*U.S. Forest Service, USA; mbumgardner@fs.fed.us*), Sperber, M. (*LIgnum, United States; michael.h.sperber@gmail.com*).

The past decades have seen numerous large U.S. secondary woodworking companies shift their production to overseas locations, mainly in Southeast Asia. Also, companies in this important manufacturing sector have been hit hard by the downturn in housing markets and the following recession. Thus, many large customers of the U.S. hardwood lumber industry have reduced or stopped their purchases, leaving mostly smaller firms as the drivers of demand for the U.S. hardwood industry. It has become, therefore, important to understand the needs of these small firms in the current business environment. This study used a census mail survey to ask participants in six states (WI, OH, WV, VA, NC, and TN) questions to help determine the unique characteristics of small firms. Both, large and small firms attributed much of their success to their manufacturing capabilities and leadership prowess. Small firms used less formal paths to gather information and planned investments less formally. Small firms, in general, also purchased more hardwood lumber using distributors, and they requested fewer specialized services from their lumber suppliers.

Relationships between environmental impacts and added value in Norwegian wood processing industries. Bysheim, K., Tellnes, L., Nyrud, A. (*Norwegian Institute of Wood Technology, Norway; kristian.bysheim@treteknisk.no; lars.tellnes@treteknisk.no; anders.nyrud@treteknisk.no*).

An ecometric approach was used to assess environmental impacts and economic value in the Norwegian wood processing industries. The industries are classified according to international business categories (NACE). Microdata were used to calculate the accumulated added value and environmental burden for the different wood-based industries and the distribution of economic value and environmental impact within the supply chain. Normalized parameters for environmental performance serve as performance indicators for sustainable development in the supply chain. The results from this study can be used to identify areas in the wood-based supply chain to be targeted for environmental improvement and increased sustainability.

Effect of water availability on the radial profile of wood density by x-ray densitometry for *Eucalyptus grandis* at 36 months old in Brazil. Castro, V., Surdi, P. (*University of São Paulo-ESALQ, Brazil; vresende@gmail.com; paulasurdi@usp.br*), Laclau, J. (*CIRAD, France; laclau@cirad.fr*), Tommasiello Filho, M. (*University of São Paulo-ESALQ, Brazil; mtomazel@usp.br*), Chaix, G. (*CIRAD, France; gilles.chaix@cirad.fr*).

The x-ray densitometry is a classic methodology to analyze tree rings and obtain the radial wood density profile as well as the intra- and inter-annual tree-rings density variation. The wood densitometric profile can be applied to studies related to wood

quality of trees, genetic studies, and management practices. In this study, the x-ray equipment LX-60 (Faxitron) was used in the wood samples diametric in 48 trees of *Eucalyptus grandis* at two water regimes (100% of rain and 66% of rain). The hydric regime with exclusion of rain (66% of rain) was performed with artificial exclusion transparent polyethylene plies covering 34% of the soil surface. The results showed: i) the densitometric profile from pith to bark; ii) limit detection of cambial age at the first and second growth ring, and (iii) there is statistical difference for the density profile by Tukey statistical test between the two treatments of water regime. These results highlight the importance and effectiveness of the method used here as a methodology for nondestructive characterization of wood according to water drought effects.

Comparative wood anatomy of *Cordia trichotoma* (Boraginaceae) from seeds of two provenances and analysis of its growth rings. Caum, C., Marcati, C. (*São Paulo State University, Brazil; carol_caum@hotmail.com; crmarcati@gmail.com*), Longui, E. (*Instituto Florestal-São Paolo, Brazil; edulongui@gmail.com*).

Our goal was to correlate growth rings with temperature and rainfall and to compare the wood anatomy of *Cordia trichotoma* that grew up in the same environment at Luiz Antônio Experimental Station, Luiz Antônio, São Paulo, Brazil; however trees were derived from seeds collected from two natural populations of Bauru and Piracicaba in São Paulo State. We used stem discs collected at 1.30 m of six trees of each provenance. Standard techniques for wood anatomy were used. For growth rings, the discs were polished manually with sandpaper and the ring widths were measured using Image-Pro Plus. To check the data quality and accuracy, the cross-dating measurements were checked with COFECHA. ARSTAN program was used to compute the tree-ring chronologies. The relationship between growth rings and climatic factors was analyzed by Pearson's correlation. Significant differences were found in vessel grouping, vessel diameter, fiber diameter, fiber lumen diameter, and axial parenchyma/mm^2 suggesting that Bauru provenances are more restrictive to water conduction. For growth rings there was significant positive correlation between ring widths and temperature from August to October, months in which temperature is milder. A negative and significant correlation between ring widths and rainfall was obtained in April, the month in which rainfall decreases sharply.

Role of extractives in the photo-discoloration of *Cryptomeria japonica* wood caused by UV irradiation. Chang, T., Chang, S. (*National Taiwan University, China-Taipei; d00625001@ntu.edu.tw; peter@ntu.edu.tw*).

The role of wood extracts in the discoloration is an interesting topic when extractive-rich wood is exposed to UV light. Even though heartwood extract of *Cryptomeria japonica* (CJ) can promote the photostability of wood, the photo-discoloration of wood caused by UV irradiation remains unclear and needs to be elucidated. The aim of this study was to investigate the photo-discoloration of CJ heartwood. After 12-h short term irradiation, the red tone of CJ extract (CJE) from heartwood faded and the yellow tone increased. However, both tones of CJE eventually faded after 48-h long-term irradiation. The discoloration of non-extracted CJ heartwood (NCJW) was similar to that of CJE in the short-term irradiation period. But in the long-term irradiation period, NCJW's yellow tone increased continuously. Even though photo-yellowing occurred in NCJW, the degree of yellowing was less in NCJW than that of extracted CJ heartwood. These results indicated that the CJE could protect wood from photo-yellowing. Consequently, the total color difference of NCJW was limited. In conclusion, CJE not only protects wood from photodegradation but also inhibits its photo-discoloration.

Assessment for half-life and carbon stock of harvested wood products in Korea. Chang, Y., Park, J. (*Seoul National University, Republic of Korea; jang646@snu.ac.kr); gentleice@nate.com*), Son, W., Park, J., Park, M. (*Korea Forest Research Institute, Republic of Korea; tistructure@forest.go.kr; jusang@forest.go.kr; mjpark@forest.go.kr*), Yeo, H. (*Seoul National University, Republic of Korea; hyeo@snu.ac.kr*).

In the overall effort to reduce greenhouse gas emissions, people have much interest in the carbon storage role of harvested wood products (HWP) in the global carbon cycle. Carbon has been stored in HWP, such as wooden buildings and furniture, for a long period of time until the wood is burned or decomposed. In order to account for the carbon amounts in HWP, it is necessary to determine the lifespan of the HWP. The time that carbon can be stored in wood products can be expressed as the half-life, which is the time required for half of the carbon in a wood product to be transformed or eliminated by normal use. In this study, methods from other countries and conditions for determining the half-life of HWP were investigated. With statistics related to the carbon flow and the type of carbon stocks in domestic HWP, the half-life (time) of HWP in Korea was estimated. The results of this study show that HWP is an important type of carbon storage that should be considered in decisions associated with climate change adaptation and mitigation in Korea.

The current status of wood utilization for residential housing in Okinawa Prefecture, Japan. Chinen, Y., Shiba, M. (*University of the Ryukyus, Japan; akamayaa@yahoo.co.jp); mshiba@agr.u-ryukyu.ac.jp*).

Okinawa Prefecture is a group of islands at the southwest end of Japan. Wood demand and supply of Okinawa Prefecture consists of local timber produced from northern parts of Okinawa's main island, domestic timber from the southern region of Kyushu, and imported timber from foreign countries. The total wood demand has recently decreased, domestic timber increases and imported timber decreases, while only 10% of the local timber production still remains. This study presents the current status of wood utilization for residential housing in Okinawa Prefecture as it significantly influences wood demand as a whole. There is a remarkable difference between wooden house rates in Okinawa Prefecture compared to the rest of Japan due to several historical reasons including the U.S. government occupation administration policy after World War II. In 2003, the rate of wood and reinforced concrete utilized for single family house construction was 5% and 75%, respectively. However in 2012, production of new wooden housing had increased to 12%, and it is expected that the wood consumption and wood-related industrial activities will also increase in the near future.

Effect of heat treatment on the physical properties of moso bamboo (*Phyllostachys pubescens*). Cho, C., Lee, J. (*National Ilan University, China – Taipei; rockcho@seed.net.tw; clcho@niu.edu.tw*).

The objective of this study was to investigate the effects of heat treatments on the physical properties of moso bamboo (*Phyllostachys pubescens*). Heat treatments were performed at temperature levels of 170 °C, 190 °C, 210 °C, and 230 °C for time

durations of 1, 2, and 4 hours. The results indicated a value of 46.45% anti-shrinkage efficiency (ASE) in volume obtained with a heat treatment of 170 °C for 1 h, and a maximum value of 91.02% could be reached with the 230 °C treatment. These revealed that the heat treatment process could effectively improve the dimensional stability of moso bamboo. The color of bamboo turned dark and more uniform after heat treatment. The abrasion resistance of the bamboo treated below 210 °C was increased when compared to control samples. The compression strength parallel to grain of specimens heat treated below 190 °C were significantly higher than that of the controls, but were not obviously different when treated above 210 °C. The modulus of rupture and tensile strength parallel to grain decreased with an increase of the treated temperatures. The strength loss of MOR and tensile strength were 12.0 to 52.5% and 50.5 to 75.6%, respectively.

Microwave-assisted extraction of condensed tannins from maritime pine (Pinus pinaster) bark. Chupin, L., Reynaud, S., Charrier, B., Charrier, F. (*Université de Pau et des Pays de l'Adour (IPREM), France; lucie.chupin@univ-pau.fr; stephanie.reynaud@univ-pau.fr; bertrand.charrier@univ-pau.fr; fatima.charrier@univ-pau.fr*).

Microwave-assisted extraction was developed to obtain condensed tannin from maritime pine (*Pinus pinaster*) bark suitable for making wood adhesives. The bark was grounded and separated into four ranges of granular size. Extractions with ethanol/water (80/20) were performed on grounded bark of 400 to 100 μm at 100 W for 3 and 5 min and performed once, twice, or four times. For each extraction, the extraction yield was measured and analyzed by reverse phase high pressure liquid chromatography (RP-HPLC). A study of the effect of granular size on the extraction of condensed tannin was conducted on samples from a single 3 min extraction. The total soluble polyphenols (Folin-Ciocalteu) and condensed tannins (vanillin and BuOH-HCl tests) were quantified. The extracts were also characterized by RP-HPLC, Fourrier transformed infrared (FTIR), and thermogravimetric analysis (TGA). The smaller the size of the particles of bark, the more polyphenols and condensed tannins were extracted. The main components extracted were catechin, epicatechin, epicatechin gallate, and gallic acid. The TGA showed that the extracts start their thermal degradation at approximately 180 °C.

Financial analysis of charcoal production methods in Ghana. Darko Obiri, B., Marfo, E. (*Forestry Research Institute of Ghana, Ghana; bdobiri@yahoo.com; emarfo@csir-forig.org.gh*), Nunoo, I. (*Kwame Nkrumah University of Science and Technology, Ghana; nunooisaac85@yahoo.com*), Obeng, E. (*Forestry Research Institute of Ghana, Ghana; amadanso@yahoo.co.uk*).

The efficiency of charcoal burning methods has generally been studied, but knowledge on their economics is limited in Ghana. This paper assessed the profitability of the earth mound and brick and metal kilns for burning charcoal in Ghana to aid in investment decisions on the choice of the most viable technology. Input-output data was collected from 200 charcoal producers and subjected to financial cost-benefit analysis. Results indicated that charcoal production is profitable but less profitable with the earth mound due to wood and higher labor costs. NPVs at 22% for the earth mound, brick, and metal kilns were US $1200, US $2900 and US $7000, respectively. The metal kiln is movable, has the highest turnover, and is known for the best conversion efficiency. The earth mound has less cost in construction, but brick and metal kilns require substantial initial investment capital. The earth mound is criticized as being destructive to the environment, and producers reported drudgery and various health hazards associated with its use. Producers reported a high demand for charcoal, but a declining demand for wood resources. The need for sustainable wood sources and the most efficient and economic charcoal burning method is imperative. Producers require loans at lower interest rates to encourage the use of the metal kiln.

Yield and chemical composition of essential oils from leaves of two Brazilian savannah trees. Del Menezzi, C., Silva, A., Resck, I. (*University of Brasília, Brazil; cmenezzi@unb.br; aninha.kakau@gmail.com; isresck@unb.br*).

Essential oils are non-wood forest products widely used by pharmaceutical, food, and cosmetic industries. The Brazilian Savannah (Cerrado) is the second largest Brazilian biome, and it presents high biodiversity. There is a lack of information regarding yield and chemical composition of essential oils of plants from this biome. In this context, the main goal of this paper was to evaluate the yield and chemical composition of essential oils from two native trees: *Tapirira guianensis* (Aubl) and *Eugenia dysenterica* (DC). Leaves from both trees were harvested between September and October 2011. The essential oil from the material was extracted by steam distillation for 90 minutes using laboratory distillatory equipment. The fresh distillate was collected and the essential oil was separated from the hydrosol by using a solvent. The essential oil yields were 0.5% and 1.6% for *T. guianensis* and *E. dysenterica*, respectively. The main chemical components found were: 2-hexenal, 4-terpeniol, linalool, and geraniol. The last two are relatively important from the industrial point of view. Finally, it could be concluded that both species present the potential for extracting essential oils, and research efforts to study further Brazilian Savannah trees must be continued.

Drying dimension lumber: winning the game without breaking the rules. Erickson, R. (*University of Minnesota, USA; erick117@umn.edu*).

In manufacturing dimension lumber, 70% of the energy used during tree harvesting through final surfacing is for kiln drying. The wood's low permeability perpendicular to the grain is largely responsible. Permeability parallel to the grain is about 15 times as great. Unfortunately, end-grain only exists at board ends. The situation is like a clogged freeway. Taking advantage of rapid parallel movement requires periodic end-grain exits. This was done for green nominal 2 by 4s via saw cuts perpendicular to grain on both wide faces. An uncut shoulder remained along each edge, thereby creating a simulated I-joist. Drying time to a uniform 10% moisture content was nearly halved. Edgewise bending strength, per the I-joist principle, was essentially retained. Grading rules for nominal 2 inch thick dimension lumber allow a specific sized hole, or equivalent smaller ones, per board length. Current focus is on a forest-like distribution of micro holes that honors the rules. A needle-type roller incisor downstream of the head rig is a possibility. Benefits to drying and preservative treatments, obtained at low cost, appear attractive. A huge savings of energy plus dependable dimensional stability for huge amounts of structural framing lumber are worthy goals.

Bringing the forest in: establishing the link between the use of wood and health in the built indoor environment. Fell, D. (*Fpinnovations, Canada; David.fell@fpinnovations.ca*).

This study looked at autonomic nervous system responses to wood in the built indoor environment to promote health and well-being. Prohealth autonomic responses to forests and natural outdoor environments have been established in the literature for some

time. Evidence suggests that exposure to forests lowers sympathetic reactivity which, in turn, can lower blood pressure, heart rate, and promote healing. Unfortunately, in western cultures we spend very little time outdoors and even less in forests. For example, Canadians spend as little as 6% of their adult lives outdoors. This study set out to establish if there are similar autonomic responses to wood in the indoor environments we spend the majority of our lives in. A total of 119 subjects were assigned to either wood or non-wood offices. Galvanic skin response and interbeat interval were monitored continually through a baseline, stress-induced, and recovery period. Skin conductance responses were significantly lower in the wood room than in the non-wood room in all periods of the study. This provides evidence that natural wood elements in the indoor environment reduces sympathetic nervous system reactivity. This and other emerging research results are building the case for the application of wood in the pursuit of healthier indoor environments.

Impact of alternative fertilization with sodium on growth and wood quality of *Eucalyptus grandis* plantations in Brazil. Franco, M.P. (*University of São Paulo-ESALQ, Brazil; marianapfranco@usp.br*), Laclau, J. (*CIRAD, France; laclau@cirad.fr*), Sette Junior, C. (*Federal University of Goias, Brazil; crsettejr@hotmail.com*), Filho, M.T. (*University of São Paulo-ESALQ, Brazil; mtomazel@usp.br*), Chaix, G. (*CIRAD, France; gilles.chaix@cirad.fr*).

Climate changes result in hydrological cycle alterations, with impacts on distribution and quantity of rainfall affecting forest plantations in the tropics and subtropics. Trees minimize water stress effects by leaf osmotic adjustments which are dependent on K ions. *Eucalyptus* plantations were established in tropical and subtropical soils especially poor in K. Fertilization by substitution of K by Na is a potential alternative way, at lower cost and greater availability, that is especially suitable for smallholder plantations. For these reasons, we studied respective K and Na fertilization effects on growth and basic wood density of *Eucalyptus grandis* plantations with different objectives (domestic energy, timber). Significant differences in volume of trunk and wood density were observed on 8-year-old *E. grandis* trees fertilized with Na vs. K and the control. Trees with Na fertilization showed a significantly higher volume with Na vs. the control and a lower volume vs. K. Wood density and radial variability were significantly lower compared to trees with K and the control. In this paper we discuss the advantages of Na fertilization both to minimize the drought stress effect due to global climate change and to optimize economically the wood production of smallholder plantations.

Evaluation of sapote fruit (*Capparis scabrida* H.B.K.) characteristics in relation to tree size in a rural community in Lambayeque, Peru. Galindo Jara, F., Guzman Loayza, D., Gonzales Mora, H. (*Universidad Nacional Agraria La Molina, Peru; indira_galindo_jara@hotmail.com; deysigl@lamolina.edu.pe; egonzales@lamolina.edu.pe*).

Research was conducted in the rural community of San Julian Motupe, Lambayeque, Peru to evaluate the influence of tree structural characteristics (height and diameter) on the chemical properties of the fruits of *Capparis scabrida* H.B.K. (sapote). The study aimed to provide basic information that could be used to enhance the acceptance and value of this fruit. Fruits were collected from selected trees and total production per tree was calculated. Total fruit production averaged 19.1 kg/tree. Endosperm represented an average of 27% of the total weight of the fruit. The composition of these fruits averaged: 4.7% ash, 4.53% fat, 33.5% protein, 45.13% nitrogen-free extracts, and 11.71% crude fiber. Based on the analysis of the relationship between tree structural measurements and the fruit's physical and chemical characteristics, it was concluded that the amount of crude fiber endosperm in sapote fruit is influenced by the height of the tree.

The occurrence of wet pockets in the drying of *Acacia mangium* using a conventional steam-heated kiln. Gan, K., Rabidin, Z. (*Forest Research Institute, Malaysia; ganks@frim.gov.my; zairulamin@frim.gov.my*).

Acacia mangium is increasing being planted in the forest plantation program in Malaysia. This species is known to grow well and fast without much problem. The wood was previously used for wood chips, wooden pallets, and composite products, but now is increasingly being used for solid wood products such as outdoor furniture and joinery products. The timber can be successfully dried using a radio-frequency vacuum dryer, but the energy cost is high. However, when the conventional steam-heated kiln is used, the timber is known to dry slowly and is prone to collapse and wet pockets. This paper discusses the development of a drying schedule using a conventional steam-heated kiln and the use of kiln treatments to alleviate the occurrence of wet pockets when drying *Acacia mangium*. A standard drying condition was adopted to quickly evaluate the various pretreatments such as hot water bath, air drying, and microwave pretreatments. The results indicated that a combination of air drying and microwave pretreatment tended to minimize the occurrence of wet pockets when using the drying schedule developed.

Role of U.S. homebuilders' psychographic orientation in their adoption and use of certified wood in residential construction projects. Ganguly, I., Eastin, I., Bowers, C. (*University of Washington, USA; indro@uw.edu; eastin@uw.edu; taitb@uw.edu*).

The residential construction industry is the largest market for FSC and SFI certified wood in the United States, although unreliable supply and high price provides little economic incentive for homebuilders to use certified wood. However, the increasing use of green building programs (GBPs), which incentivize the use of certified wood, represents an opportunity to expand the demand for certified wood in the United States. This study utilizes the structural equation modeling (SEM) approach to develop a comprehensive understanding of the role of the homebuilders' psychographic orientations in influencing their use of certified wood in residential construction projects. The paper also analyses the recursive causal relationship between the GBPs and certified wood usage in U.S. residential construction projects. The empirical estimation of the model was based on responses obtained from a national survey of 513 residential homebuilders and remodelers conducted during the 3rd and 4th quarter of 2011. The modeling results reveal that the builders' environmental orientation positively influences their awareness and use of GBPs and wood certification programs. The results also reveal that green building programs play a statistically significant role in awareness generation and use of certified wood in the U.S. residential construction industry.

Optimization of dilute acid hydrolysis of I-214 poplar clone wood grown in Turkey. Gurboy, K. (*Istanbul University, Turkey; gurboyb@istanbul.edu.tr*), Bayramoglu, M. (*Gebze Institue of Technology, Turkey; mbayramoglu@gyte.edu.tr*), Mertoglu Elmas, G. (*Istanbul University, Turkey; mertoglug@istanbul.edu.tr*), Korkut, I., Ovali, B. (*Gebze Institute of Technology, Turkey; ikorkut@gyte.edu.tr; bovali@gyte.edu.tr*), Özden, Ö., Koçer, S.

Beneficiation of renewable energy sources is the solution to the growing energy demand for sustainable development all over the world. Ethanol is the one of the most popular renewable energy sources produced through fermentation of sugars. Potential sources for low cost ethanol are lignocellulosic materials chosen by considering economical, geographic, and climatic conditions of the country. Fast growing native trees such as poplar are suitable in terms of energy forestry in Turkey. Dilute sulfuric acid pretreatment at high temperatures is a leading technology for the thermochemical pre-hydrolysis of wood. This study is focused on the experimental optimization of dilute acid hydrolysis applied to the I-214 poplar clone grown in Turkey. Constrained D-optimal plan was used to obtain regression models of three process responses, namely hexose, pentose, and total sugar yields, which were separately optimized for the detection of suitable ranges of process factors.

The conversion yield from wood to charcoal can be estimated by near infrared spectroscopy. Hein, P., Trugilho, P. (*Universidade Federal de Lavras, Brazil; paulo.hein@dcf.ufla.br; trugilho@dcf.ufla.br*), Andrade, C. (*Universidade Federal de Goiás, Brazil; cra.florestal@yahoo.com.br*).

The charcoal produced from wood originating from planted forests is an important source of energy used in metallurgical operations as a reducing agent, especially in Brazil, the largest producer of green steel. The evaluation of the yields obtained in the carbonization process is extremely important when biomass is intended for charcoal production. High gravimetric yield in the carbonization processes is desired for several aspects, for instance, for a better utilization of the blast furnace in terms of volume per unit of wood used to produce charcoal. The aim of this study was to investigate the applicability of near infrared spectroscopy for monitoring the fixed-carbon content of the charcoal. Partial least square (PLS) regressions were established for estimating the gravimetric yield (GY) of the charcoal by means of the NIR spectra recorded from ground charcoal. The predictive models were validated by cross-validations and independent test sets. PLS-R models developed from first derivative NIR spectra for estimating GY provided R^2p of 0.79 and root mean squared error of prediction of ~2.43%. The promising findings on laboratory scale and conditions indicate that this approach could be implemented in steel industries for inspecting the quality of their raw material in real situations, where new solutions are required for controlling the charcoal productivity with speed and precision.

Optimizing wood utilization in regard to GHG emissions and primary energy consumption on a regional level exemplified for south-east Germany. Höglmeier, K., Weber-Blaschke, G., Richter, K. (*Technical University of Munich, Germany; hoeglmeier@hfm.tum.de; weber-blaschke@hfm.tum.de; richter@hfm.tum.de*).

Low value wood assortments like forest residues, residues from wood industry, and post-consumer waste wood can partly substitute for each other in various applications as an energy source and resource for materials such as particleboard. Recently, the concept of cascading, the sequential use of a certain resource for different purposes, is increasingly often proclaimed as the optimal way of utilizing those resources in order to minimize environmental impacts and especially GHG emissions. Yet, no comprehensive assessments of the environmental impacts of cascading in comparison to other utilization pathways are available on the level of whole regions. We conducted lifecycle assessments for various utilization scenarios of the wood amounts available annually in south-east Germany, focusing on production of energy and wood panels. A special focus was placed on cascading utilization ways. The effects of product substitution will be assessed by including functional equivalent non-wood products in the scenarios. The results will provide scientifically based information for an optimized allocation of low value wood assortments in terms of GHG emissions and primary energy consumption for the study area. The effects of the concept of resource cascading on the environmental impacts of wood utilization are identified.

Consumer preferences for wood product information content in sustainability context. Holopainen, J., Toppinen, A., Rekola, M. (*University of Helsinki, Finland; jani.m.holopainen@helsinki.fi; anne.toppinen@helsinki.fi; mika.rekola@helsinki.fi*).

Despite recent emergence of bioeconomy in policy and industry level rhetoric, little is yet know about in-depth stakeholder views on what constitutes sustainability when doing everyday material choices. This study seeks to fill the gap by expanding our understanding on the dimensionality of sustainability in consumer preferences towards wooden products. Factors behind the consumer value from sustainability were derived from the literature on sustainable consumption and tested on a specific case of wood products through a developed survey instrument. Four key contextual determinants for consumer preferences for sustainable and responsible wood products were identified, where one of the identified dimensions, named Information, was characterized by a variety of information on social and responsibility issues such as legality, also including a requirement for more information about environmental effects of wood products on health. In order to better understand and manage the content of this key determinant for the consumers' purchase decisions, it was divided into different genres including information on: (a) origin, (b) environmental sustainability, and (c) social values. The consumer valuation of these different items was tested by applying it to a choice experiment in the Finnish wood product market context.

Firewood production of *Eucalyptus urophylla* in Brazilian Savanna area. Imana, J. (*University of Brasilia, Brazil; jose.imana@gmail.com*), Santana, O. (*Federal University of Pernambuco, Brazil; otaciliosantana@gmail.com*), Meira-Junior, M. (*University of Brasilia, Brazil; milton.serpa@gmail.com*).

Brazilian *Eucalyptus* wood of 8 to 10 years old is normally destined to the industrial production of cellulose, panels, firewood, and charcoal. The objective of this work was to evaluate the silvicultural, management, and economic aspects of a reforestation company which works now with cut cycles of only 3 years. The study was accomplished in a *Eucalyptus urophylla* plantation in the central region of the Brazilian savanna. The cut rotation of 3 years is based into the regional market demand. Dendrometrical data were collected in 11 plots of 1 000 m^2, with approximately 150 trees for plot. About 9.64% of the trees were dead. The data base was formed of 1 545 living trees with an average DBH of 12 cm and 11 m for the total height. The volume production oscillated around 113.12 m^3/ha. Every year the company cuts approximately 5 000 ha, corresponding to 565.6 m^3 of firewood. The market cost of each m^3 for firewood is now US$ 1.35, therefore a value of about US$ 763.56 per cycle for the company. *Eucalyptus urophylla* firewood is being well accepted for the firewood consumer.

Intra-annual phloem and xylem formation and primordial shoot development in Norway spruce saplings exposed to elevated CO_2 and temperature. Jyske, T. (*Finnish Forest Research Institute, Finland; tuula.jyske@metla.fi*), Schiestl-Aalto, P. (*University of Helsinki, Finland; piia.schiestl@helsinki.fi*), Sutinen, S., Linkosalo, T. (*Finnish Forest Research Institute, Finland; sirkka.sutinen@metla.fi; tapio.linkosalo@metla.fi*), Zhang, C. (*Forestry and Forest Products Research Institute, Japan; chunhua@affrc.go.jp*), Hayashi, N., Kuroda, K., Abe, H., Pulkkinen, P.

In boreal conditions, climate change is predicted to affect the timing of phenological processes of Norway spruce (*Picea abies* (L.) Karst.). The spring phenology of trees (e.g., bud development, cambial activity) is mainly determined by photoperiod and accumulation of temperature and may advance due to the elevation in temperatures. Increasing concentrations of atmospheric CO_2 can also affect the phenology. Recently, many studies on intra-annual cambial activity have focused on xylem formation. However, vascular cambium is a bifacial meristem in which the cellular divisions produce new xylem (inward) but also new phloem (outward) followed by cellular differentiation. Our current knowledge on phloem formation and differentiation is fragmentary. The control and interrelations between xylem and phloem formation and other phenological growth processes have also attained less attention. We analyzed the timing and coordination of phenological growth processes in grafted saplings of Norway spruce exposed to conditions representing current climate and conditions forecasted for year 2080 (elevated CO_2 and temperature). The following parameters were measured: (1) photosynthesis, (2) development of primordial shoots in buds, (3) cambial reactivation and xylem and phloem formation and differentiation, and (4) the seasonal variation in nonstructural carbohydrates in xylem and phloem.

Comparison of color, brightness, and chroma of natural dye-coated veneer. Kim, J. Suh, J. (*Korea Forest Research Institute, Republic of Korea; jikim99@forest.go.kr; jssuh@forest.go.kr*), Park, R. (*Natural Dye Research Institute, Republic of Korea; busanminsok@hanmail.net*), Park, S., Yoo, B. (*Korea Forest Research Institute, Republic of Korea; parksb@forest.go.kr; boyoofri@forest.go.kr*).

The use of dye-coated veneer EC (echo crack seal) and OSM (Osmo) considerably changed the color hue (Munsell color hue). In non-treated Korean pine veneer, EC showed yellowish red (9.4) and OSM showed yellow (0.4). In the case of Korean pine veneer dye-coated by *Phellodendron amurense*, EC and OSM showed 5.4 and 7.4 of BG group, respectively. In the case of non-treated radiata pine veneer, EC and OSM showed 0.1 and 2.7 of yellow group, respectively. In the control (no dye), EC and OSM as public yellow system respectively showed 1.7 and 1.8 in the Yellow poplar veneer. The brightness of dye-coated Korean pine veneer showed a lower value than that of non-treated veneer, whereas Korean pine veneer stained with *Phellodendron amurense* showed higher brightness and chroma values. In the case of Korean pine veneer, chroma value showed higher in the order of *Phellodendron amurense*, non-treatment, and sappan wood.

Enzymatic biodegradable characterization of wood decaying fungi. Kim, M., Ahn, H. (*Korea Forest Research Institute, Republic of Korea; mkkim@forest.go.kr; with-hoon@hotmail.com*).

The biodegradation of woody biomass by wood rot fungus is a complex reaction of a number of enzymes. In this study, we checked various growth conditions (pH and temperature) from the representative wood rot fungus to investigate the expression of lignocelluloses-degrading enzyme genes as part of the basic study of the mechanism for the bioconservation of woody components such as cellulose, hemi-cellulose, and lignin. We cultured two white rot fungi, *Phanerochaete chrysosporium* and *Trametes versicolor,* and one brown rot fungus, *Tyromyces palustris* for 7 days in different conditions. The temperatures were 25, 28, and 30 °C, and pH was 4, 4.5, 5, 5.5, and 6. The best culture conditions were pH 5.0 and 28 °C for all three species. In the case of the growth rates, *P. chrysosporium* occupied the plate in 3 days, but *T. versicolor* was slow to grow and took 7 days. The gene expression of the lignocelluloses-degrading enzymes, cellulase, manganese-peroxidase, laccase, and lignin-peroxidase will be analyzed using RT-PCR and compared with each other as we further our study.

Heterologous expression of lignin-degrading enzymes from white rot fungi in *Pichia pastoris*. Kim, M., Ryu, S. (*Korea Forest Research Institute, Republic of Korea; mkkim@forest.go.kr; shryu@forest.go.kr*).

White rot fungi produce three types of lignin-degrading enzymes namely: laccase, manganese dependent peroxidase (MnP), and lignin peroxidase (LiP). Efficient and quicker strategies are required to transform these organisms using appropriate vectors in order to improve their efficacy for lignin degradation. To enhance the productivity of ligninolytic enzymes as well as obtain a simple, quick, and an efficient source of lignin-degrading enzymes from white rot fungi, the *laccase1* (pPICαLac1) and *MnP4* genes (pPICαMnp4) from *Polyporus brumalis*, *laccase* gene (pPICαPILac) from *Phlebia tremellosa,* and *MnP* gene (pPICαTVMnp) from *Trametes versicolor* have been cloned into vectors and successfully expressed in the *Pichia pastoris*, under the control of the methanol induced alcohol oxidase promoter (aox1). Laccase and MnP activities were measured using *o*-tolidine, ABTS, and DMP in *P. pastoris*. The activities of the transformants were observed to be significantly higher than that of the wild type. Heterologous expression of ligninolytic-enzyme-encoding genes from white rot fungi was successfully achieved in the methylotrophic yeast *P. pastoris* with efficient enzymatic activities of lignin-degrading enzymes.

Screening of fruiting genes in *Lentinula edodes*. Kim, M., Ryu, S, Bak, W. (*Korea Forest Research Institute, Republic of Korea; mkkim@forest.go.kr; shryu@forest.go.kr; wcbak@forest.go.kr*).

To obtain gene data related to *Lentinula edodes* fruiting, we used expressed sequence tags (ESTs) and differentially expressed gene (DEG) analysis. We screened several genes that were effectively expressed at different stages in the life cycle of *L. edodes* (inoculation, incubation, primordium formation, and fruiting) by microarray analysis. Next, we confirmed the expression of genes responsible for fruiting in *L. edodes* by real-time PCR. The effective genes identified were hexose carrier protein, β-galactosidase, and laccase 1 at the primordium stage and 1DEG11, cytochrome P450, 12-kDa heat shock protein (glucose and lipid-regulated protein), laccase 2′, and exo-β-1,3-glucanase at the fruiting stage. To our knowledge, 1DEG11 was identified as a gene underlying fruiting in *L. edodes*.

Sustainable management of copaiba (Copaifera spp.) for oil production: definition of an optimal rotation. Klauberg, C., Vidal, E., Rodriguez, L. (*University of São Paulo, Brazil; carine_klauberg@hotmail.com; edson.vidal@usp.br; lcer@usp.br*), Diaz Balteiro, L. (*Technical University of Madrid, Spain; luis.diaz.balteiro@upm.es*).

The study deals with the definition of optimal regimen cycles for copaiba trees (Copaifera spp.), a low-density species sparsely distributed in the Amazon Basin. The copaiba oil, a nonwood product extracted from adult trees, is an important source of income for local communities. The main objective of our study was to determine whether an optimal extraction cycle exists. This is part of a case study in the State of Pará (Brazil) where 118 different trees have been monitored since 2006. Data has been collected for different cycles between 1 and 5 years. Considering two different outcomes, oil production and net present value, we discuss the effect of introducing randomness during the process of determining the optimal cycle. Therefore, the question becomes: do we get the same result when the optimal cycle is determined by means of a deterministic analysis and a Monte-Carlo simulation analysis? According to the dataset used, the results consistently pointed to a 3 year cycle, regardless of the analysis method (deterministic and stochastic) and the way outcomes were measured (production or NPV). These results confirm previous recommendations published by other authors and predicted in the norms that regulate the management of copaiba trees in Brazil.

Harvesting the dead and decaying forests: potential carbon storage and avoided emissions. Klopp, W. (*University of Northern Bristish Columbia, Canada; wsklopp@gmail.com*).

The mountain pine beetle (MPB: *Dendroctonus ponderosae* H.) epidemic is among the most recent and largest natural disturbances to occur in British Columbia, Canada. The death and decay of these stands threatens sustainable forest management and their associated carbon (C) balances at both regional and provincial scales. Our project investigates potential C storage and avoided C emissions in harvesting these forested stands. Presented findings highlight the differences in net C balances of two differing wood products: softwood lumber and wood pellets. For our analysis a C accounting framework was created to track harvested wood products throughout their life stages using a reference flow of 1 m^3 harvested raw timber. This framework allowed us to differentiate points of emission and quality of the timber and enables comparisons between differing wood products and processes. Our findings demonstrate the critical role C neutrality plays in affecting the net C balance of the life cycle of either wood product.

Livelihood sustenance potentials of herbal medicine in rural areas of Abia State, Nigeria. Kola-Oladji, K. (*Forest Research Institute, Nigeria, Nigeria; kikdiji@yahoo.com*), Olutayo, L. (*University of Ibadan, Nigeria; lantopamtu@yahoo.com*).

This study was carried out to find the sustenance potentials of herbal medicine for the livelihood, survival, and sustenance of families in the rural areas of Abia State, Nigeria. A multi-stage stratified random sampling method was used for the study. A total of 207 household respondents were sampled with only one 185 valid for the study. Also, three sellers were randomly selected in each selected market, giving a sample size of 27 sellers of which 25 respondents were valid. Findings revealed that the market is heterogeneous in terms of sex and free in terms of entry. There is no restriction to age as all age ranges were involved. Affiliation to membership association is by choice unlike the trading at the household level. Transportation and other costs were very minimal resulting in a low total cost. A benefit-cost-ratio of 4.1 was obtained with a profitability ratio of 3.11, implying that for every dollar invested, there is a profit of $0.02 returns, showing that the business is very lucrative. A total of 61 families with 164 species were identified for sales/uses for the management and curing of different ailments. Respondents' were ready to adopt any improved technology introduced to conserve against eminent extinction.

Developing the evaluation method for wood stiffness of sugi (Japanese cedar, *Cryptomeria japonica* D. Don) at nursery stage. Kurahara, Y. (*Forestry and Forest Products Research Institute, Japan; yujikura@affrc.go.jp*).

Sugi or Japanese cedar (*Cryptomeria japonica* D.Don) is one of the most important tree species in Japanese forestry. As its lumber is more useful and it grows faster than any other major tree species in Japan, it has been planted in half of the country's 10 million hectare of managed forest. Wood stiffness, measured in term of its modulus of elasticity (MOE), is the most important property of construction lumber. Generally in pine species, specific gravity (SG) is usually a good indicator of wood stiffness. But Japanese cedar shows a weak relationship between MOE and SG. Therefore, MOE is regarded as a better indicator of the quality of Japanese cedar. There is a great variation in the MOE among individual cultivars in this species, and this variation is regarded as a disadvantage when wood of sugi is used in construction. But sugi has required long periods of time for wood stiffness breeding, and this long time (over 15 years) have hampered tree improvement. Therefore, a major aim of this exercise was to develop the method for evaluation of wood stiffness at the nursery stage by using the stress wave.

Morphological variability and nutrient composition of Tunisian aromatic Apiaceae *Magydaris pastinaceae* L. growing in the Northern Forest zones. Labidi Ben Slimane, A., Khaldi, A., Mohamed El Arbi, K. (*Institut National de Recherches en Génie Rural, Eaux et Forêts (INRGREF), Tunisia; arbia.labidi@hotmail.com; khalditn@yahoo.fr; khoujalarbi@yahoo.fr*), Ramona, T. (*AGQ Labs, Spain; rtorres@agq.com.es*).

Magydaris pastinaceae is an Apiaceae native to the Mediterranean basin. In Tunisia, the specie is present mainly in mogod forests (Northern region), and it is submitted to strong pressure caused by its harvest for use as incense aroma. It can be considered as endangered species. Scientifically, it can be considered as a neglected species because it is not well studied by scientists. The analysis of the morphological diversity and mineral composition of the species would help in its preservation, better valorized use, and potentially its culture. Morphological analyses of *M. pastinaceae* at 11 sites in Northern Tunisia (Beja, Bizerte, and Siliana) using 10 parameters inspired from the descriptors for Apiaceae (International Plant Genetic Resources Institute (IPGRI)) showed a significant difference between two parameters, plant length and fruit weight. Nutritional parameters (moisture, dry matter, crude fats, proteins, fibers, nitrogen, carbohydrates, and energy values) and nutrient analysis (K, Na, Ca, Fe, P, Mg, etc.) were evaluated in leaves, fruits, and roots of *M. pastinaceae* using standard techniques. The results showed that fruits of *M. pastinaceae* had the highest proportion of crude fats, fibers, and had the highest energy value. Leaves were also rich in essential minerals such as iron, calcium, magnesium, and potassium, while the trace elements and heavy metals composition were marginal.

Production of cellulose from wood: formation of oxidized groups and their effect on cellulose properties. Lachenal, D., Perrin, J. (*Grenoble INP-Pagora, France; dominique.lachenal@grenoble-inp.fr; jordan.perrin@grenoble-inp.fr*).

The interest of cellulose for purposes other than paper, such as textile and plastics, has been growing very fast during recent years. The main reason is linked to environmental considerations. Cellulose is a renewable polymer, available in considerable quantity. The problem is then to extract cellulose from wood and purify it using green processes. This was the topic of this work. More particularly, efficient green bleaching processes have been developed. They include the use of ozone. Characterization of cellulose after ozone treatment showed that it contained carbonyl groups. These new groups made cellulose very sensitive to alkaline conditions, which resulted in a marked darkening and a severe depolymerization in caustic soda solutions and also in a tendency to yellow under heat exposure. These drawbacks might be a serious handicap in the manufacture of textile fibers which requires strong alkaline treatments. It was found that carbonyl formation could be reduced by some modification of the ozone stage and that the carbonyl groups were almost entirely destroyed by a hydrogen peroxide treatment. The chemical mechanisms involved in these treatments have been explained. These results pave the way to the production of high quality cellulose by environmentally friendly processes.

Domestication of the prioritized medicinal and aromatic plants in community forestry. Lamichhane, D. (*Ministry of Forest and Soil Conservation, Nepal; dlamichhane@gmail.com*), Devkota, K. (*Institute of Forestry, Nepal; devkotakpd@yahoo.com*).

High value medicinal and aromatic plants (MAPs) play a significant role in biodiversity conservation and socioeconomic development in the mountainous areas of Nepal. The study was conducted in four community forests (CFs) of Kaski District to explore the nationally prioritized MAPs and assess their potential for cultivation, commercialization, and marketing, and to establish their demonstration plots. Two top prioritized MAPs from each of the four CFs were considered for analysis after conducting prioritization by local people. Methodology included the collection and analysis of socioeconomic and biophysical data using a semi-structured questionnaire, key informant interviews, plot establishment in the forest, seedling production, cultivation, and measurement of growth performance of selected MAPs. Research results revealed the significant variation in distribution of MAPs in the forest according to altitude, slope, aspect, and crown cover. Various growth performances of the selected MAPs were observed in cultivation under different treatments. Local people were found to have limited use of the valuable MAPs for occasional medicinal purposes. Forest users mostly lacked knowledge and information about collection, processing, and marketing of valuable MAPs. The existing high demand in national and international markets would indicate the enormous potentiality of valuable MAPs for economic development of rural communities.

Coumarins content of seed and crude oil of *Calopyllum inophyllum* from forest stands in Indonesia. Leksono, B. (*Center for Forest Biotechnology and Tree Improvement, Indonesia; boedyleksono@yahoo.com*).

Nyamplung (*Calophyllum inophyllum*) seeds, known as an alternative source of biofuel, have been revealed to contain coumarins compound, making it potentially promising as a medicinal source for disease therapy. Coumarins are components in seeds that need to be eliminated as a waste before the biofuel production process is conducted. This valuable source of coumarins as a drug has increased the value and function of nyamplung seeds. Coumarins are elements of phenylpropanoid compounds of which their derivates are pharmacologically essential for different physiological activities (anti-HIV, anti-cancer, anti-inflammation, anti-oxidant, anti-bacterial, anti-coagulant, analgesic, and comparative immune-modulation). The aim of this study was to examine variations of total coumarins content of nyamplung seeds from 12 nyamplung stands (6 Java island, 6 outside Java) throughout the seven islands in Indonesia. Results indicated a very high variation in coumarins content between nyamplung stands in Indonesia. The ranges of coumarins content in seeds from Java and outside Java were 0.101–0.354% and 0.261–0.412%, respectively. Variations were higher in crude oil, both fresh and one year preserved, in materials from the seven islands in Indonesia, with concentrations of 0.328–1.109% and 0.229–1.330%, respectively. Coumarins content and variations between stands have been shown to be higher in crude oil than in seeds.

Intra- and inter-island variations of biofuel content and their physical-chemical properties of *Calopyllum inophyllum* in Indonesia. Leksono, B., Hendrati, R., Windyarini, E., Hasnah, T. (*Center for Forest Biotechnology and Tree Improvement, Indonesia; boedyleksono@yahoo.com; rina.l.hendrati@gmal.com; e_windyarini@yahoo.com; triemaria@yahoo.com*).

A global energy crisis causing increasing biofuel prices has driven the world to emphasize the importance of environmentally-friendly renewable-energy (biofuel). *Calophyllum inophyllum* (nyamplung), whose seeds have long been used for biofuel, is one potential tree species with an energy source that can be harvested repeatedly for 50 years. Technical practices of biofuel production for nyamplung seeds have been developed at energy self-sufficient villages based on nyamplung in five villages in Java and one outside Java. Optimation of industrial production is hindered by the availability of research on biofuel content and quality. This research is carried out to reveal biofuel content variations of intra (six within Java) and inter (seven within Indonesia) islands and their properties, for genetically improving its seed sources. Results showed a great variation in biofuel content among populations. Values ranged between 37–48% vertical hot press (VHP) and 50–58% screw press expeller(SPE) for crude oil, 36–48% (VHP) and 40–53% (SPE) for refined oil, and 17–33% (SPE) for biodiesel. Highest variation in refined oil is due to high-content seed resin. All of the 18 properties tested varied, and most are in line with international standards of biodiesel. DNA analysis confirmed intermediate to high genetic variation, with two clusters for intra and inter islands. The results will be used to improve nyamplung breeding strategy.

Growth stresses and wood basic density of *Eucalyptus* related to the productivity of the plantation site. Lima, J., Silva, J., Trugilho, P. (*Federal University of Lavras, Brazil; jtlima@dcf.ufla.br; jreinaldo@dcf.ufla.br; trugilho@dcf.ufla.br*), Vieira, R. (*Federal University of Tocantins, Brazil; renato@vieiramail.com.br*), Cruz, C. (*Federal University of Reconcavo Of Bahia, Brazil; claircruz@ufrb.edu.br*).

One question that always preoccupies producers and wood researchers is the influence that the environmental conditions for tree growth have on the quality of the wood. In *Eucalyptus*, information on this relationship is scarce, especially when comparing

wood from identical genetic material, planted in different sites. The objective of this study was to compare the wood density and growth stresses of seven *Eucalyptus* clones of the same age, planted at two sites with different productivity conditions. For this, three trees were sampled from each of seven clones, at 7 years of age, planted simultaneously in Paraopeba (site of higher productivity) and Bocaiuva, both located at Minas Gerais State, Brazil. Growth stresses were assessed by the measurement of longitudinal residual strains (LRS) in standing trees, using an extensometer. For wood basic density (BD) assessment, discs were cut along the stems. The LRS ranged from 50 to 95 micrometers, while BD ranged from 0.513 g/cm^3 to 0.618 g/cm^3. All clones showed higher LRS and BD for Paraopeba, the site of greater productivity. The LRS can be estimated by the BD, according to the quadratic model with R^2 = 80% for Paraopeba and R^2 = 54% for Bocaiuva.

Bidimensional scanning by means of acoustic tomography of six trees in the park of Ducuara at the University of Tolima, Colombia. Lozano Botache, L., Fajardo García, C., Bonilla Vargas, J. (*Universidad del Tolima, Colombia; llozano@ut.edu.co; califaga@gmail.com; forest.lorena@gmail.com*).

The internal status of six stems or trunks of *Senna siamea* (Iam.) trees in the Ducuara park of the University of Tolima was evaluated by means of nondestructive and non-invasive methods using acoustic tomography. The selected trees were located in a busy area, which is why it was essential to reduce the risk of branches or the tree itself falling on people or park infrastructure. With this method the possible rot of the wood along the first two meters of each stem was detected. It was concluded that the trunks of these six trees were not affected by rot at the heights of 40, 80, 120, and 200 cm measured above the ground. In general, each tree showed bad scars due to inadequate pruning and cracks in branches which provoked infections and rot at the cuts and affects the equilibrium of the trees. It is recommended to use this evaluation technology because it is easy to apply and delivers reliable results.

What makes wood so attractive? Transforming consumers` emotions into material characteristics. Manuel, A. (*University of Freiburg, Germany; andreas.manuel@fobawi.uni-freiburg.de*), Leonhart, R. (*Institute of Psychology Freiburg, Germany; leonhart@psychologie.uni-freiburg.de*), Breinig, L. (*Forest Research Institute of Baden-Württemberg, Germany; lorenz.breinig@forst.bwl.de*), Broman, O. (*Luleå University of Technology, Sweden; olof.broman@ltu.se*), Becker, G. (University of Freiburg, *Germany; gero.becker@fobawi.uni-freiburg.de*).

Flooring and other wood products are highly attractive due to their surface appearance. Besides the structure and color of wood, knot patterns are significant features influencing consumer appreciation. In contrast, the wood processing industry grades their products based on technical parameters where such features are regarded as defects. However, for wood product marketing the importance of consumer`s choice will most likely increase. Consequently, product design should meet consumer preferences. The aim of this study is to (a) investigate consumer preferences regarding wooden floorings, and (b) link descriptive surface characterization with technical product parameters. Spruce boards were composed to represent floor samples, and virtual images were acquired via optical surface scanner sensors. A total of 165 virtual floor samples with different optical characteristics were produced to test in an online study (about 460 participants) where a random selection of 5 floor samples was evaluated with seven subjective criteria found in a preliminary study. Results of cluster analysis indicate that consumer groups with different preferences coexist, and surface characterization can be associated to technical parameters relevant for floor board production (sawing pattern, floor composition). This may help to achieve higher consumer satisfaction, added-value and reduced rejects during production in the industry.

The Utah biomass resources group: from the dragon wagon to mobile pyrolysis. McAvoy, D. (*Utah State University, USA; darren.mcavoy@usu.edu*).

Pinyon Juniper woodlands have grown to cover nearly 50 million acres of the Intermountain West. This expansion and densification has created a fuel buildup that poses a hazardous to landscapes and communities. By creating a value for this woody biomass, more acres can be treated. The Utah Biomass Resources Group (UBRG) seeks to develop technologies and markets to utilize woody biomass while diversifying rural economies, creating jobs, and producing home-grown fuels. This presentation will introduce the UBRG and detail our research and educational programs. The (UBRG) hosted Utah's first ever wood powered concert, with power supplied by Utah State University's mobile gasification unit known as the dragon wagon. The UBRG is currently conducting demonstrations of mobile pyrolysis, transforming woody biomass into biochar and bio oil in the field. The UBRG conducts research on biomass harvesting, pyrolysis, biochar, bio oil, cofiring and more. Through research and education, the UBRG is building knowledge and awareness to promote woody biomass utilization in the Intermountain West.

Indonesian fast-growing tree species as alternative raw material for forest industries. Mindawati, N., Bogidarmanti, R. (*FORDA, Indonesia; ninapulp@yahoo.co.id; rinabogidarmanti@yahoo.com*).

Recently, wood production from existing natural forests have been unable to supply wood industries due to productivity decreases. Meanwhile, wood production from plantation forests of *Acacia mangium, Eucalyptus pellita,* and *Falcataria moluccana* do not show significant increases in production due to site degradation and pest and disease attacks. To solve this problem, the Forest Research and Development Agency (FORDA), Ministry of Forestry has a program to enhance the productivity and to look for some promising alternative tree species. This poster is aimed at giving information about some fast growing species to consider as raw material alternatives for forest industries for both construction and pulp wood in Indonesia. Suggested species include *Anthocephalus cadamba, Anthocephalus macrophyllus, Octomeles sumatrana, Michelia champaca, Disoxylum mollissimum, Camnospermum coriaceum,* and *Cratoxylum arborescens* which are characterized as fast growing species with a cutting cycle 6–15 years. Silviculture techniques for these species have been studied but are still limited, so further research is needed to fulfil the raw material demand of forest industries in Indonesia.

Macroscopic characterization and dimensional stability in selected specimens of *Prosopis alba* Griseb. in the Chaco Region of Argentina. Molina Bejarano, A. (*Universidad Distrital Francisco José de Caldas, Colombia; alisson_molina@hotmail.com*), Moglia, J. (*Universidad Nacional de Santiago del Estero, Argentina; vieckymoglia@gmail.com*), Cadena, M. (*Universidad Distrital Francisco Jose de Caldas, Colombia; cademielro@hotmail.com*).

This paper evaluated the macroscopic characterization and determination of dimensional stability in selected specimens of *Prosopis alba* Griseb. located in Villa Angela, Chaco. Through descriptive analysis and design of a randomized complete block experiment with 2 × 4 × 2 factorial sampling, we determined the sapwood-heartwood proportion and presence of defects and variation in radial tree level. Under the agreement between the University District and the Universidad Nacional Santiago del Estero, we assessed the quality of solid wood for timber species and prospects of the Chaco region. The proportion of heartwood was 90.95% with an interspecific variation in sapwood and heartwood color. Blemishes were evaluated as the percentage of incidence. The average value of radial contraction was 0.074, tangential shrinkage was 0.123, and longitudinal contraction was 0.024. The Bonferroni test statistical model we used allowed us to infer the largest sector instability. The proportion of sapwood-heartwood turned out to be efficiently solid, and we used a representation of 9.05% sapwood as a desirable amount. The values indicate that the species is within a normal range for contractions and anisotropy, and its solid wood is suitable for applications and derived products as long as you perform a drying program appropriate to the species. The analysis identified the pieces that have a lower quality in terms of increased contractions.

Impact of compression and thermal modification on mechanical properties of silver birch and European aspen wood. Mottonen, V., Marttila, J., Heräjärvi, H. (*Finnish Forest Research Institute, Finland; veikko.mottonen@metla.fi; juhani.marttila@metla.fi; henrik.herajarvi@metla.fi*).

Combination of compression and thermal modification of wood is a potential innovation for improving the utilization rate of light weighted wood species in solid wood products. The objective of the study was to determine the effect of compression and thermal modification on the modulus of rupture, modulus of elasticity and Brinell hardness of silver birch (*Betula pendula*) and European aspen (*Populus tremula*) wood. The modifications were carried out in an industrial-sized pilot device capable of drying, compression, and heat treatment of sawn timber. Combinations of two different degrees of compression and two different temperatures of thermal modification were used. Differences were found in the relative increase of Brinell hardness between species, degree of compression, and thermal modification. Due to the variation in the location of densified peaks in the specimen profile, differences in Brinell hardness at different depths were observed as well. Both modulus of rupture and modulus of elasticity were clearly affected by compression and thermal modification. The relative improvement in mechanical properties as a result of densification was larger for lighter weighted aspen than for birch. To conclude, combined compression and thermal treatment shows high potential for improving the mechanical performance of silver birch and European aspen wood.

Evaluation of pellets fabricated from plantation wood and several agricultural crops utilizing x-ray densitometry. Moya, R., Aragón, S. (*Escuela de Ingeniería Forestal, Costa Rica; rmoya@itcr.ac.cr; stefag1091@gmail.com*), Valaert, J. (*Pelletics, Costa Rica; jorre@agrepforestal.com*), Tommasiello Filho, M. (*University of São Paolo-ESALQ, Brazil; mtomazel@usp.br*).

The objective of this study was to evaluate the density variation and surface quality of pellets manufactured from raw material such as wood and other tropical agricultural crops from Costa Rica. Visual x-ray evaluation of the pellets showed that a uniform surface can be observed and the pellet can be cataloged as good quality. Other pellets presented small irregularities which cataloged the pellet as moderated quality. Finally, easily visible cracks were observed in other pellets. Another aspect shown by the x-ray images were clearer areas in the pellets, indicating higher densities. The evaluation of the cross section showed three patterns of variation: high density around the surface, irregular density, and uniform density. The first pattern has a high density at the pellet surface and a lower density inside. The irregular density has high density values at any point at the pellet diameter, and the uniform density pattern presents similar values across the diameter. Two patterns of density variations were observed in longitudinal direction: uniform density and irregular density. The first type shows little variation throughout the length and the second pattern shows areas of high density mixed with areas of low density.

Premature failure of creosote-treated electricity transmission wood poles in Zambia. Ncube, E., Chungu, D., Ng'andwe, P. (*Copperbelt University, Zambia; enncube@yahoo.com; donald.chungu@cbu.ac.zm; pngandwe2002@yahoo.co.uk*), Kamdem, D. (*Michigan State University, USA; Kamdem@msu.edu*), Chongo, A., Mwale, E. (*Copperbelt University, Zambia; cnncsiro@yahoo.com; enzama@tsamail.co.za*).

Creosote utility poles (*Eucalyptus grandis* Hill ex Maiden) should remain in service for over 40 years, but most are being replaced after 10 to 15 years in Zambia. The aim of this study was to determine causes of premature failure. Analysis of utility pole replacement frequency in Kitwe and Kalulushi regions was undertaken during July-December annual maintenance windows in 2010 and 2011. Sixty four wood pole specimens of 0.9 m length and 15–20 cm diameter range were treated to determine uptake, penetration, and retention using the Bethel process. Wood shavings from each specimen were obtained from level 1 and 3 sapwood band from cambium to pith. The retention of creosote was determined by automated soxhlet extraction using diachloromethane solvent. Full sapwood penetration (96.53%) and 3.34 kg/m^3 preservative uptake were realized. However, sapwood retention (60 kg/m^3) was significantly lower than the standard (115 kg/m^3). The observed increase in utility pole replacement frequency with distance from Nkana mine (i.e., Mine township < Kitwe south < Kitwe North) to Kalulushi region suggest that emissions from mining suppress biotic activity. The study showed that despite full sapwood penetration, the concentration of active ingredients was below acceptable thresholds, thus are susceptible to biodegradation. The results transform our understanding on optimizing utilization of utility poles in Zambia and elsewhere.

Growth drivers within the firewood industry. Nybakk, E. (*Norwegian Forest and Landscape Institute, Norway; nye@skogoglandskap.no*), Rasmussen, C. (*Norwegian University of Life Science, Norway; Casper.rasmussen@umb.no*), Panwar, R. (*Northland College, USA; rpanwar@northland.edu*), Lunnan, A. (*Norwegian University of Life Sciences, Norway; anders.lunnan@umb.no*).

Traditional firewood is an important bioenergy source in both the developed and the developing worlds. Primary solid biomass accounts for approximately 10% of the world's total primary energy production. However, there has been little research on traditional firewood. This study examines the relationship among customer orientation, innovativeness, tenacity, risk taking,

growth willingness, and growth in low-technology micro firms. A survey was sent to 3 000 managers in the Norwegian firewood industry, and 514 usable responses were received. The findings showed that customer orientation, innovativeness, and tenacity have a significant effect on growth in micro firms. In contrast with earlier studies, we found no support for interaction effects among innovativeness, tenacity, risk taking, and customer orientation. Managers should increase their focus on customer needs with regard to the manner in which goods are delivered. Although firewood is the most significant source of bioenergy, there has been little research on business or management in this industry. To reach the ambitious goal of reducing carbon dioxide emissions, we must pay more attention to this industry. Furthermore, to promote further growth, policymakers should understand how the industry operates and develops.

Sustainable bio-energy development in Kenya. Oduor, N. (*Kenya Forestry Research Institute, Kenya; nelliecoduor@yahoo.com*), Maingi, D. (*Wanley's Consultancy Services, Kenya; drmaingi@gmail.com*), Githiomi, J., Anapapa, A. (*Kenya Forestry Research Institute, Kenya; josephgithiomi@ymail.com; anapapaa@yahoo.com*), Gachanja, M. (*Kenya Forests Working Group, Kenya; gachanja2000@yahoo.com*).

It is estimated that 90% of rural households in Kenya use fuel wood or charcoal, with fuel wood meeting the energy needs of over 93% of rural households and charcoal being the dominant fuel in urban households. A recent study on the demand and supply of wood products indicates that the country has a wood demand of 41.7 m^3 against a national supply of 31.4 million m^3. The demand for wood fuel (firewood and charcoal) is 35 million m^3 against a supply of 21 million m^3. Forecasts for a 20-year period for wood fuel indicate a 16.9% increase in demand and a 15.6% increase in supply by the year 2032, which signifies a gradually increasing deficit. This paper looks at the sustainability measures available to address this challenge. Some of them include on-farm cultivation of fast maturing tree species for energy from plant species such as *Acacia, Eucalyptus*, bamboo, and *Casuarina*; management and utilization of invasive plant species for energy such as *Prosopis*; and the development and production of energy efficient technologies for cook stoves for domestic households and small businesses. Strategies for an enabling policy environment will be evaluated too.

Forest leafy vegetables marketing and sustainable rural livelihood in Rivers State, Nigeria. Oladele, A., Aiyeloja, A. (*University of Port Harcourt, Nigeria; adekunle.oladele@uniport.edu.ng; aiyeloja@yahoo.com*).

Leafy vegetables from forests are capable of sustainably generating income and employment for rural populations. An investigation of wild vegetable marketing was conducted in Port Harcourt, Oyigbo, and Ahoada West local government areas of River State, Nigeria with well-structured and pretested questionnaires. Data were analyzed using descriptive statistics, net profit, rate of return on investment (RORI), regression, and sensitivity analysis. Weekly profits and RORI were: Port Harcourt city (₦1134.48k, 34.1%), Oyigbo (₦2152.2k, 30.9%), and Ahoada West (₦608.98k, 21.89%) with 1USD=160 Nigerian Naira (₦). *Gnetum africana* had the highest daily profit of ₦159.30k. Sensitivity analysis of RORI showed profits were threatened at various degrees of increasing cost: Port Harcourt (35%), Oyigbo (35%), and Ahoada West (25%). Multiple regression showed that education, market, startup capital and product supply sources significantly influenced profit margins at $\rho = 0.05$. Wild vegetable marketing showed potential for increasing household income and sustaining livelihoods. Research on domestication, improved marketing, and provision of cooperatives loans is recommended for sustainable marketing.

Energy value of wood residues from *Gmelina arborea Roxb.* and *Tectona grandis Linn. f*. Oluwadare, A. (*University of Ibadan, Nigeria; femioluwadare@yahoo.com*), Anguruwa, G. (*Forestry Research Institute of Nigeria, Nigeria; glo.vision@yahoo.com*), Sotannde, O. (*University of Maiduguri, Nigeria; femsot@gmail.com*).

Large scale wood conversion processes generate lots of wood residues, and disposal is a major challenge. Alternative use of these residues for value-added products including energy is of great importance in Nigeria. This study was conducted on wood residues from *Gmelina arborea* and *Tectona grandis* to determine their energy value and value-added chemical compounds. Sawdust of the wood residues were collected from Forestry Research Institute of Nigeria sawmill. Extractive-free sawdust (10 g) was prepared using ethanol-toluene solution according to ASTM standard D1107 while lignin (acid insoluble) was extracted using 72% H_2SO_4 and 1.25 N NaOH (alkaline hydrolysis method). Extracted lignin (EL) and sawdust samples were subjected to calorific test, elemental analysis (Mg, Ca, Al, Fe, Mn, Cu, Zn and Pb), and compositional analysis to determine the functional groups using atomic absorption spectrophotometer (AAS) and FT-IR, respectively. Heating value was higher in sawdust than extracted lignin but was statistically similar. The metals K, Mg, Ca, Mn, Fe, Pb, and Zn were detected in both sawdust and lignin but at reduced concentrations in EL. Aromatic and nitro compounds were present in the materials. Observed heating values and presence of various compounds show possible use of these wood residues for energy production and value-added products.

Non-timber forest products in the Atlantic Forest and Savanna in São Paulo state, Brazil. Ota, L. (*São Paulo State University, Brazil; lizmsota@gmail.com*), Carvalhaes, M.A. (*EMBRAPA, Brazil; mariana.carvalhaes@embrapa.br*), Zakia, M.B. (*Forestry Science and Research Institute, Brazil; zeze.zakia@uol.com.br*).

The objective of this study was to make an assessment of the most interesting NTFP that could make environmental plantings economically attractive, especially for small rural properties. We also assessed the obstacles that are found by those who work in these production chains. We listed 70 species from 32 families that provide a product from at list one of the following categories: alimentation, ornamentation, biochemistry products, medicinal products, and handcrafted products. We considered the pulp of *Euterpe edulis* Mart. the product on the list with the greatest potential. The main obstacles found in the production of NTFP were: (1) legislations that are too restricted or not adequate to small-scale producers; (2) difficulties in getting credits and financial aid for the forestry activity that has a medium/long term payoff and for landholders that do not have legal documentation proving the land ownership; and (3) the weak market of the NTFP that still has a lot of intermediaries that keep big part of the profits. Next step is to propose adjustments in the environmental and sanitary legislation and to propose some actions for the state to make it easier for the landholder to get access to credits and financial aids which will help to stimulate the NTFP markets.

Potential for promotable oil products identified by traditional knowledge on native trees in Burkina Faso. Ouedraogo, A. (*University of Ouagadougou, Burkina Faso; o_amade@yahoo.fr*), Lykke, A. (*Aarhus University, Denmark; aml@dmu.dk*), Lankoandé, B., Korbéogo, G. (*University of Ouagadougou, Burkina Faso; lankoandehatina@yahoo.fr; kgabin1@hotmail.com*).

Oil products from native trees are far from fully exploited in West Africa. Only well-known species like shea (*Vitellaria paradoxa* C.F.Gaertn.) and oil palm (*Elaeis* guineensis Jacq.) receive attention. We used quantitative questionnaires in 12 villages in Western Burkina Faso to assess the knowledge of four ethnic groups on 28 tree species and how their oil is used. Sixteen species were used the most. Among them, *Vitellaria paradoxa*, *Elaeis guineensis*, *Carapa procera* DC., *Pentadesma butyracea* Sabine, and *Lophira lanceolata* Tiegh. ex Keay received the most citations. Oils were used for soap (22%), food (21%), medicine (19%), body care (18%), and hair care (14%). Significant differences were found among ethnic groups concerning knowledge and preferences of oil products. Apart from the well-known species, *C. procera*, *L. lanceolata,* and *P. butyracea* appear to be promising species for promotable oil products and a number of less known species may show potential as well.

Development of center-bored outer-surface sealed timber drying method and evaluation of the drying energy consumption. Park, J., Chang, Y., Yang, S. (*Seoul National University, Republic of Korea; gentleice@nate.com; jang646@snu.ac.kr; sly1357@snu.ac.kr*), Eom, C. (*Korea Forest Research Institute, Republic of Korea; willyeom@forest.go.kr*), Yeo, H. (*Seoul National University, Republic of Korea; hyeo@snu.ac.kr*).

Large cross-sectional round timber of pitch pine (*Pinus rigida*) was dried after a center-boring process involving the drilling of a hole in the longitudinal direction in the central portion of the timber. In order to shorten the drying time, high-temperature drying was applied. Outer surface sealing on the timber was done to inhibit the occurrence of surface checks. In comparison with non-bored round timber drying as a control group, the drying time and energy required during the center-bored drying of timber were analyzed. To dry the control green round timber (Ø 140 mm) to moisture content (MC) of 11% required nearly 4 days, with defects such as surface check and end checks appearing. On the other hand, the center-bored timber was dried rapidly to MC 6% in 2 days without drying defects. High-temperature drying after a center-boring process, when compared to the drying of round timber, greatly reduced the drying time while also reducing the amount of energy required by more than 50%, and created no defects as well. It was confirmed that high-temperature drying after a center-boring process and after sealing the outer surface is a very efficient drying process as it reduces the drying time, required energy, and number of drying defects in large cross-sectional timber in this study.

Contribution of NTFPs in livelihood and carbon management in moist temperate forests of Kashmir Valley, India. Peerzada, I., Zargar, M. (*Shere Kashmir University of Agriculture Sciences & Technology, India; drishtiyak@gmail.com; peerzis@gmail.com*).

This study is being carried out in the moist temperate forests of Jammu and Kashmir (J&K) State of India. J&K is situated between 32.17° and 36.58° north latitude and 37.26° and 80.30° east longitude. It is well accepted that many NTFPs are critical for the livelihood of millions of people and also play an indispensable role in forest ecosystems. Hence, it is equally significant that they are sustainable managed. It is beyond doubt that the biggest threat to forests and forest products is illicit extraction, harvesting, and trade. It can be controlled to a great extent by providing alternative opportunities to forest dwellers through participatory and sustainable management of NTFP resources. It will also be helpful for better management of forests which can play an important role in carbon management, and thus, reducing the emissions from deforestation and forest degradation. Therefore, this study is designed to assess the role of NTFPs in livelihood improvement of forest dwellers and as a carbon management (REDD+) tool through people participation and protection measures.

Factors impacting exports of U.S. hardwoods: a case of study in Germany, China, and Vietnam. Quesada, H., Smith, B., Arias, E. (*Virginia Tech, USA; quesada@vt.edu; rsmith4@vt.edu; earias@vt.edu*).

According to the American Hardwood Export Council (AHEC), in 2011 the United States (U.S) exported over $2.5 billion in hardwood products, with 79% of those exports being lumber and logs. Main markets for U.S hardwood were Canada and Mexico (33.4% of demand), East and Southeast Asia (33%), and the European Union (27.2%). Traditional markets for U.S. hardwoods, such as Canada and Mexico, are well understood, and there are a lot of resources available to support exporters to this market. However, little is known about markets in East and Southeast Asia and also in the European Union. The goal of this research project was to investigate factors that impact the export of U.S. hardwoods to those two regions. More importantly, the identification of not just economic factors but also social and cultural factors that potentially could increase the exports of higher value-added products such as dimensioned lumber, veneers, and furniture over lower value-added products such as logs and lumber is also important for this research. Based on personal interviews to more than 40 hardwood importers in Germany, China, and Vietnam, data were collected and analyzed using qualitative and quantitative techniques. Main results indicated that there are a large number of unknown and unexploited opportunities for U.S. hardwood producers to increase value to their exports to these specific markets.

Phophine fumigation for protection of wood from powderpost beetle damage in Indian conditions. Ramdevi, O.K. (*Institute of wood science and technology, India; okremadevi@gmail.com*), Deepthi, T.R. (*Institute of Wood Science and Technology, India; deepthitrarun@gmail.com*).

Wood being an organic material is damaged by xylophagous insects both when it is in the tree and after it is harvest. In Indian log storage conditions, powderpost beetle (*Sinoxylon anale*) is the most devastating wood pest. Use of wood fumigation with phosphine to control wood boring insects is not being practiced in India. Different concentrations of phosphine were tested against adults of *S. anale* in desiccator tests. The mortality was 75% at 100 ppm, 85% at 150 ppm, and 100% at 200 ppm levels of the gas. LC50 was calculated as 61.73 ppm. In field trials using infested stacked logs of subabul and eucalyptus, observations were taken on the response of baited insects against different doses of phosphine. After 72 hours, samples of wood logs were removed from different levels of the stack, autopsied, and observations were taken on the effectiveness of phosphine on larvae,

pupae, and adults. All stages were found dead, indicating a good penetration of phosphine into the logs. The residue of aluminium tablets was found in the form of powder. The study indicated that phosphine fumigation can be adopted to cure the infestation of *S. anale* in wooden logs and products.

Platform for cost efficient environmental assessment. Raty, T. (*Finnish Forest Research Institute*, *Finland; tarmo.raty@metla.fi*).

The research on environmental performance of wood and communication of environmental performance shows low impact in industry. Recent market gains of the wooden multi-store houses are promising, but there are no signs that the environment has been the critical success factor. Our new initiative, Platform for Environmental Assessment (PEnA), was launched to promote the accumulation of environmental information and its usage in decisionmaking. It aims to improve the ability and willingness of wood product companies to communicate the environmental attributes by lowering the efforts needed to produce environmental information. The effects are sought by creating an open access database of environmental impacts and by developing data supporting environmental assessment tools. The database will first provide primary information about the stand-level carbon balance and its allocation to harvested wood, as well as generic descriptions of how it impacts the wood processing chain. The data can be extracted into the form of standard environmental product declarations (EPDs). The process of creating EPDs for wood products is cumulative and is facilitated by developed low entrance level environmental assessment tools reading the database and pointing for supplementary information. PEnA supports building information model (BIM), making it possible to compare the environmental impacts of alternative materials and constructions.

Use of medicinal plants among Panchen-Monpa tribe in remote region in the Eastern Himalayas, India. Saha, S., Chakraborty, T. (*University of Freiburg, Germany; somidh.saha@waldbau.uni-freiburg.de; tamalika.chakraborty@waldbau.uni-freiburg.de*).

This paper reports on ethnobotanical use of herbaceous plant species combined with ethnopharmacological approaches among the Monpa people of remote Zemithang region, Arunachal Pardesh, Eastern Himalayas. The previous works on ethnobotanical uses of plants in the Eastern Himalayas of the Arunachal Pradesh mainly covered up to the forests of the lesser Himalayas. But this research focused on more high altitude sites in the Northeastern Himalayan subalpine region. It was also the first comprehensive ethnobotanical and ethnopharmacological research on the Monpa people of Zemithang region, living at the extreme of north-western Arunachal Pradesh along the border with China and Bhutan. The participatory transect walk and interviews and discussions with traditional healers were used for ethnobotanical and ethnopharmacological data collection. We described 53 plant species from the study area which are being using in traditional medicine. We documented and described 24 ethnomedicines prepared for healing purposes from these 53 plant species. These traditional medicines were most commonly used to heal a wide range of diseases such as: arthritis, rheumatic pain, malaria, cough and cold, and dysentery. We also documented ethnopharmacological prescriptions for epilepsy, herpes, and oedema rarely found in past studies. Our studies showed the high importance of documenting traditional knowledge.

Potential of non-timber forest products in Perum Perhutani. Sambodo, C., Muharyani, N. (*Perum Perhutani, Indonesia; corrysambodo@yahoo.com; novincimuharyani@yahoo.co.id*).

Perum Perhutani, is a state-owned forestry enterprise in Indonesia with a management area in Java and Madura island that covers 2 426 207 ha of forest area. This area has a large number of non-timber forest products (nTFPs). Based on regulations issued by the Indonesian Ministry of Forest, NTFPs are defined as non-timber forest products collected from protected forest or production forest areas. The corporate policy is focused on forest chemical products, forest food and health products, ecotourism, and landscape beauty. The mainstay of NTFPs in Perhutani are pine resin (483 272 ha production area), gum rosin (produced 71 976 tons in 2011) and turpentine (produced 15 353 tons in 2011), while the NTFPs that need to be developed are honey, *Amorphophallus*, medicinal plants, alternative energy sources, and ecotourism. Contribution from these products covered 42.5% of total revenue for the company in 2011, showing that NTFPs are a promising forest product.

Endophytic fungi as a source of bioactive compounds. Sarjala, T. (*Finnish Forest Research Institute, Finland; tytti.sarjala@metla.fi*).

All higher plants are generally hosts to endophytic bacteria and fungi, which live in the intercellular spaces of the plant tissues. They constitute a vast and largely untapped source of secondary metabolites, which may be potential novel drugs. Secondary metabolites are often involved in a host-endophyte relationship and contribute to the protection of the host. Endophytes are known for their bioactive compounds with cytotoxic, antitumor, anti-microbial, neuroprotective, antioxidant, and anti-inflammatory activities. The rationale for studying endophytic microbes as a source for new medicines is related to the fact that it is still a relatively unexplored area. In Finland, trees that are growing in drained peatland forest sites may face several abiotic stress conditions such as drought, flood, and limitations of nutrients. In these sites we have found endophytic root-associated fungi in Scots pine to be very common in comparison with typical ectomycorrhizal species which are normally abundant in the tree roots on mineral soils in Finland. Under harsh conditions, the endophytic fungi may have a protective role in the hosts, and we assume that drained peatland forests may serve as a big reservoir of endophytic fungi with bioactive potential for novel drug development.

Key problems of the use of environmental-friendly straw board in furniture production: some countermeasures. Shen, L. (*Nanjing Forestry University of China, China; shenlimingda@hotmail.com*), Lewark, E. (*University of Freiburg, Germany; siegfried.lewark@fobawi.uni-freiburg.de*), Yu, N., Zhu, Y., Zhong, S. (*Nanjing Forestry University, China; yuna96@hotmail.com; zhuyun0911@163.com; sluzh@163.com*).

Straw board is a new kind of panel, using straw from agricultural production as the main raw material. It is free of formaldehyde, and therefore belongs to the new environmentally friendly furniture materials. But due to the significant differences among straw board, particle board, and medium density fiber board in mechanical properties, mechanical processing performance, surface

quality, etc., it is difficult to replace these boards with straw board in furniture production. The three key problems of the straw board use in furniture production are discussed, namely the veneer and edge banding technology, surface treatment and coating technology of straw board, and the type and strength of joints of the straw board furniture component. Based on the results of experiments, joint types were developed which increases joint strength in straw board furniture. The relationship between paint film adhesion, surface quality of the straw board, and the coating process has been determined. Methods of improving the straw board surface decoration quality and dimensional stability was developed. The results provide basic information for the application and promotion of the new environmental friendly straw board in furniture production.

Main non-timber forest products socio-economic importance for inhabitants of the Czech Republic. Šišák, L., Kupcak, V., Jarský, V., Riedl, M. (*Czech University of Life Sciences Prague, Czech Republic; sisak@fld.czu.cz; kupcak@fld.czu.cz; jarsky@fld.czu.cz; riedl@fld.czu.cz*).

We present an analysis of the socio-economic importance of free gathering of main non-timber forest products (NTFP) by inhabitants of the Czech Republic (CR) in 1994–2012. Gathering and use of NTFP in the CR has been systematically analyzed every year since 1994, always using basically the same methodology of personal questionnaire surveys, interviews with representative samples of inhabitants of the CR, and quota selection. The importance of edible mushrooms and main forest berries (bilberries, raspberries, blackberries, cowberries, and elderberries) was investigated. The results showed high importance of NTFP for inhabitants of the CR. Investigations proved that the majority of the inhabitants and households in CR gathered NTFP. On average, 10.7 kg of main NTFP were gathered annually by a household in 1994–2012, which amounts to 38.9 million kg and 143.3 million EUR in the total CR. The value is about 1/6 of the average timber harvest annual value. Nevertheless, the amounts of NTFP collection fluctuate substantially between individual years. A comparatively small part of the population gather NTFP to save money (about 12%), and an even lower share sells NTFP in the market (1.5%).

Evaluation of environmental impacts for Korean harvested wood products. Son, W. (*Korea Forest Research Institute, Republic of Korea; tistructure@forest.go.kr*), Kang, K. (*EcoServices Consulting Co., Ltd, Republic of Korea; kyungseoky@ecoservicesi.com*), Park, J., Park, M. (*Korea Forest Research Institute, Republic of Korea; jusang@forest.go.krmjpark@forest.go.kr*).

Establishing the environmental impact or carbon footprint of products has been important and is required as global warming and climate change have become world issues. To achieve this, a methodology of life cycle assessment (LCA) which can quantitatively calculate the environmental impacts of products and services throughout its life cycle, has begun to emerge. Therefore, this study performed LCA of harvested wood products (HWP) in Korea in order to determine greenhouse gas (GHG) emissions of HWP and amount of carbon storage. Function and functional unit of target system are respectively defined as manufacturing HWP used for secondary products or timber frame buildings, and a cubic meter of the target products. System boundary includes afforestation and transportation for round wood and manufacturing processes such as sawmill, drying, and processing for HWP. In addition, raw materials, ancillary materials, and energy usage as well as air emissions and wastes are collected in each unit process. Although the target system has multiple input and output processes, collectible data of energy usage are managed as integrated data. For dividing undistributed energy usage, this study considered specifications of machines such as motor power and feeding speed, and annual production time per product. The results of this study can establish the environmental impacts of target products during its life cycle and propose improvements for HWP.

Dynamic characteristics of 25 Mexican woods with a potential for structural use evaluated by stress waves. Suárez-Béjar, G., Sotomayor-Castellanos, J. (*Universidad Michoacana de San Nicolás de Hidalgo, Mexico; gezzoster@gmail.com; madera999@yahoo.com*).

There is a great number of wood species in México with a potential for use in structures and construction. Some of these species are being over-exploited to the point of endangerment, subutilized, or are commercialized only as raw materials. A contribution to the solution of this problem is providing, through research, technological data about Mexican woods. The objective of this study was to determinate density, speed of stress waves, and modulus of elasticity for 25 wood species. These species were studied using stress waves techniques. For each species, 20 specimens were tested. The specimens were 50 mm × 50 mm × 500 mm. The average moisture content was 10 percent. The densities ranged from 338 kg/m^3 to 1147 kg/m^3. The speeds of wave ranged from 3 007 m/s to 5 181 m/s, and the moduli of elasticity ranged from 3 053 MPa to 17 532 MPa. The variability shown in the results is due to the different densities of the wood. It can be concluded that the development of a different approach in the evaluation techniques of wood products, acceptable from an ecological and social point of view, will aid to promote an increase in the use of the Mexican wood as a structural and construction material.

Protecting forest and medicinal plant resources: a legal brief on *Prunus africana*. Suka, E. (*Ministry of Environment, Protection of Nature and Sustainable Development, Cameroon; emmanuelsuka@yahoo.com*).

Access is open to forests in Sub Saharan Africa for collection of medicinal plants including *Prunus africana* for local use and export to cosmetic and pharmaceutical industries abroad. The bark and roots treat many ailments, particularly human prostate cancer. The plant is endemic to Africa with high altitude characteristics known to exist only in Cameroon, Kenya, and Madagascar. It is exploited extensively and unsustainably to meet high demands by pharmaceutical companies in developed countries. Unfortunately, national legislatures do not have regulatory instruments for sustainable medicinal plant collection and trade. Methods used are based on the best available technology taken from integrated agroforestry and on-farm medicinal plant domestication and cultivation. Documents and texts consulted included 1992 Convention on Biological Diversity/protocols, 1973 Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and World Trade Organization (WTO). Government officials and local communities holding important traditional knowledge on medicinal plants were also consulted. Multilateral instruments above are not fully implemented. Forests and medicinal plant resources can be conserved and benefits sustained in the long term if contracting parties legislate and implement CBD, CITES texts and protection provided by WTO for Intellectual Property Rights of Indigenous People's Knowledge and trade on genetic resources.

Saving blood fruit and monkey cola from disappearing in Cameroon's forest. Suka, E. (*Ministry of Environment, Protection of Nature and Sustainable Development, Cameroon; emmanuelsuka@yahoo.com*).

Blood fruit (*Trichoscypha arborea*), an Anarcardiaceae, and Monkey cola (*Cola pachycapa*), a Sterculiaceae, are primary forest fruit trees in Cameroon among many other non-timber forest products that are threatened. Their fast disappearance away from the tropical forest of Africa is alarming partly due to insufficient knowledge and financial means for their management, and fully due to exacerbated pressures from unorthodox forest exploitation and massive unsustainable agricultural systems. These forest fruit trees have zero conservation status despite their environmental, social, and economic importance in the livelihoods of forest dwellers and forest dependent communities. *Trichoscypha arborea* fruits per se are a source of vitamins valuable to diets for food security in addition to its blood provision qualities critical to health that the pharmacology industry has yet to research. To ensure sustainable management and conservation of these species, a holistic method using an environmentally sustainable and socially inclusive approach was used with adoption of on-farm multiplication and cultivation through agroforestry systems in the area. Research results contributed to forest conservation and REDD+ objectives, thereby mitigating climate change effects. Conserving forest fruit trees promotes wise forest use and adaptation strategies that provide alternative incomes and incentive to rural communities that improve their livelihoods, local economies, and sustainable development.

Physical and chemical characterization of three hardwood species with potential for commercial use. Takeshita, S., Andrade, A., Jankowsky, I. (*University of São Paulo-ESALQ, Brazil; takeshita.sa@gmail.com; ariel@anpm.org.br; jankowsky@usp.br*).

Nowadays the search for a sustainable source of raw material is the focus of numerous studies. Among several alternatives, wood stands out because it is a natural resource, renewable, reusable, and recyclable. However, the only commercially known species are used on a large scale. Thus, the purpose of this research was to carry out physical and chemical characterization of three potential species for commercial use so they may become an alternative to avoid more intensive exploration of only a few species. The species studied were *Erisma uncinatum Warm*., *Tachigali myrmecophyla* (Ducke) Ducke, and *Lecythis usitata* Miers. The characterization of specific gravity and dimensional changes was conducted according to Brazilian Standard NBR 7190. Chemical analysis determined glucose, xylose, arabinose, and galactose using HPLC (high performance liquid chromatography). Extractive and lignin content were also determined according to TAPPI T204 cm97 and TAPPI T222 om02, respectively. As a result, the specific gravity of *Erisma uncinatum, Tachigali myrmecophyla,* and *Lecythis usitata were* 0.56, 0.62, and 0.88 g/cm³. The lowest dimensional changes were presented by *Lecythis usitata,* however cracks were observed during drying. In general, these species present potential for commercial uses and can be introduced into the market.

Dimensional changes in behavior of *Erisma uncinatum* Warm. submitted to additional heat treatment at 90 °C after conventional drying. Takeshita, S., Jankowsky, I. (*University of São Paulo-ESALQ, Brazil; takeshita.sa@gmail.com; jankowsky@usp.br*).

Defects such as warping and cracking presented by wood are the result of their hygroscopic character and consequent dimensional changes. To minimize this effect, wood is submitted to air drying or kiln drying processes, but hygroscopicity is not completely eliminated. The purpose of this research was to evaluate the effects of an additional heat treatment at 90 °C after kiln drying on the reduction of dimensional changes in the of wood of *Erisma uncinatum* Warm. This temperature was chosen so it is possible to apply the treatment in practice, using existing equipment in industries. After the kiln drying processes, the samples will be submitted to 90 °C temperatures with different combinations of time, and then they will be conditioned in an environment of low relative humidity (between 20–30%) followed by an environment of high relative humidity (between 80–90%) to evaluate the effect of treatment on the rate of wood sorption and its dimensional changes. It is expected this will result in a decrease in the dimensional changes due to the application of the additional heat treatment to improve the quality of the final product, thus reducing rework and waste of raw material resulting from incidence of defects.

Plants used to treat infectious diseases in Togo: *Pterocarpus erinaceus* Poir (Faboïdeae) and *Daniellia oliveri* (Rolfe) Hutch. and Dalz (Caesalpinoïdeae). Tittikpina, N., Gbogbo, K., Agban, A., Hoekou, Y. (*University Of Lome, Togo; Knassifa@yahoo.fr; kagbogbo@gmail.com; agbanamegninou@yahoo.fr; patrick21h@yahoo.fr*), Pereki, H. (*University of Lome, Togo and Hamburg University of Applied Sciences, Germany; pereki@daad-alumni.de*), Batawila, K., Akpagana, K.

This study was run to identify plants used to treat infectious diseases due to *Candida albicans* and *Staphylococcus aureus* in the central region of Togo. A semi-structured ethnobotanical survey showed that the most used plants by traditional healers are *Pterocarpus erinaceus* and *Daniellia oliveri*. The plant parts commonly used are barks and roots. The extraction on the roots, barks, and leaves of these two plant species was realized using two different means: an exhaustive, successive extraction and a crude hydro-ethanol extraction. The antimicrobial activity tests, using a broth dilution coupled with the spread on agar, confirmed that all the plants parts were active against the two pathogens, but their leaves were the most efficient with a MIC ranging from 1.875 mg/mL to 7.5 mg/mL. The phytochemical study has shown the presence of alkaloids, flavonoids, saponins, tannins, and anthraquinone compounds in the plant extracts. The results confirm the use of *Pterocarpus erinaceus* and *Daniella oliveri* as anti-infectious diseases agents and propose the use of their leaves as an alternative to prevent their disappearing.

Case study: impact of climate change on industrially relevant white spruce wood traits determined with SilviScanTM. Tong, T. (*FPinnovations, Canada; Tessie.Tong@FPInnovations.ca*), Beaulieu, J. (*Natural Resources Canada, Canada; jean.beaulieu@NRCan.gc.ca*), Sherson, G. (*FPInnovations, Canada; gail.sherson@fpinnovations.ca*).

Climate change affects not only tree growth and survival but also wood quality. Given the importance of wood quality and resulting product performance to the economic values of forests, it is imperative to understand how wood quality responds to climate change. Advanced technologies such as SilviScan are available for research into impacts of climate change on industrially relevant wood traits. SilviScan rapidly and cost-effectively determines multiple wood quality traits on the same increment core or wood disc sample, offering high-resolution pith-to-bark measurements. In this case study, transfer models were developed to establish the relationship of white spruce wood quality traits with transfer distances for 17 annual climate variables. Wood

samples were selected from 3 planting sites and 21 provenances in eastern Canada. Quadratic regression analyses showed that variation in wood quality traits between provenances is large, reflecting the significant genetic control of wood traits. The study also revealed a significant impact of climate change on wood quality traits, even with the restricted range of climate values available in the study. For example, total annual precipitation alone accounted for 18% of the variation in fiber coarseness, one of the key fiber attributes impacting pulp and paper product performance.

Longitudinal and radial variation of the charcoal production in eucalypts. Trugilho, P. (*Federal University of Lavras, Brazil; trugilho@dcf.ufla.br*), Arantes, M. (*Federal University of Espírito Santo, Brazil; mdonaria@hotmail.com*), Lima, J., Silva, J., Paula, L., Neto, R.G. (*Federal University of Lavras, Brazil; jtlima@dcf.ufla.br; jreinaldo@dcf.ufla.br; luanafloresta@hotmail.com; rmgnetto@yahoo.com.br*).

This research aimed to determine the longitudinal and radial variation of the charcoal production in one hybrid clone of *Eucalyptus grandis* x *E. urophylla* in three diametric classes. A total of 34 trees were used made up of 22, 9, and 3 trees in the 14.2 cm, 11.4 cm, and 8.1 cm diameter classes, respectively. The longitudinal sampling consisted of removing discs at 2, 10, 30, and 70% of the commercial height, up to 5 cm in diameter. The radial sampling was performed on the disks at up to five positions (20, 50, 70, 80, and 90% of the radius), depending on the diameter of the discs. The results indicated that charcoal production was reduced from pith to bark and with tree height in all diameter classes. Larger variations in both radial and longitudinal charcoal yield occurred in the largest diameter classes (14.2 cm and 11.4 cm). In the 14.2 cm class, higher values of charcoal yield occurred at 10% of the commercial height at 20, 50, and 70% of the radius; however for the classes of 11.4 cm and 8.1 cm classes, the highest yields were at 2% tree height at 20 and 50% of the radius.

Production of mate (*Ilex paraguariensis*) in Rio Grande do Sul, Brazil in the last years: discussing the current crisis. Vassali, M. (*Federal Rural University of Rio de Janeiro, Brazil; mauriciovassali@gmail.com*), Lopes, M. (*Federal Rural University of Rio Grande do Sul, Brazil; manoelasm@gmail.com*).

Since before the first settlers arrived in Brazil, mate (Ilex paraguariensis St. Hil.) was used by the natives. Today, the culture of tea mate persists, especially in the southern region of the country. In keeping with tradition, the main form of exploitation is the extraction of the culture, of which approximately 700 000 acres are intended for the production of mate with more than 95% of it in southern Brazil. The economy generates hundreds of thousands of jobs, although not always legally, using few chemicals and assisting the maintenance of forests, being one of the most sustainable in the scenario. With the current crisis of production and the increasing price of the product on the market in RS state, this work aimed to raise the amount of mate produced in planted areas according to SINDIMATE data from between 2001 and 2010 as a way to initiate a discussion on this important subject. The results showed that, although the amount produced has remained relatively constant since 2007, the planted area was reduced by at least 30% in the period of 2007–2010, which can be explained by the long time for the plant to get ready for production and low trade price in recent years.

Wood materials and products in the development of bio-economy: RDI program of the Finnish Forest Research Institute (METLA). Verkasalo, E., Heräjärvi, H., Hänninen, R., Kärkkäinen, K., Lindblad, J. (*Finnish Forest Research Institute, Finland; erkki.verkasalo@metla.fi; henrik.herajarvi@metla.fi; riitta.hanninen@metla.fi; katri.karkkainen@metla.fi; jari.lindblad@metla.fi*).

The wood products sector is in a key position to develop bio-economy. Novel business concepts, products, services, and life cycle thinking are expected to increase the competitiveness of the enterprises of the sector. The growing demand of goods and services in the building and living logistics sector as well as bio-refineries call for increased understanding and efficiency in production and management of wood-based material streams. Knowledge-based renewal created by research, development, and innovation (RDI) is the key success factor for the sector, through better customer orientation and profitability in the entire value chains and adoption of good practices from the neighboring sectors. Finnish Forest Research Institute (Metla) recently launched the RDI program, Wood Materials and Products in the Development of Bio-Economy (2014–2018). The aim is to create a basis for the Finnish bioeconomy through the wood products sector and new opportunities for the enterprises in the context of bio-economy. The program includes five themes: 1) wood products sector in bio-economy; 2) wood utilization, products, and services; 3) raw materials and side-streams; 4) measurements; and 5) genetics and quality. The first themes have a more applied character, whereas the last themes focus more on basic research. METLA is seeking international project collaboration in these themes.

Biomass supply chains: mapping flows and identifying forest sector business opportunities. Vlosky, R. (*Louisiana State University, USA; vlosky@lsu.edu*), Kolluru, R., Smith, M. (*University of Louisiana at Lafayette, USA; kolluru@louisiana.edu; mxs2356@louisiana.edu*), D'Agostino, C. (*Louisiana Business & Technology Center, USA; cdag@lsu.edu*).

We will provide results of an integrated research and outreach effort to identify potential alternative bio-based revenue and profit streams of members of the forest sector supply chain in Louisiana, USA. We mapped the supply chain for forest products in Louisiana and identified potential wood-based bio-business options that can be integrated into supply chain member current business models to enhance profitability and diversify revenue streams. Forest and production mill residues and dedicated forest biomass production were the focus of the project. We used a mixed mode phone interview and mail survey methodology to identify current and potential business positions and identify willingness to participate in new wood bio-based business opportunities. The outreach component consisted of two business education workshops designed to increase target audience understanding of options and opportunities, provide guidelines and advice on how to proceed if they are interested in pursuing alternative business strategies, and provide potential matchmaking linkages to potential business partners in forest-based bio-based ventures.

Wood-based biomass-to-electricity sector development in rural Uttarkhand, India. Vlosky, R., Mishra, A. (*Louisiana State University, United States; vlosky@lsu.edu; amishr3@tigers.lsu.edu*).

This study examines the social, technical, and economic viability of forest biomass-gasification-electricity businesses in rural Uttarakhand, India. A survey of rural households was conducted to understand their energy needs, perception about biomass

power, and willingness to participate in the briquetting business. In addition, other stakeholders were interviewed, including scientists from the Indian Institute of Science, the Energy Research Institute, and local/state politicians, to understand current plans and potential future support for this business model. The economic viability of different scenarios was also examined by evaluating net present value (NPV) and internal rate of return (IRR).

Consumer perceptions of children's furniture in Shanghai and Shenzhen, China. Wan, M., Toppinen, A., Chen, J. (*University of Helsinki, Finland; minli.wan@helsinki.fi); anne.toppinen@helsinki.fi; jzchen@mappi.helsinki.fi*).

With the improvement of living standards, Chinese people are increasingly concerned about their life quality, especially when buying consumables like clothing and durables like furniture for their children. In the past 10 years, the Chinese children's furniture market has developed rapidly. However, no studies concerning the analysis of consumer behavior in this market segment exist yet. The objective of this study was to fill this gap by examining consumer perceptions of children's furniture by conducting quantitative surveys in Shanghai and Shenzhen in China in 2012. The data revealed that 67% of the 299 respondents were females, and 63% and 23% of respondents were in the range of 31–40 and 20–30 years old, respectively. Results indicated that eco-friendliness, use of natural materials, and safety were the primary consideration for parents in buying children's furniture. Consistent with this finding, 83% of respondents chose solid wood as the primary raw material for children's furniture, and 98% of respondents were willing to pay premiums for eco-friendly children's furniture. Nevertheless, Chinese consumers had low brand awareness and their price expectations on solid wood furniture were below current market levels. Despite these concerns, children's furniture presents a growing high-end market potential for both furniture producers and wood raw material suppliers.

Nondestructive estimation of mode I fracture toughness of wood using near infrared (NIR) spectroscopy. Watanabe, K., Ukyo, S., Hiramatsu, Y., Yamada, T. (*Forestry and Forest Products Research Institute, Japan; kenwatanabe@affrc.go.jp; ukyo@ffpri.affrc.go.jp; yash@ffpri.affrc.go.jp; yamadat@affrc.go.jp*), Kambe, W. (*Kanto Gakuin University, Japan; wkambe@kanto-gakuin.ac.jp*).

This study investigated the application of near infrared (NIR) spectroscopy to estimate fracture toughness of wood. One hundred air-dried Sugi (*Cryptomeria japonica*) samples were prepared and NIR spectra were obtained from transverse, radial, and tangential surfaces of each sample. The critical stress intensity factor of mode I (K_{IC}) was measured by single-edge-notched bending tests. Partial least squares (PLS) regression models were developed for estimating K_{IC} using the NIR spectra collected from each surface and validated by leave-one-out cross-validation. The spectra collected from the transverse surface gave a better prediction than the ones collected from radial and tangential surfaces. The relationships between measured and estimated K_{IC} were good with a coefficient of determination of 0.62 and a root mean square error of 0.017 MPa/m^2. These results indicate that NIR spectroscopy has the potential to estimate K_{IC} of air-dried Sugi samples.

Contradictive dragon blood rattan: promising people livelihood, conversely, species in the doorway of extinction. Widyati, E. (*FORDA, Indonesia; enny_widyati@yahoo.com*).

Dragon blood (DB) is a reddish-purple resin extracted from young rattan fruit of *Daemonorops* genera. This resin is usually utilized as a traditional medicine, cosmetics, and dye agent. DB has been a hereditary livelihood of the people in Sumatera and Borneo. The product was mostly exported to China. Until now, a global demand for DB did not exist. Consequently, the price is getting higher and higher. At the farmer level, the best grade of DB reaches 400 US$/kg. This paper discusses some identified obstacles in utilizing DB rattan sustainably. Data were collected based on field studies, interviews, statistical data from local governments, and related published studies and reports. Studies carried out in South Sumatera and Jambi Province showed that rattan fruits supplying DB customarily come from wild harvest. The increased deforestation during the recent decade has decreased the natural populations. However, cultivation efforts to satisfy the supply have encountered some limitations. People prefer to harvest the young fruits for producing resin rather than harvesting the mature fruits for a seed source, causing regeneration stock to become a big problem. Other problems were lack of information on its natural potential, phenology, seed handling, market regulation (both seed and resin), and community perception.

Soil contamination with chromated copper arsenate preservative, an organophosphate and two synthetic pyrethroids affecting seed germination of okra and tomato vegetables. Wong, A., Bulan, P., Tawi Anak Daud, C. (*University of Malaysia-Sarawak, Malaysia; awong.unimas@gmail.com; petrus@frst.unimas.my; carlsontawi@gmail.com*).

Careful handling and use of wood protecting chemicals helps to safeguard the surrounding soil (groundwater) environment in any operational wood treatment process and with long-term exposure of treated wood in service. A study was done on the effects of both filter paper and red-podzolic soil contaminated with chromated copper arsenate (CCA) preservative and water-borne termiticides chlorpyrifos, cypermethrin, and permethrin on the seed germination rate of okra (*Abelmoschus exculentus*) and tomato (*Solanum lycopersicum*) vegetables seeds. Results overall, irrespective of filter paper or soil substrate, revealed that seed germination rates were affected by increased chemical concentrations and corresponding acidities of CCA and chlorpyrifos contaminated solutions. CCA preservative was much more phytotoxic than chlorpyrifos, while the synthetic pyrethroids showed no observed phytotoxic effect. Extrapolating, from an environmental perspective CCA preservatives and chlorpyrifos, but probably not permethrin and cypermethrin, could pose serious threats to the soil (i.e., groundwater) environment and affect seed germination of certain plants if chemical spillage due to mishandling or to leaking storage devices or if possible long-term leaching of such treated wood into soil occurs.

Soil contamination with aqueous wood extractives does not inhibit seed germination of okra and tomato vegetables. Wong, A., Tan, W., Bulan, P (*University of Malaysia-Sarawak, Malaysia; awong.unimas@gmail.com; weikhong90@hotmail.com; petrus@frst.unimas.my*).

A study was done on the effects of contamination of both filter paper and red-podzolic soil with aqueous heartwood extractives of Sarawak-Malaysian wood species kempas (*Koompassia malaccensis*), Belian (*Eusideroxylon zwageri*) *Acacia mangium,* and

extractives of undifferentiated wood of Engkabang jantong (*Shorea macrophylla*) on seed germination rate of the vegetables okra (*Abelmoschus esculentus*) and tomato (*Solanum lycopersicum*). Among these woods, Belian heartwood extractives are well-known for conferring the natural durability of the wood. Phytotoxicity tests revealed variable seed germination rates of both plants depending on the seed quality and extractive types/concentrations of cold water and hot water extracts contaminating the filter paper and soil substrates. However, the highest concentrations showed no observed inhibitory effects on seed germination. This suggests that in reality, concerns of leaching of aqueous wood extractives from externally stored raw wood materials (including logs, sawnwood, wood chips, and sawdusts) or wood pulping processes, even from a naturally durable wood, into surrounding soil environment (as groundwater contamination) may not necessarily pose phytotoxic threats to certain plant species.

Bamboo shoots sector in China: encountering a great opportunity with some challenges. Wu, L. (*China National Bamboo Research Center, China; boteatree@163.com*), Li, R. (*Zhejiang University, China; zhedalirui@zju.edu.cn*), Gao, G., Zhong, H. (*China National Bamboo Research Center, China; anshu998@163.com; zhonghao0726@163.com*).

Bamboo, with two main products of bamboo timber and bamboo shoots, is one of the earliest non-wood natural resources developed and used by human beings. Bamboo shoots are rich in protein, high in fiber, low in fat and calories, and are used as a delicacy in human food. With a good reputation both in domestic and international markets, China has achieved a rapid development of the bamboo shoots sector in the past 30 years. This article briefly introduced the bamboo shoots resource in China and the nutritional and medicinal value of bamboo shoots. An analysis and classification was taken of the history and achievements of bamboo shoots cultivation and utilization in China. The emphasis was put on the problems and changes in the development of the bamboo shoots sector in China in order to promote further progress. In summary, the suggestion and orientation of the bamboo shoots sector were proposed for China and the world.

Effect of different surface treatment processes on the printability and absorbability of decorative base paper. Xu, J., Long, L., Peng, X. (*Chinese Academy of Forestry, China; xujianfeng198216@aliyun.com; longling@caf.ac.cn; pengxr@caf.ac.cn*).

Wood-based panels overlaid with decorative paper are rich in color, beautiful, and have excellent visual effects. Decorative paper can protect wood-based panel from wear, heat, and contamination. So the properties of decorative base paper, especially the printability and absorbability, directly affect the quality of wood-based panel products. The former affects the print quality and the latter affects the absorption of melamine in the production of decorative paper. In this paper, the way to get excellent printability and absorbability of decorative base paper was studied. Three types of mixture including starch, starch and styrene acrylic ester (SAE), and starch and polyurethane (PU), were respectively used in the surface-treatment of decorative base paper. The effect of the kind of mixture and the dosage of each component on the printability and absorbability of paper were investigated. The results showed that excellent surface-treatment effects were obtained when starch and SAE with a mass ratio of 20:1 was used. Compared with the value of paper without surface-treatment, the tensile strength increased by 40% and smoothness doubled. Meanwhile, color density was higher and absorbability was maintained.

Forest products trade and wood carbon flows: case study of forest product trade between U.S. West Coast and China. Zhou, X. (*U.S. Forest Service, USA; xzhou@fs.fed.us*), Yang, H. (*Nanjing Forestry University, China; yhqnfu@gmail.com*).

Forest products in transit carry massive amounts of wood carbon. The trade of forest products leads to the flow of carbon stored in the wood in or out of the countries involved. The accounting of wood carbon flow among trading parties will have a significant impact on total carbon estimates in the forest sector for the trading countries. Over 65% of the U.S. log export and about 27% of the U.S. lumber export were shipped out from the West Coast during the second quarter of 2013. China has been a major forest product trade party to the U.S. West Coast since 2008. This study will track the forest products trade between the U.S. West Coast and China to show the wood carbon flow from the trade and the impact on the total forest carbon estimation among trading parties in the forest sector.

GENERAL POSTER SESSIONS

IUFRO Division 6: Social Aspects of Forests and Forestry

Participation of stakeholders in community-based forestry in Cross River State, Nigeria. Abi, E. (*Forestry Research Institute of Nigeria (FRIN), Nigeria; eneabi2008@yahoo.com*), Babalola, F. (*University of Pretoria/University of Ilorin, South Africa; Fola.Babalola@up.ac.za*), Ibor, O. (*University of Calabar, Nigeria; otu_crs@yahoo.co.uk*).

Participation of stakeholders is pertinent to effective implementation of community-based forestry (CBF). This study therefore evaluated the participation of and working relationships between timber dealers and forestry officials in implementing CBF in Cross River State, Nigeria. Primary data were collected through administration of a structured questionnaire to the forestry officials in the local communities where CBF is practiced, as well as to the timber dealers involved in harvesting, transportation, and processing of timber resources obtained from community forests under CBF. As stakeholders in CBF, forestry officials are responsible not only for the utilization of timber resources but also for regulating and monitoring all activities. The highest economic benefit derived from CBF by timber dealers is timber extraction, which also leads to income generation and job creation for the rural dwellers. Plantation establishment ranked topmost among the CBF activities involved in by timber dealers; however, timber dealers are not involved in forest protection and the decision-making process. Introduction of CBF in the selected communities of the state has contributed to community development, improvement in the timber business, and cordial working relationships among the forestry officials, timber dealers, and rural residents. For effective participation in CBF, however, empowerment of stakeholders in the decision-making process has been identified as crucial.

Valuation of ecotourism potential of Olumo Rock, Abeokuta, Nigeria, using the travel-cost model approach. Akintunde, O., Olakunle, S. (*Federal University of Agriculture, Abeokuta, Nigeria; akol_ak@yahoo.com; olakunlesegun60@yahoo.com*).

This paper investigated the monetary value placed on ecotourism potential of Olumo Rock, Abeokuta, Nigeria, as perceived by visiting tourists. Open-ended questionnaires in a non-probability snowballing method were used to capture primary data from visiting tourists on ecotourism values of the resort. Descriptive statistics, multiple regression analysis, and the travel-cost model approach were used to analyze the data. Results indicated that most visitors were male (54%) and residents of Lagos State, Nigeria (60%). Thirty-eight percent of visitors were students, and 44% had some college education. Other results were as follows: 72% were visiting for recreational purposes, 26% encountered hill climbing as a problem, and 74% were fairly satisfied with the staff-visitor relationship and the site resources and facilities. Most (68%) came in their private vehicles. The vast majority (90%) indicated they wanted to return, but most (66%) were not saving for such a trip (66%). The travel cost analysis showed that visitors using private transportation incurred more expenses than those using public transport. The reduced model regression revealed that variables such as income, distance to site, and travel cost significantly influenced the visitation rate to Olumo Rock. Effective management of park resources and facilities and improvement in staff benefits were some of the respondents' recommendations.

Beyond individual plant yield: integrating diverse socio-environmental factors into estimates of commercial production of an Amazonian non-timber forest product. Alechandre, A., Melo, T. (*Federal University of Acre, Brazil; andreaalechandre@hotmail.com; tadeu.melo12@gmail.com*), Fonseca, F., Munaretti, A., Evangelista, J., Wadt, L.O. (*EMBRAPA Acre, Brazil; fernanda.fonseca@embrapa.br; alisson@florestal.eng.br; joziane.gestorambiental@gmail.com; lucia.wadt@embrapa.br*).

Non-timber forest product estimates are one of the biggest challenges for sustainable forest management by Amazonian smallholders. Often, producers generate optimistic overestimates, which can have negative ramifications for buyers, who need to reliably satisfy market demand. Although *Euterpe precatoria* is an abundant, fruit-producing Western Amazonian palm with an established market, consistent production by smallholders is hindered by several factors: thin stems which must be skillfully climbed to reach crown fruits, rapid fruit perishability (after only about 48 hours without refrigeration), and often difficult access to sufficient fruit quantities. The authors analyzed production from one landholding, mapping 12 ha of 50-m riverine transects. Seventy percent of 772 individuals were scalable, yielding an estimated 7.6 tons of fruit based on 14 kg of fruit per plant. Nonetheless, poor fruit formation and bird predation diminished production to such low levels that the harvester did not enter the market. The authors conclude that smallholder productivity estimates must go beyond individual plant yield estimates to include wildlife interactions, harvest and transportation logistics, sales price, labor availability, and social organization to potentially group smallholder sales. Perhaps consideration of these multiple factors for production estimates would increase the likelihood of smallholder business success.

Stakeholders' perception as support for forest landscape planning in Ciliwung watershed, Indonesia. Alviya Abdul Manap, I., Suryandari, E., Muttaqien, Z., Maryani, R. (*Forest Research and Development Agency, Indonesia; iisalviya@yahoo.com; elvida_ys@yahoo.com; zahrul-m@indo.net.id; retnomaryani@hotmail.com*).

Forests play a vital role for people in both rural and urban communities. An important aspect of forest management is the addressing of perceptions of forest users towards forest practices. This paper aimed to illustrate stakeholders' perceptions about criteria for forest management and about current biophysical, socioeconomic, and institutional aspects of forest landscape management. Information was gathered through a survey instrument designed to identify the preferences, perceptions, and expectations of people with an interest in the general impact of ongoing management of Ciliwung watershed in Indonesia. Data were analyzed descriptively and quantitatively using a Likert scale. Respondents in government and upstream communities indicated the institutional aspect was the most important factor in forest landscape management of Ciliwung watershed. In contrast, communities of the middle watershed indicated biophysical and socioeconomic factors were the most important. Regarding biophysical aspects, respondents indicated reforestation and conservation of soil and water in the upper watershed were the most important programs to undertake. In socioeconomic aspects, compensation mechanisms from downstream communities

to upstream communities are needed in order to increase upstream community welfare because of the low incomes of upstream residents. In institutional aspects, stakeholders say there is still a need to increase interaction and coordination among stakeholders, law enforcement, and forestry managers to support the preservation of forest in the upstream watershed.

Assessing cultural ecosystem services and their association with other ecosystem services in a research forest in the western Cascade Mountains of Washington, USA. Ameyaw, L., Weir, E., Petri, D., Ettl, G. (*University of Washington, USA; lkameyaw@uw.edu; ellenf3@uw.edu; dianap@uw.edu, ettl@uw.edu*).

Field observations, interviews, and questionnaires were used to document visitor use at the 1 740-ha University of Washington (USA) research forest. The visitor use data were combined with maps of forest stand age, geologic features and waterways, and scenic vistas to describe the relative importance of provisioning and biotic ecosystem services to cultural ecosystem services (i.e., visitation for recreation and solitude). Visitors entered the forest primarily on foot or by horseback with most access happening along two state highways that border the forest. Most of the visitors lived within 20 miles of the forest entrance and had visited the forest more than 10 times in their lives. Analysis showed that visitor activity was mostly dog walking, horseback riding, observing/photography, or hiking/walking, or a combination thereof. Visitors most frequently visited one of the following locations: old-growth forest reserve, confluence of a medium and large river, a waterfall, several isolated trails, and the gravel road network. An analysis of visitor use data with other landscape and forest stand (age, tree size, reserves vs. production forests) attributes was used to examine the relative importance of forest management to the cultural ecosystem services provided by a working forest.

Amenity forestry and environmental sustainability: the example of Calabar Botanic Garden, Cross River State, Nigeria. Aya, F. (*University of Calabar, Nigeria; ayafelix@yahoo.co.uk*), Fidalgo Fonseca, T. (*University of Trás-os-Montes and Alto Douro, Portugal; tfonseca@utad.pt*).

This research focused on the importance of amenity forestry in environmental sustainability. The study site was Calabar Botanic Garden, which is located in the city center of Calabar (4°57′0″N, 8°19′0″E), the capital of Cross River State, Nigeria. This location offers a rare situation: a natural habitat-of-choice where birds and other wildlife live freely within a highly populated human environment. Facilities for recreation and special events are also in place. Inventory of all tree species and selected species of shrubs, herbs, grasses, and fauna was carried out. A total of 302 tree species were enumerated, representing 171 (57%) and 131 (43%) indigenous and exotic species, respectively. The garden has a total area of 34 835 m^2. Tree crown cover was 10 731 m^2, of which 9 374 m^2 (87%) was from indigenous trees and 1 357 m^2 (13%) from exotic trees. Total mean wood volume of trees was 253 m^2, to which indigenous trees contributed 238 m^2 (94%) and exotic trees 15 m^2 (6%). Total population density of tree species was 0.028 tree m^2, with indigenous and exotic species contributing 0.016 tree/m^2 and 0.012 tree/m^2, respectively. In conclusion, the greenbelt status of the garden offers tangible and intangible benefits comparable to those of a natural forest.

Preparing forestry students for the labour market outside targeted sectors. Barianti Ahlberg, D., Lewark, E. (*University of Freiburg, Germany, dbarianti@yahoo.com; siegfried.lewark@fobawi.uni-freiburg.de*).

More than one-third of graduates with a degree in forestry find jobs outside forestry, forest-based industry, or natural resource management, according to recent analyses in Germany. These employment results indicate that forestry programmes need to prepare their graduates for career choices outside the targeted sectors. There is, however, limited information available on forestry graduates' successful employment in non-forestry sectors. This paper reviewed relevant literature on the employability skills of forestry graduates, their employment situation, postgraduate placement trends, and the challenge and experiences of transition from higher education to work, along with employers' and recruiters' views on hiring and working with forestry graduates in non-forestry sectors. It also reviewed factors determining the employment of forestry graduates and graduates of higher education institutions in general. The relevance of the skills gained in these studies for the world of work as perceived by graduates, employers, and recruiters was also explored using a signaling model and human capital theory. Findings from this review may shed light on the design of curricula that aim to educate future forestry graduates to fulfill alternative roles in non-forestry sectors.

Updated identification and evaluation of species produced by the Barreirinha Municipal Garden nursery in Curitiba, Paraná, Brazil. Batista, D.B., Araújo, D., Viezzer, J. (*Federal University of Paraná, Brazil; dbiondi@ufpr.br; damarislevita11@yahoo.com.br; jeviezzer@yahoo.com.br*).

Plants produced in municipal nurseries supply urban forests and should be evaluated in the context of the urban population and local ecosystem. Origin of species (exotic or native), toxicity, and invasive features (as nationally or regionally invasive exotic species) are some aspects that should be considered. Plants from municipal nurseries are used mainly for ornamentation, urban forests, recovery of degraded lands, and environmental education. The objective of this study was to identify and evaluate tree species produced by the Barreirinha Municipal Garden nursery, in Curitiba, Parana, Brazil, from 2008 to 2013. Methods were based on previous research conducted in 2008 that used the following variables: scientific name, popular name, family, life form, toxicity, species origin, invasive features, and use. The number of species produced was reduced from 165 prior to 2008, to 138 species. Of these, 44% were new species. Among them, 22% are exotic, including an exotic invasive (*Schefflera actinophylla*) and one with toxic sap (*Aphelandra squarrosa*). The adoption of this form of evaluation is recommended to maintain an updated production record, which can help in establishing criteria for the production of more suitable species for urban forestry in Curitiba.

Project Floresta-Escola: an interaction between elementary school students and the forest. Batista, D.B., Soldera, C., Perego, D., Bouças, G.C., Wassem, G.F. (*Federal University of Paraná, Brazil; dbiondi@ufpr.br; carolsoldera54@gmail.com; dioney_perego@hotmail.com; gabriele_calle@gmail.com*), Francisco, R.A., Candido, S., Melnik, C.S, Tokarski, A.A.B., Viezzer, J., Martini, A.

Environmental education is an important tool for building values in people and aims at developing the relationship between human beings and the environment. To this end, the project "Floresta-Escola," begun at the Federal University of Paraná in Brazil in 2006, brings environmental education activities to students of public and private schools through an informal curriculum. Excursions are made to a fragment of the Araucaria forest in the city of Curitiba, Brazil. Inside this forest, students are taught about topics such as identification of local plant species, climate, water conservation, nutrient cycling, and interactions between the forest and its wildlife. At the end of each field trip, the students and visiting teachers receive booklets developed by the supervisors reinforcing the content presented during the excursion. Visitors evaluate the activities by completing surveys, which in turn are used to analyze and improve the learning experience. Weekly meetings are held with the supervisors to discuss experiences and suggestions for improvement. Since its inception, the project has reached 200 schools and more than 4 000 students, thereby promoting environmental education to students and enriching the related curriculum.

Participatory monitoring of non-timber forest products. What factors lead to cooperation? Brites, A., Morsello, C. (*University of São Paulo, Brazil; alicebrites@usp.br; alicebrites@gmail.com*).

The commercialization of non-timber forest products (NTFPs) has been promoted in communities inhabiting natural areas as an activity that promotes economic development with low environmental impacts. However, studies have shown that, frequently, there is a tradeoff between conservation and development objectives.To take into account these different objectives, it is suggested that these initiatives need to be monitored. Participatory monitoring has been widely discussed in the literature. For participatory monitoring to be successful, however, it is necessary to know if communities are willing to participate. But what leads an individual to engage in monitoring? Gathering knowledge about cooperative behavior from areas like social psychology and economics, the authors are attempting to identify the factors that can influence participation. The hypothesis is that subjective characteristics (e.g., perception of impacts) have a greater influence on the propensity to participate than do objective factors (e.g., gender). To test the hypothesis, a study was conducted in a Brazilian Amazon community that trades NTFPs. Three approaches were used: survey, focus group, and implementation of experimental monitoring. The results will improve understanding of the factors that promote or constrain participation and will allow creation of monitoring plans best suited to the context of each NTFP trade.

Community food forests in the United States: What environmental and social benefits do they provide? Who is using them and why? Bukowski, C., Munsell, J. (*Virginia Polytechnic Institute and State University, USA; cjbukows@vt.edu; jfmunsel@vt.edu*), Chamberlain, J. (*U.S. Forest Service, USA; jchamberlain@fs.fed.us*).

Community food forests are increasing in popularity across the United States. Although they have a long history in many countries, their use across U.S. landscapes constitutes a new frontier where agriculture and forestry combine via the science and practice of agroforestry to produce food, provide ecological services, and contribute to community development. Food forests represent an opportunity for expanding the use of agroforestry in the United States, ranging from individual landowners to whole communities. An increase in agroforestry across both rural and urban landscapes has important implications for the health and productivity of communities and ecosystems. This research will examine the environmental and social benefits that food forests provide. The development process, forest structure, and community characteristics of food forests in the United States will be examined. Stakeholder motives, preferences, and perspectives on the role of food forests are being studied, along with the processes used to design, establish, and manage them. Project objectives are to provide one of the first generalizable studies of community food forests in the United States and develop best practices at the outset of an emerging movement.

Comprehensive Curriculum Revision 101. Bullard, S., Coble, D., Coble, T., Darville, R., Rogers, L., Stephens Williams, P. (*Stephen F. Austin State University, USA; bullardsh@sfasu.edu; dcoble@sfasu.edu; tcoble@sfasu.edu; rdarville@sfasu.edu; rogersla@sfasu.edu; stephensp@sfasu.edu*).

In order to meet the needs of the changing profession of forestry, it is important for education programs to systematically review and revise their programs to reflect those needs. Curriculum review and revision is not for the meek, yet is absolutely necessary. In 2013 the Arthur Temple College of Forestry at Stephen F. Austin State University (ATCOFA, Texas, USA) completed a year-long study not only to obtain the best possible information for revision of its own curriculum, but also to help in development of a template that other forestry programs could use in their review processes. ATCOFA used a mixed method approach first grounded in the Pinchot Institute Report of 2001 and importance/performance methodology. Using surveys of alumni and focus groups of current and potential employers, ATCOFA was able to obtain a big picture of what the needs of its students may be over the next 20 years. This information was taken to the faculty for discussion and incorporation into the current and future curriculum. After completion of the curriculum revision, the research team revised the process and tools to produce a model for usage by other forestry programs. This presentation gives a brief overview of the process and the results.

Ecosystem services and human well-being in the Brazilian Amazon: contributions from a landscape analysis. Camilotti, V., Pinho, P., Escada, I. (*National Institute for Space Research (INPE), Brazil; vagner.camilotti@gmail.com; patricia.pinho@inpe.br; isabel@dpi.inpe.br*).

The Amazon rainforest is considered one of the most important ecological systems. It is responsible for the provision of crucial ecosystem services and goods with economic and social values essential for the maintenance and improvement of human well-being. This research investigates through landscape analysis how community households use some important forest resources (timber and non-timber forest products) and how these vary in a landscape gradient. By applying semi-structured questionnaires about the perception of several dimensions of well-being and the use of forest products, the authors were able to link these to a disturbance gradient in the study area located in the Midwest region of Pará State, Brazil. Results showed that forest products have low to high importance for household consumption and low value for income generation. Results also indicated that exploitation of the forest is generally carried out without any forest management. Well-being indicators differed greatly; health, education, and income showed the lowest values whereas others like security in the community and households' participation in

community decision-making varied from medium to high. These results were integrated into a landscape analysis in which relationships among landscape characteristics, human well-being, and the use and importance of forest resources could be observed.

Mapping boundaries of Community Conserved Areas: institutional and operational challenges. Chaliha, S., Ved, N. (*Foundation for Ecological Security, India; swatichaliha@gmail.com; nimesh.ved@gmail.com*).

Defining spatial boundaries of Community Conserved Areas (CCAs) is important for consistent understanding among stakeholders and for laying down operational rules. In Nagaland, India, assigning natural features as boundaries has been the customary practice and cadastral maps do not exist. Defining CCA boundaries there is crucial in the current context of development and conservation. The process of mapping boundaries raised many questions. While in one CCA of Nagaland, the authors, with villager assistance, mapped the boundary by using GIS data and walking with GPS receivers. In another CCA, efforts involved teaching selected villagers to use GPS for mapping. In the first case, an organized arrangement between the traditional local leadership and the institution managing the CCA aided the mapping process. In the second case, the terrain was difficult and coordination between different governing institutions was weak. Questions arose as to whether it is worth the effort and whether boundaries recollected from customary practice would suffice. Villagers expressed confusion about many topics, ranging from whether they would lose land to whether a boundary could be changed at a later stage. Because these CCAs differed in context, geography, and institutional arrangements, the authors' work with them helped demonstrate that multiple participatory approaches for mapping could be effective and aid management decisions for different kinds of CCAs.

Integrating forestry capstone curriculums: preparing today's students to be tomorrow's forest managers through education in sustainability and certification. Cushing, T. (*Clemson University, USA; tcushin@clemson.edu*).

This paper presents an innovative curriculum designed by Clemson University (USA) with funding from the American Forest Foundation. The curriculum is designed to provide faculty members with the tools needed to teach an integrated capstone course that highlights the importance of understanding the objectives of different ownership groups. The curriculum includes six sets of PowerPoints with lecture notes, questions for instructor use, and a Web site with discussion board. The curriculum was designed to be portable throughout the United States and available to anyone. Students will benefit from this integrated approach as not all course instructors have been able to work with a diversity of owners. The curriculum includes information on public ownership, investment, industry, and family owners. The paper will discuss the need, framework, content, and results of evaluations from faculty using the curriculum.

Distribution of potential REDD+ benefits from agricultural lands in forests and forest-savanna transition zones of Ghana. Damnyag, L., Oduro, K., Foli, E. (*Forestry Research Institute of Ghana, Ghana; lawdam@yahoo.com; kwameoduro@gmail.com; efoli@hotmail.com*).

REDD+ is designed to create incentives for the reduction of emissions from deforestation and forest degradation, carbon stock enhancement, and conservation and sustainable management of forests in developing countries. Emphasis on addressing issues of REDD+-related benefit distribution has mostly been at the international and national levels, with very limited analysis at the lowest tier of the administrative hierarchy, namely, the village, community, or farm. Ghana has had no experience with implementation of REDD+ pilot projects. Therefore, how benefits under REDD+ implementation should be shared between stakeholders, particularly at the forest and farmland level where emissions reduction activities take place, is yet to be fully understood. This paper presents an analysis of how potential REDD+ benefits could be distributed among beneficiaries at the community/forest level to ensure effectiveness, efficiency, and equity in REDD+ implementation. Data were collected from 236 farmers in two communities each from three administrative districts in Ghana using individual interviews. The paper presents models for potential REDD+ benefit distribution at the community level, and to individual farmers to secure legitimacy and support for national REDD+ strategy design and implementation. Community preferences would not be static but are subject to changes, particularly as REDD+ activities proceed.

Dietary pattern of indigenous people, local people, and immigrants in the vicinity of Harapan Rainforest, Indonesia. David, W. (*Bakrie University, Indonesia; wahyudi.david@bakrie.ac.id*), Widianingsih, N. (*University of Copenhagen, Denmark; nayu@foi.ku.dk*), Ardiansyah, A. (*Bakrie University, Indonesia; ardiansyah@bakrie.ac.id*), Ploeger, A. (*University of Kassel, Germany; a.ploeger@uni-kassel.de*).

Dietary patterns of societies depend on their household income, geographic location, and culture. According to Indonesian regulation No. 18/2012 and Presidential Regulation No. 22/2009, Indonesia Food Security Policy is based on optimization of local resources for acceleration of food consumption. Local food security can be achieved if the carrying capacity of the environment is suitable to meet local needs. Harapan Rainforest (HRF) is a forest restoration area in accordance with regulation SK 327/Menhut-II/2010 and SK 293/Menhut-II/2007 and is located in Jambi and South Sumatra. Three different ethnic groups (indigenous, local, and immigrant) have been using the resources within 20% of the area, which is tropical lowland rain forest. Communities residing in or near restoration areas generally have fewer financial assets but are rich in natural resources. Thus, a thorough review of the daily food intake type from forest resources is needed for each ethnic group in the context of local food security to avoid conflicts between restoration and community needs in and near HRF. This research will be carried out from November 2013 to February 2014 using the survey method in three villages located next to HRF.

The local particularity of the livelihoods of taungya participants in the teak plantations in the Bago Mountains, Myanmar. Ei, Takeda, S. (*Kyoto University, Japan; ei641986@gmail.com; takeda@asafas.kyoto-u.ac.jp*).

Since the 19th century, teak (*Tectona grandis* L.) plantations have been established in the Bago Mountains of Myanmar using the taungya system. This system combines plantation operations with intercropping and is carried out by local swiddeners, who practice a type of cultivation that is also known as "taungya". Nowadays, taungya participants still play an important role in teak

plantation programs because of the cost-effectiveness of the taungya system, which was adopted for Myanmar forestry centuries ago. However, taungya participants in the teak plantations have gradually formed communities that are engaged in various kinds of taungya practices for their livelihoods, especially after the recent expansion in private plantations. To explore the interactions between teak plantations and the local communities, a study was conducted at three different locations in the Bago mountain range, giving preference to both those areas which, historically, have had teak plantations and those which are currently most densely planted with teak. Using questionnaires and semi-structured interviews, the household surveys sought information on crop production and consumption, plantation work and income, the experience of the taungya participants, and other matters at each location. The different ways in which people participated in the taungya system were clearly observed at each site. These differences among the communities and their concerns with the teak plantations are discussed in this study.

Promoting co-benefits of ecotourism as a complementary strategy for sustainable management of Gunung Halimun Salak National Park. Ekayani, M., Nuva, N., Nurrochmat, D. (*Bogor Agricultural University, Indonesia; metieka@yahoo.com*, *nuvamaresfin@yahoo.com; dnrochmat@yahoo.com*).

The richness of Indonesia rain forest biodiversity not only provides invaluable ecological functions but also is very important to support economic development and local communities. Ecosystem services contributed up to 21% of Indonesia's GDP, including 75% of income for the rural poor. Despite this importance, Indonesia's biodiversity is under threat from habitat degradation, deforestation, climate change, unsustainable forest management practices, and overexploitation of natural resources. A large number of endemic plant species are endangered, suffering from intense deforestation and other destruction. Therefore, conservation of forest plants is vital to Indonesia not only biologically, but also economically. The Gunung Halimun Salak (TGHS) National Park has been playing a pivotal role in conserving genetic resources and the habitat of native plants. In addition to its role as a conservation forest, the park has provided several co-benefits such as wonderful landscapes and ecotourism attractions. The park is an ideal ecotourist destination because it meets the three most important criteria for ecotourism: an interesting place for nature tourism; supporting environmental education; and improving the regional economy as well as social well-being. This study confirmed that the co-benefits of ecotourism play an important role in supporting sustainable TGHS national park management.

The role of mangrove forests in sustaining household livelihoods in the Niger Delta, Nigeria. Eleanya, K. (*Federal University of Ducima, Nigeria; kele802001@yahoo.com*), Agbeja, B. (*University of Ibadan, Nigeria; olasinaa@yahoo.com*).

Mangrove forests are increasingly recognized as crucial ecosystems in sustaining the livelihoods of households that dwell in and around them. This study provided a critical assessment of household livelihood opportunities derivable from the mangrove forest in Akassa in the Niger Delta. Non-compliance with the Akassa Forest Policy has led to continued deforestation of the vast mangrove forest resources, thereby threatening the livelihoods of a growing rural population in the Niger Delta wetland. Structured questionnaires were used to gather information from the households, and participatory rural appraisal techniques were also adopted to gather relevant data. Measures of economic evaluation and analysis of variance were some methods used to analyze data. Willingness to participate in Akassa Forest Policy was dependent on location of households. The three highest average monthly income values for livelihoods in naira (₦) were speedboat driving (₦38 952), canoe carving (₦36 824), and logging/chain saw rental (₦31 075). In the face of the current unsustainable trend of mangrove forest exploitation, approaches for adopting people-centerd and community-driven forest policy are offered for attaining sustainable livelihoods.

Development of a trail auditing tool for trails at the wildland-urban interface. Gatti, E. (*University of Utah, USA; elise.gatti@utah.edu*).

This poster presentation describes a trail auditing tool devised to assess trails at the wildland-urban interface, including trails that originate within or at the periphery of urbanized areas and extend into more natural areas. The tool was developed using a segment of the popular Bonneville Shoreline Trail in Salt Lake City, Utah, USA. A new trail assessment tool is necessary because the motivations and preferences of trail users in the wildland-urban interface differ from users of urban-only trails or trails within designated wilderness. Specifically, these users are in search of naturalized conditions that provide a context for physical activity close to home or work. A review of existing approaches to evaluating urban and wilderness trails and a pilot study was used to inform the development of this new trail auditing tool, which uses GPS and GIS to document trail conditions and experiential characteristics. This tool will be of interest to trail and forestry professionals who must address the tensions inherent in heavily used and accessible trails in the wildland-urban interface, mainly by balancing the demands of urban development with retaining a natural setting.

Multi-stakeholder approach for managing conflicts and developing shared vision on community-based forest management in Nepal. Ghimire, M. (*Ministry of Forests and Soil Conservation, Nepal; ghimire.madhu@gmail.com*).

The forests of Nepal significantly influence the people's well-being directly and indirectly by providing environmental services. Nepal has pioneered community-based forest management (CBFM), and its different models are promoted and strengthened to sustainably manage the forests and address community needs and aspirations. This study assessed and compared the models on conceptual, legal, institutional, and operational aspects, and on their acceptance and degree of complexity in implementation. The study also explored possible strategic measures for developing shared vision and minimizing conflicts using a multi-stakeholder approach. This study was based on primary data (field visits and expert consultations) and a literature review. Results show that these models have many similarities, especially regarding community empowerment and sustainable management, but differ on community engagement, governance, and ownership arrangements. Performance of each model is governed by local conditions of landscapes, resource distribution, community participation, and degree of conflicts. A gap exists between policy and practical applications of these models, and there is limited evidence for making valid comparisons. However, the recently promoted multi-stakeholder approach has been effective in managing conflicts by promoting constructive ideas through concurrent existence of various approaches working towards a shared vision.

The effect of the deforestation rate on human activities in Central Africa: CoForTips project. Gillet, P. (*University de Liège-Gembloux Agro-Bio Tech, Belgium; pgillet@ulg.ac.be*), Feintrenie, L. (*CIRAD, Cameroon; laurene.feintrenie@cirad.fr*), Vermeulen, C. (*University de Liège-Gembloux Agro-Bio Tech, Belgium; cvermeulen@ulg.ac.be*).

The objectives of this study were to evaluate the impact of deforestation on human activities in Central Africa and to analyze changes in these activities. The research was based on the use of an interactive model and on surveys held in villages located at three different stages on Mather's deforestation curve (Mather, 1992). This curve shows the relationship between forest cover and population density. The three stages in this study were: (1) large proportion of intact forest cover, (2) forest partially degraded and under pressure of conversion to other land uses, and (3) smaller areas of degraded forest with a trend of deforested land being planted with useful trees. The three study sites represent three different Central African socio-ecosystems. The surveys provided information on the evolution of schooling, diet, the percentage of the family budget required for food, productivity of agriculture, change in land tenure rules, and change in the use of non-timber forest products. An interactive model was also used as a tool for participatory mapping in order to describe villagers' perception of space and time. Results of this study focus on socioeconomic data such as a description of life conditions and enhancement of resources in the three villages.

Bird song diversity influences young people's appreciation of urban landscapes. Hedblom, J. (*Swedish University of Agricultural Sciences, Sweden; marcus.hedblom@slu.se*), Heyman, E. (*COWI, Sweden; erhe@cowi.se*), Antonsson, H., Gunnarsson, B. (*University of Gothenburg, Sweden; henrik.antonsson@bioenv.gu.se; bengt.gunnarsson@bioenv.gu.se*).

Increased losses of green areas in cities reduce people's experience of flora and fauna. Earlier studies have shown that biodiversity has benefits for urban inhabitants, but the influence of animal sounds on people's experience of green space is poorly known. A sample of young urban people (N=227) rated their reactions—positive or negative— to three bird song combinations (house sparrow (*Passer domesticus*), willow warbler (*Phylloscopus trochilus*), and seven urban woodland species), three urban settings (residential areas with varying amount of greenery), and nine combinations of song and setting. Bird song was generally considered positive and singing by several species was more highly rated than singing by a single species. On average, urban settings combined with bird song were more highly appreciated than the settings alone and even more so where there was singing by several species rather than just one. The authors conclude that our data support the idea that bird song contributes to positive values associated with urban green space. Urban planners should consider preserving a variety of habitats in cities for hosting a diversity of birds and thereby boost both conservation of songbird diversity and recreational experiences for urban people.

Creative approaches to joint urban forest management: a case study of several urban parks in Guiyang, China. Hu, X. (*Seoul National University, Republic of Korea; huxiaohuan1989@gmail.com*).

Urban parks can provide citizens with diverse ecosystem services that are essential to the urban public welfare. On the one hand, local governments in China with limited budgets feel thwarted in their efforts to build more urban parks for the public. On the other hand, governments are criticized for selling public land, which is usually surrounded by beautiful natural landscapes, to real estate developers in order to enhance government income. Such sales remove the right of public access to those lands for citizens' recreational. This study is based on field research and analysis of stakeholders regarding several newly built urban parks located in Guiyang, a southern China city. It explored a variety of examples that make joint management between governments and real estate developers possible. In practice, governments authorized the developers to build residential buildings at the edge of natural landscape areas under the stipulation that the developers must invest in and improve those areas by creating parks that are accessible and open to the public and offer amenities. Furthermore, the developers are responsible for paying for the future daily maintenance of the urban parks. Results of this survey give fresh insights for future urban planning and development.

Study on forestry and related students' cognition, attitude, and behavior toward biodiversity in Taiwan. Huang, M. (*National Chiayi University, China-Taipei; myhuang@mail.ncyu.edu.tw*); Chiang, A. (*National Chengchi University, China-Taipei; eliot.chiang@gmail.com*), Fong, C. (*National Chiayi University, China-Taipei; s1000090@mail.ncyu.edu.tw*).

This study investigated the cognition, attitude, and behavior of students in forestry and related disciplines toward biodiversity and examined how students' different background affected their cognition, attitude, and behavior toward biodiversity. Furthermore, the study explored relations among cognition, attitude, and behavior toward biodiversity. A questionnaire was administered to undergraduate students in forestry and related departments in Taiwan. There were 630 valid samples, for a response rate of about 87%. Key findings follow. First, regarding background, there were significant effects of gender and residence before entering universities on attitude toward biodiversity. Participating in biodiversity courses, field trips, or camps had a significant influence on attitude and behavior toward biodiversity. Second, there was positive significant correlation between (1) cognition and attitude toward biodiversity and (2) attitude and behavior toward biodiversity. Results and suggestions from this study would provide useful information for policy-makers in the educational agencies of the government when they establish and implement policies about environmental education related to biodiversity.

The value of graduate undergraduate mentorship programs in academia. Hulbert, J. (*Oregon State University, USA; joseph.hulbert@oregonstate.edu*).

Graduate students in the College of Forestry at Oregon State University (USA) initiated a Graduate Undergraduate Mentorship Program (Forest GUMP) in spring 2013. In the first term, 20 undergraduate students were paired with graduate students. At the end of the term, a survey of the participants was conducted and analyzed. The questionnaire focused on program values and improvements. Sixteen graduate students and 12 undergraduate students participated in the survey. Results from the analysis suggest graduate students are capable of contributing unique values compared to other individuals in academia. Of the surveyed graduate student mentors, 94% agreed participation gave them new insight, or experience, that will be helpful in future mentorship roles. Two-thirds of undergraduate survey participants indicated that after participating, they were more interested in graduate school, 75% indicated they would think more carefully about future goals, and 83% claimed they were more prepared to reach

their future goals. All responding graduate and undergraduate students indicated they would participate next term. Graduate undergraduate mentorship programs can be valuable components of academia and the organizers of Forest GUMP have already spoken with three other Oregon State University graduate student groups about starting similar programs.

Higher education and capacity development for sustainability and clean technologies: experiences from Mozambique. Husgafvel, R., Martikka, M. (*Aalto University, Finland; roope.husgafvel@aalto.fi; mikko.martikka@aalto.fi*).

Higher education needs to address the existing and emerging sustainability challenges in the forest sector and in bioproducts technology through the introduction and application of sustainability and clean technologies. Therefore, this study presents experiences from a collaborative project between two universities from Mozambique and Finland. The two universities aimed at (1) developing a specific study module with associated curriculum to offer expert training on sustainability and clean technologies and (2) developing Mozambican capacity to provide services for and to establish strong links with industry, national sustainable development efforts and initiatives, and other higher education institutions. The project activities presented encompass study module development, workshops, networking, and review of potential ways to bridge the gap between higher education for sustainability and addressing the main sustainability challenges within both industry and national sustainable development efforts. Lessons learned and recommendations can be applied to similar development efforts in any country or higher education institution. There are many potential benefits associated with incorporating sustainability and clean technology aspects into forestry education.

Tropical Hardwood Tree Improvement and Regeneration Center: strategies for creating a new collaborative research and extension partnership. Inman-Narahari, F. (*University of Hawaii, USA; finman@hawaii.edu*), Constantinides, M. (*Natural Resources Conservation Service, USA; michael.constantinides@hi.usda.gov*), Dudley, N. (*Hawaii Agriculture Research Center, USA; ndudley@harc-hspa.com*), Friday, J. (*University of Hawaii, USA; jbfriday@hawaii.edu*), Giardina, C. (*U.S. Forest Service, USA; cgiardina@fs.fed.us*), Imoto, R., Koch, N., Litton, C., Masuda, R., Michler, C., Robinson, M.

The Tropical Hardwood Tree Improvement and Regeneration Center (TropHTIRC.org) is the first tree improvement research and extension center for tropical hardwoods in the United States. Its mission is to advance the science of tropical hardwood tree improvement, utilization, conservation genetics, and reforestation. TropHTIRC profits from a unique partnership between industry, university, private, state, and federal entities including the U.S. Forest Service, the University of Hawaii, and Purdue University. The strategy to build the center is to create a successful program with one species, then expand to other species. The initial focal species is *Acacia koa* (koa), Hawaii's premier timber tree. Koa is a fast-growing species that produces high value lumber, improves endangered species habitat, and is a cultural icon. Through traditional breeding for increased disease resistance, growth, form, and wood quality, the center is developing improved trees to increase forest productivity and the economic value of reforestation programs. Current activities include establishing seed orchards to provide improved seed for large-scale reforestation of degraded lands, developing systems for nursery production and plantation establishment, and conducting research on ecological tolerances and disease management. The vision of TropHTIRC is to become the internationally recognized leader in sustainable production, protection, and utilization of tropical hardwoods.

Present situation of forest education, including forestry, environmental studies, and outdoor activities, in Japan. Inoue, M., Oishi, Y. (*Forestry and Forest Products Research Institute, Japan; imariko@ffpri.affrc.go.jp; oishi@ffpri.affrc.go.jp*).

Activities related to forest education have been widely carried out in Japan. Purposes of these activities include education about forest environments, learning about trees, environmental studies and education on sustainable development, and outdoor education. Moreover, classes related to forests and forestry have been taught in universities and vocational high schools for human resource training. In order to gain a comprehensive understanding of these various types of forest-related education, the content and purposes of the programs were classified based on analysis of literature, and then present situation of forest education was examined. Results indicate that forest education was offered as school education, vocational education, or training such as on-the-job training and lifelong education. Contents of forest education can be classified into four categories: forest resources, natural environment, nature experiences, and regional culture. The various purposes of forest education were summarized as "education through direct experience in forests for human resources who know regional forests as a natural environment and trees as circulation resources, who have acquired skill and awareness of forests, and who will support and promote a culture which establishes symbiosis with nature and a sustainable society."

Participatory forestry and rural development: sharable lessons for better management across South Asia. Islam, K. (*Bangladesh Agricultural University, Bangladesh & Kyushu University, Japan; kamrulbau@gmail.com*), Mallik, R. (*Nabakrushna Choudhury Centre for Development Studies, India; rmallik2004@yahoo.co.in*), Fujiwara, T., Sato, N. (*Kyushu University, Japan; takaf217@gmail.com; sato.noriko.842@m.kyushu-u.ac.jp*).

Participatory Forestry has emerged as a key approach to forest management in many Asian countries over the last few decades. This study looked at the foremost enabling factors as well as main constraints of PF towards rural development in South Asia. The study was based on case studies conducted in a Social Forest Management (SFM) site in Bangladesh and Community and Joint Forest Management (CFM, JFM) sites in India. Results revealed that SFM and JFM have been implemented as an extension of state control, rather than as a move towards real democracy. CFM, on the other hand, was initiated by the local community. However, every management system has some degree of success in addressing rural development issues, such as equity, participation of women, formation of local committees, benefit sharing, and improvements in overall livelihood. SFM and JFM have suffered from a rigid framework, whereas CFM has its own effective rules and management systems that bring local people to the center of planning. But CFM lacks government support services. Therefore, it is essential to fill the gap between policy and implementation, and the key issue is to adopt CFM approaches with appropriate government supports in order to enhance rural development in this region.

Prospects for strengthening social forestry in the coastal areas through introducing mangrove species at Shyamnagar upazila in Satkhira district, Bangladesh. Islam, M. (*University of Queensland, Australia; wasiulislam7@yahoo.com*), Baishnab, S. (*Khulna University, Bangladesh; ram080508@gmail.com*), Sadath, M. (*Khulna University, Bangladesh & Georg August University, Germany; mnsadath@yahoo.com*).

Social forestry through introducing mangrove species is becoming an increasingly important component of the environment and economy of Bangladesh. This study aimed to analyze how social forestry implemented by planting mangrove species affected the local people of Shyamnagar upazila in Satkhira district, in terms of socio-cultural, economic, environmental, and institutional impacts. This area has potential for mangrove social forestry because of its proximity to the coast. The field survey was conducted in 2012 using the purposive sampling method to collect data on the perceptions of the local residents and officials (forest department and NGOs). The results showed that respondents strongly agreed with the idea that the practice of mangrove social forestry provided many economic, environmental, and sociocultural benefits to the local people. It was also found that such forestry practice at Shyamnagar had high potential to generate income, help to protect the coastal land, build environmental awareness within local communities, conserve natural resources, improve the standard of living, and provide other benefits. The findings of this study may be helpful in developing a strategic management plan for mangrove social forestry at Shyamnagar upazila for the betterment of the local community as well as the environment.

Multi-level policy dialogues and actions for REDD+ social safeguards: observations from a global comparative study on REDD+. Jagger, P. (*University of North Carolina, USA; pjagger@unc.edu*), Brockhaus, M. (*Center for International Forestry Research (CIFOR), Indonesia; m.brockhaus@cgiar.org*), Lawlor, K. (*University of North Carolina, USA; klawlor@email.unc.edu*), Duchelle, A. (*Center for International Forestry Research (CIFOR), Brazil; a.duchelle@cgiar.org*), Sunderlin, W. (*Center for International Forestry Research* (*CIFOR), Indonesia; w.sunderlin@cgiar.org*).

This study provides a multiscale institutional analysis of actions related to social safeguards and Reducing Emissions from Deforestation and Forest Degradation (REDD+). The authors analysed the institutionalization of international REDD+ social safeguards through the development of international, national, and sub-national policies and processes directly related to the development, implementation, and assessment of REDD+. Data from the Global Comparative Study on REDD+ (GCS-REDD+) by the Center for International Forestry Research (CIFOR) were used from three countries, Brazil, Indonesia, and Tanzania. While these countries' safeguard policies and actions respond in part to the same set of international guidance and incentives, their national, subnational, and local contexts differ in important ways. The authors identified lack of national awareness of REDD+ social safeguards, limited debate among key actors including civil society and government, differences in how sub-national governments have approached social safeguards, and the extent to which national and subnational dialogues facilitate or hinder the integration of measurement, reporting, and verification of social safeguards at the project level as key areas of institutional strengths or weaknesses. Findings suggest that systems of polycentric governance related to REDD+ are likely to foster meaningful institutionalization of REDD+ social safeguards, particularly when compared with donor-driven dialogues and processes.

A research and experimental center for technology transfer regarding drought, land degradation, and desertification. Jamsran, T. (*Mongolia; tsogtbaatarj@magicnet.mn*), Akhmadi, K., Nyamtseren, M. (Mongolian Academy of Sciences*, Mongolia; khaulenbek@yahoo.com; maaggi@yahoo.com*).

Drought, land degradation, and desertification (DLDD) are ecological problems threatening not only the drylands of Mongolia but also forest ecosystems. According to the latest assessment of drought phenomena across the country, almost one-third of the total territory is affected by moderate or severe drought conditions. The hotspots identified by long-term drought monitoring showed that the Central Mongolian transition zone of steppes and dry steppes are the most vulnerable to this disastrous process. Besides the drought assessment, the latest desertification assessment, conducted in 2010, concluded that almost 60% of the steppe region is desertified. In 2008, the first research and experimental center of its kind was established in Elsen Tasarkhai, in the Bulgan region of Mongolia. As a part of its operational program, several technologies have been tested as responses to different kinds of land degradation processes occurring in the region. According to a sociological survey of the local population, such demonstrations positively influence people's land use practices. The center makes it easy for local residents to obtain environmental information anytime and its training programs provide environmental education, thus supporting local initiatives in tackling DLDD-related processes.

Development of a tool for analysing forest owners' strategies to manage risks and adapt to climate change. Jönsson, A. (*Lund University, Department of Physical Geography and Ecosystem Science, Sweden; anna_maria.jonsson@nateko.lu.se*), André, K., Gerger Swartling, Å., Vulturius, G. *(Swedish Environment Institute; karin.andre@sei-international.org; asa.swartling@sei-international.org; gregor.vulturius@sei-international.org*).

Climate change is expected to lead to more climate extremes, which increase the risk of forest disturbances with negative impacts on timber production and biodiversity. Through active choices, many forest management decisions can be taken to reduce the risks. To obtain the best possible basis for decision-making, an active science-practice dialogue is needed on adaptation strategies, model uncertainties, and management of conflicting goals. This study aimed to develop and test a discussion-support tool for analysing forest owners' decision-making strategies regarding risks of climate change, extreme events, pest infestation, and preservation of biodiversity. Through science-stakeholder dialogues with Swedish non-industrial forest owners, potential synergies and conflicts between active, proactive, and reactive risk management strategies in relation to forestry objectives are elucidated. The research shows how forest owners relate to and motivate these strategies in dialogue with scientists. The authors conclude that it is necessary to consider all three types of strategies to achieve the goal of sustainable forestry capable of producing a diversity of ecosystem services.

Too safe to survive: going overboard on free and prior informed consent. Kant, P. (*Institute of Green Economy, India; promode.kant@gmail.com*), Wu, S. (*Chinese Academy of Forestry, China; shuirongwu@126.com*).

Deforestation and forest degradation often result from economic activities that provide sustenance to communities. Policies and programs aimed at reducing resulting emissions could, therefore, deepen poverty and have other unintended social consequences unless properly safeguarded. Free Prior Informed Consent (FPIC) is an important safeguard celebrated for its moral value in recognizing the claims of original people of a land. But morality-based actions suffer from an inherent defect that compels movement towards positions perceived to be even higher in morality even when these positions are against overall public interest and bring little benefit to the communities themselves. FPIC also has the potential of being misused by vested commercial interests by misleading the traditional indigenous institutions, or colluding with their unscrupulous leadership, into withholding consent. This potential for misuse is compounded by the fact that often the traditional institutions are not democratic, tend to exclude women from decision-making, and are reluctant to share opportunities and resources with exogenous groups in their geographical space even when legitimate. The authors analyze examples from Asia to present cautionary and implementable limits on FPIC that can serve to further both REDD+ and the interests of indigenous communities.

Willingness of local communities to participate in REDD+ activities: a case study in communities in forest and forest savanna transition zones in Ghana. Kofie, W., Damnyag, L., Foli, E. (*Forestry Research Institute of Ghana, Ghana; winniekofie@yahoo.com; lawdam@yahoo.com; efoli@hotmail.com*).

This study was carried out to determine the willingness of local communities to participate in REDD+ projects and to explore the preferred form of REDD+ benefits and their distribution. Questionnaires were administered, and a literature review was conducted. The vast majority of the respondents (99%) in the communities were willing to participate in REDD+ projects, with farmers, landowners, traditional rulers, and community and opinion leaders being identified as key beneficiaries. The preferred forms of benefit sharing identified were cash (62.7%), in-kind benefits (10.6%), and a combination of both (22.9%). Most of the respondents (96.1%) indicated that monetary incentives should be given directly to individual households/farmers, 1.7% said it should be given to the community, and 2.1% indicated that it should be given to both households and the community. The authors concluded that at the local level, where activities contribute to deforestation and forest degradation, forest stakeholders are willing to participate in activities that would reduce deforestation and forest degradation and contribute to the enhancement of forest carbon stocks provided they receive commensurate benefits.

Analysis of factors contributing to urban greenspace cooling island intensity in the summer. Kong, F., Yin, H. (*Nanjing University, China; Fanhuakong@163.com; qzyinhaiwei@163.com*).

In this paper, greenspace cooling island (GCI) intensity as a GCI characteristic was first defined, and then multiple linear regression models were established to explore the combined effects of related greenspace pattern and background environment variables on the intensity of GCIs in urban areas. GCI intensity was significantly correlated with the size of the cooling island and its mean temperature. Results indicate that a cooling island is the aggregated result of cooler pixels and such a cooling sink may create an area of lowest temperature in the cooling islands. Multiple linear regression analysis showed that cooling island intensity was affected by the area and spatial arrangement of forest vegetation, as well as by the composition of the cooling island and the adjacent environment. The analysis will help to manage and plan the spatial arrangements of greenspace in cities to mitigate the urban heat environment and help cities adapt to climate change.

Alaska Natives, local knowledge, and climate change. Kruger, L. (*U.S. Forest Service, USA; lindalaska2003@gmail.com*), Powell, J. (*University of Alaska, USA; jim23powell@gmail.com*).

Tlingit people have called Southeast Alaska (USA) home since "time immemorial." Over the years generations have observed—and experienced—a variety of environmental, social, economic, and cultural changes. The authors are interested in what changes they currently are experiencing and how they are responding to those changes. Understanding how they perceive and experience change, how changes have influenced their lives and livelihoods, and how they respond to change may help us better understand, prepare for, and help other local residents prepare for climate change. This study employed in-person conversations with individuals, couples, and small groups in three rural communities in Southeast Alaska. Conversations were recorded and videotaped with permission. Conversations were transcribed and analyzed, and themes were extracted. Findings provide insight into plant and animal species that are culturally important, observed changes ranging from individual species to weather patterns, and insight into how people have responded to change in their past and current adaptation activities. The presentation will include quotations from the participants and a video clip of them speaking in their own words about these topics.

Environmental and economic impact of mangrove deforestation – case study of Vadamaradchy East, Sri Lanka. Kumarasamy, S. (*Norwegian University of Science and Technology, Norway; sasi451@yahoo.com*).

This study was conducted in Vadamarachchi-East in Sri Lanka over 2 months in 2011. Factors contributing to mangrove deforestation within the study area, and resultant impacts from deforestation, were examined. The study found that the main factors that have contributed to deforestation are: long civil wars in the region; poverty, which pushed people to clear the forest to earn income through the sale of firewood and timber; industrial development; increasing demand for farm and settlement land; limited knowledge within the local community; weak government policies and implementation strategies; and natural disasters, especially destruction by the 2004 tsunami. Environmental and economic impacts included loss of income sources, loss of biodiversity, climate change, desertification, conflicts in the use of forest products, and loss of land productivity because of reduced fertility caused by soil erosion. However, strategies have been put in place by the government to ensure the sustainable use of mangrove forest products, though these have not proved successful in reducing deforestation. Recommendations were made to the government and other stakeholders to work together to ensure sustainable use of natural resources, for example by implementing laws and regulations aimed at controlling deforestation.

Addressing climate change adaptation and mitigation through community-based forest management in Nepal. Lamsal, R. (*Ministry of Forests and Soil Conservation, Nepal; ramplamsal@gmail.com*), Kanel, K. (*Resource Identification and Management Society, Nepal; keshavkanel@gmail.com*).

Adaptation and mitigation can complement each other and together can significantly reduce the consequences of anthropogenic climate change. Community Forests (CF) have potential not only at the frontline in mitigation but also in increasing resilience through increased adaptation to major impacts of climate change. Based on case studies using participatory rural appraisal (PRA) methodologies in three CF sites of the Terai Arc Landscape area of Nepal, this study explored the role of CFs in contributing to mitigation and adaptation goals and provides insights into how and why adaptation considerations can be integrated within forest-based mitigation efforts. The study reveals that CF has the potential not only to protect land and people from some of the harmful effects of climate change but also supports community resilience, thus responding to multiple needs. Until recently, adaptation and mitigation have often been considered separately in climate change science, policy, and implementation. The cases demonstrate a strong adaptation-mitigation nexus. Although the contributions of CF to mitigation are well recognized, adaptation has received less attention at national and international levels until now. Therefore, it is imperative for the two actions to be integrated. Finally, recommendations are made on how to address these issues and future strategic considerations.

Ensuring social safeguards: forest use rights of local communities and participatory process of Lombok KPH REDD+ feasibility study in Indonesia. Latifah Endang Sunarya, S., Afifi, M. (*University of Mataram, Indonesia; slatifa23@yahoo.com; mansurafifi@yahoo.de*), Kim, I. (*University of British Columbia, Canada; inae.kim@alumni.ubc.ca*), Bae, J. (*Korea Forest Research Institute, Republic of Korea; forestry@forest.go.kr*), Fisher, L. (*University of Arizona, USA; lafisher@email.arizona.edu*), Kim, Y.

Ensuring indigenous populations' and local communities' rights, knowledge, and participation is an essential element of successful implementation of REDD+ projects. The authors present results from the recently completed Lombok KPH REDD+ feasibility study, in which mechanisms for ensuring social safeguards in REDD+ were explored. Participatory rural appraisal, focus group discussions, and household surveys in 14 administrative villages surrounding West Rinjani KPH were used. The research compares local people's rights, land tenure status, and forest governance institutions under different forest management systems including HKm (community forest) and KPH (forest management unit), and examines a gap between statutory and customary forest use rights. HKm gives rights to the local community to manage a state forest and has a unique mechanism for providing more secure tenure for local farmer groups in Indonesia. Four villages institutionalizing the HKm in forest management had higher land tenure security. Therefore, a few other villages intend to institutionalize HKm although the process takes 3–5 years. Meanwhile, KPH has apparently played an important role in developing formal and informal agreements with local communities to ensure greater social safeguards in managing forest resources.

Ecosystem services and protected areas: contribution of Pendjari National Park to Benin economy. Lawani, A. (*University of Kentucky, USA; abdelawani@gmail.com*).

Using the Pnedjari National Park (in Benin), this study provides additional arguments in favor of protected areas establishment. It shows that the benefits of protected areas go beyond their value to the environment and extend to the local, regional, and national levels. Ten activities have been identified around the Pendjari and the value of their contribution is $5,017,700 (0.07% of the GDP). Tourism, fishing, and game hunting contribute the most, but the profits generated from these activities are unequally distributed among the different players involved. More than 80% of the wealth generated by the tourism industry and almost 99% of revenue from game hunting do not benefit the local population. In contrast, traditional activities such as "Nere" (*Parkia biglobosa*) and Shea chains contribute equally to the livelihood of local residents, especially the poorest. Paradoxically, poaching activities, which violate conservation objectives, are found to be more profitable than beekeeping and organic farming. These findings support the hypothesis that we cannot expect active participation of local populations in protected areas conservation if they cannot reap more attractive and equitable benefits from them.

Social sciences in forestry curricula – experiences at the University of Freiburg, Germany, over 20 years. Lewark, E. (*University of Freiburg, Germany; siegfried.lewark@fobawi.uni-freiburg.de*).

Forestry curricula at universities traditionally include many disciplines/subjects, from natural sciences, technical sciences, and social sciences. Some universities have a traditional focus in subjects from natural sciences, others in technical sciences, with a guiding idea of preparing graduates for a position of a director of a forest district, very often in publicly owned forests. This paradigm was common in Central, Northern, and Eastern Europe. Since the introduction of new study programmes along with the Bologna Process, we have observed a diversification and new guiding ideas and approaches in Europe. In many cases new Master programmes centered around social science subjects have been started. The University of Freiburg, Germany, provides an example of curriculum revision. In 1995 a 5-year forest sciences programme was introduced giving equal time to subjects from natural sciences, technical sciences, and social sciences. When after 10 years Bachelor and Master programmes were introduced, this division of subjects was modified, and an international Master programme, "Master of Environmental Governance," was devoted entirely to social science disciplines. Some experiences with the background and experiences with these sample curricula will be related.

Research on present status of sustainable livelihood of workers' families in China's key state-owned forest region. Liang, Y., Zhu, H., Cao, Y. (*Northeast Forest University, China; 3259468@qq.com; 1512678643@qq.com; cyklk@163.com*).

China's key state-owned forest region refers to the Heilongjiang, Inner Mongolia, Jilin, Xingan, and Changbai Mountain forest sectors, also known as the northeast Inner Mongolia key state-owned forest region. In recent years, this forest region has experienced a transformation from timber production base to ecological functional area. Key state-owned forest household workers are a special group different from the peasants and urban workers. This study found that living conditions of the key state-owned forest region residents are better than those of farmers in the same area, but there is great disparity compared with urban residents. Forest resources were found to contribute little to household income, and there is still great potential for income generation from the forest. Findings revealed a heavy economic burden on these families. The population shrank noticeably in these regions. The authors' suggestions to policy-makers are as follows: (1) to invest more in the key state-owned forest region and to devote more attention to it, (2) to encourage residents to stay in these regions by some preferential policies, and (3) to make full use of the forest land resources, thereby increasing household income.

Enhancing community livelihoods through nature-based enterprises: the case of Matinyani women group, Kitui, Kenya. Lishindu Chiteva, R., Mayunzu, O., Wachira, N. (*Kenya Forestry Research Institute, Kenya; rchiteva@yahoo.com; omayunzu@gmail.com; normanwachira@yahoo.com*).

Nature-based enterprises (NBEs) are ventures that can be used to support biodiversity utilization, conservation, and equitable benefit sharing from derived resources. This paper highlights the potential of NBEs in enhancing community livelihoods in Kenya, with specific emphasis on Matinyani Enterprise in Kitui. In 2010, the 60-member group received both theoretical and hands-on training by Kenya Forestry Research Institute (KEFRI) in product development and setting up and registering an enterprise with the Ministry of Sports, Culture and Arts. The training included propagation, processing, and value addition of *Tamarindus indica* fruit for jam, juice, and wine. Frequent monitoring is done by KEFRI to ensure adherence to Kenya Bureau of Standards regulations and to maintain the quality of products. Evidence of the adoptability of the technologies and of improvements in group members' livelihood includes: increased awareness of sustainable utilization and conservation of indigenous fruit trees (IFTs), value-added indigenous fruit products being sold locally, and a small saving scheme "merry-go-round." A challenge remains with the adoptability of the propagation techniques because of the long time indigenous fruits take to mature. Therefore, there is a need to fast-track research in this area.

Páramos as changing ecosystems: a multi-temporal analysis of perceptions on the change of páramo areas in the delimitation process, Colombia. Lopez Gomez, C. (*Universidad Nacional de Colombia, Colombia; cplopezg@unal.edu.co*).

Multi-temporal analyses involving socioeconomic and cultural information were used to define the change of relationships between the population and protected high-altitude *páramo* areas as well as natural resources in the territory. The study aimed to identify the major changes in the areas in the course of the delimitation process in order to define the historical and cultural relationships between people and traditional or technologically advanced production systems and technologies that are being applied by the communities of the surrounding region within the jurisdiction of the local environmental Corporation of Corantioquia. It evaluated the impact of these production systems and technologies on the biodiversity and ecosystem services of *páramos*, and also defined sociocultural parameters that can be linked with physical and biotic criteria for the delimitation of *páramo* areas. The results highlighted the challenges and limitations of the participatory process and criteria for inclusion of the population in managing and transforming protected areas of high social value (e.g., the *páramos*) because of their importance for the provision of ecosystem services such as water. In addition, the current pressures on these ecosystems in the Department of Antioquia, Colombia, are evaluated, and the relationship between actors as the main axis for making decisions on protected areas, is analyzed.

Survival analysis in plantations of *Araucaria angustifolia* (Paraná pine) derived from seedlings and seeds. Maran, J. (*Federal University of Paraná, Brazil; jess.maran@gmail.com*), Rosot, M., Radomski, M. (*EMBRAPA, Brazil; augusta_rosot@hotmail.com; maria.radomski@embrapa.br*), Kellermann, B. (*Federal University of Paraná, Brazil kdbetina@hotmail.com*).

The forest type most characteristic of southern Brazil is the Araucaria forest, strongly marked by the presence of Paraná pine (*Araucaria angustifolia*). Overexploitation of this species reduced its range to 2% of its original area. A research project developed by EMBRAPA Forestry is concerned with the planting of *A. angustifolia* on small farms as a strategy for the conservation of the species and as an economical alternative to the producer. Therefore, an experiment was conducted to evaluate germination, survival, and predation rates of seeds and seedlings of *A. angustifolia*, analyzed as a completely randomized unbalanced factorial design with two factors (type of plantation: pure/mixed; raw material: seeds/seedlings), for a total of three treatments, with three replicates each. Fourteen months after planting only 17% of the seed spots contained live plants; 14% of planted seedlings survived. About 9% of the seeds did not germinate, and 60% were consumed by animals. Seedling mortality was 59% in the "pure" treatment and 80% in the mixed treatment. In the mixed treatment, seed losses due to fauna attack were lower (42%) compared to the "pure" treatment (69%); the opposite pattern was observed for seedlings.

A comparative analysis of global stakeholders' perceptions of the governance quality of the CDM and REDD+. Maraseni, T. (*University of Southern Queensland, Australia; tnmaraseni@hotmail.com*), Cadman, T. (*Griffith University, Australia; cadman@gu.edu.au*).

This paper provides a quantitative and qualitative analysis of global level stakeholders' perceptions regarding the governance of the clean development mechanism (CDM). The research conducted via an anonymous online survey, using a normative framework of principles, criteria, and indicators. It compares these findings with the results of a similar survey conducted by the authors on REDD+. Stakeholders from both the global North and the global South were asked to rate the quality of these mechanisms against 11 performance indicators, using a scale from "very low" to "very high" (1-5). Overall, the results from CDM stakeholders from both the global North and global South were very similar. The highest and lowest total scores were obtained from the institutional and social stakeholders, respectively. These results demonstrate that these two groups have considerable differences in perceptions. CDM failed in two indicators, "equality" and "resources," and passed marginally in all other nine indicators. The performance of REDD+ was much higher than CDM in all aspects of governance surveyed. The major differences were in "equality" and "problem solving." If the CDM is to be continued in the post-Kyoto period, some major systemic changes in governance are necessary, and some lessons can be learned from REDD+.

International Masters in Wood Energy: an EU project for developing higher education in the bioenergy sector. Marchi, E. (*University of Florence, Italy; enrico.marchi@unifi.it*), Tasanen, T. (*Seinäjoki University of Applied Sciences, Finland; Tapani.Tasanen@seamk.fi*), Jager, L. (*University of West Hungary, Hungary; jagerla@emk.nyme.hu*), Bonet, J. (*University of Lleida, Spain; jantonio.bonet@exchange.ctfc.es*), Picchi, G. (*National Research Council* (*CNR), Italy; picchi@ivalsa.cnr.it*), Navarro i Maroto, P., Smith, M.

The EU has set very challenging goals for the partial replacement of fossil fuels with renewable energy by 2020. In many EU countries forests are the main source of renewable energy and wood energy is booming all over the continent. Technologies for woody biomass production, transportation, and energy conversion are rapidly expanding both inside and outside the EU. In this

context highly trained professionals who understand and can apply the latest technology, international trade rules, and environmental frameworks, are essential to secure practical and sustainable development solutions in wood energy production. This challenge has been addressed by six higher educational institutions and bioenergy research organizations from across Europe. The consortium, in the framework of the EU Erasmus Multilateral Programme, is developing a masters program for educating experts in wood energy production, trade, and transportation as well as modern research and development methods, within the EU and globally. The relevant stakeholders in the sector of wood energy had been interviewed by means of a questionnaire and online survey to better understand their view of this sector and which skills they consider essential in master of science professionals. The outcomes of the survey are here analyzed and the resulting structure of the masters curriculum is described.

Decision-support tools for sustainable rural development: the case of the alpine area of Como Lake, Italy. Martire, S. (*European Forest Institute, Finland; salvatore.martire@efi.int*).

Local policies aim to merge the needs of local communities with the objectives of multi-level regulations. For European rural areas, the role of forests in leading rural development is growing, as emphasized by the EU Forestry Strategy 2013, and their role as a source of fuel is well-known. Usually, economic feasibility is the main constraint for developing local energy facilities. Indeed, developing sustainable forest-energy chains is crucial to preserving ecosystem services and overall environmental quality, thus ensuring social and economic benefits. Decision-making should be supported by assessment tools able to consider different aspects related to the sustainability of processes. This paper aims to illustrate how sustainability impact assessment and carrying capacity evaluation can synergistically lead decision-making processes through exploration of tradeoffs between multi-functionality of forests and needs of natural resources. Specifically, this assessment aims to support the planning of a local bioenergy chain in the alpine area of Como Lake, where local authorities believe that developing bioenergy chains can lead the development of rural areas. The main challenge has been to deal with fragmentation and inconsistency of data. Nevertheless, it has been possible to get useful results for local decision-makers to get a big picture of the forestry sector and valuable quantitative information on different energy development scenarios.

Fear of crime in urban parks—Do age, gender, and ethnicity makes a difference? Maruthaveeran, S. (*University of Copenhagen, Denmark; sree@life.ku.dk*), Arnberger, A. (*University of Natural Resources and Life Sciences (BOKU), Austria; arne.arnberger@boku.ac.at*), van den Bosch, C. (*University of Copenhagen, Denmark; cck@life.ku.dk*).

Although the many benefits of urban green spaces are usually emphasized, these environments also provide some disservices. For example, encounters with natural threats may evoke strong fear or other negative emotions. However, very few studies have examined the negative emotions associated with urban green spaces, particularly regarding social danger, such as fear of crime. This questionnaire survey (N=657) was conducted in the city of Kuala Lumpur, Malaysia, in an attempt to examine the effects of different age, gender, and ethnic groups on fear of crime in urban park settings. Manipulation of the environmental and social cues was represented via photographs created using Adobe Photoshop 6.0 software. Respondents were requested to view a set of 12 manipulated photographs and rate their perceived threat for each photograph by using a seven-point Likert scale. Analysis of descriptive statistics showed that photos with evidence of social disorder (for example, graffiti, trash, low maintenance), with high levels of concealment, and without the presence of other people were considered the most fear evoking. Photos without the presence of physical disorder, with low concealment, and with the presence of others were considered less fear evoking. The results of the independent t-test revealed that female respondents were significantly more likely to feel fearful than male respondents ($p < 0.001$). No difference was found between different age and ethnic groups. The subsets of respondents in each age and ethnic group are too small to justify detailed analysis of the results.

Perceived personal safety in urban parks through the eyes of urban park users of Kuala Lumpur. Maruthaveeran, S. (*University of Copenhagen, Denmark; sree@life.ku.dk*), Arnberger, A. (*University of Natural Resources and Life Sciences (BOKU), Austria; arne.arnberger@boku.ac.at)*, van den Bosch, C. (*University of Copenhagen, Denmark; cck@life.ku.dk*).

Although the many benefits of urban green spaces are usually emphasized, these environments also provide some disservices. For example, encounters with natural threats may evoke strong fears or other negative emotions. However, very few studies have examined the negative emotions occurring in urban green spaces, particularly regarding fear of crime. This study attempted to examine the effects of environmental cues and social cues on fear of crime in urban park settings. Manipulation of the environmental and social cues was represented via photographs created using Adobe Photoshop 6.0 software. Respondents were requested to view a set of 12 manipulated photographs in an urban park setting. As they looked at each scene, they were asked to imagine that they were actually in that setting walking alone and moving towards the situation in the photograph. The respondents were then asked to rate their fear of crime for each photograph by using a seven-point Likert scale. Analysis of data based on the Fisher and Nasar model (1992) found that photographs with lower levels of potential refuge and with the presence of disorder (for example, graffiti, lack of maintenance) appeared to be perceived with more fear. However, the presence or absence of people (social cues) in the photographs seems not to have any effect on the fear of crime.

Carrying capacity approach to forest management in developing countries. Masuda, M., Iwanaga, S. (*University of Tsukuba, Japan; masuda.misa.gm@u.tsukuba.ac.jp; iwanagasage@yahoo.co.jp*), Shiga, K. (*University of Tokyo, Japan; shiga@anesc.u-tokyo.ac.jp*), Prasetyo, L., Damayanti, E. (*Bogor Agricultural University (IPB), Indonesia; lbprastdp@yahoo.com; e11yn.d4mayanti@gmail.com*).

Demands on forests and forest land have been transformed by changes in external conditions such as economic globalization. Human impacts on forest ecosystems caused by commercial motivations have become common aspects in rural societies of developing countries, and conventional forest dependency models like non-timber forest products (NTFPs) for subsistence should be examined in present-day contexts. As forests decrease in size and deteriorate and the population continues to rise, holistic approaches to forest management, particularly in developing countries, are called for. This report focuses on carrying capacity of forests and presents an estimation how many people can be economically supported by a unit area of forest. Because the longer value chain in forest products compared to agricultural products makes such estimation difficult, the authors applied a raw

material production model to micro-scale forests and surrounding societies. An example was selected from long-rotation teak plantations and another was from short-rotation plantations. Both examples were in Java Island, which faces extremely high population pressure. The results suggested that multiple uses of forest resources and forest land could increase carrying capacity, yet the current situation shows the local community's dwindling dependence on NTFPs.

Implementing REDD+ in community managed forests: lessons from India. Mehra, S., Reddy, M. (*Iora Ecological Solutions, India; swapan@ioraecological.com; mohan@ioraecological.com*).

This presentation explores how REDD+ and potentially other payments for ecosystem services (PES) mechanisms can be integrated into community-based forest management to reward conservation and increase in forest cover. The presentation proposes a governance-, benefit-, and responsibility-sharing model which demonstrates how different stakeholders including the communities, forest departments, investors, and community-based organizations (CBOs) will interact to ensure the success of a project. The project proposes a multi-tiered framework to ensure cost-effective monitoring of carbon and non-carbon benefits from a project. These benefits include biodiversity and community benefits. The presentation uses information from case studies in Garo Hills, Meghalayal; Kohima, Nagaland; Tilari Region, Maharshtra; Shimoga, Karnataka; and other areas where the authors are engaged in developing pilot REDD+ projects in partnership with various CBOs, national and international agencies, and forest departments.

Linking quantitative projections and qualitative scenario methods for modeling ecosystem services from forest landscapes. Mozgeris, G. (*Aleksandras Stulginskis University, Lithuania; gintautas.mozgeris@asu.lt*), Brukas, V. (*Swedish University of Agricultural Sciences, Sweden; Vilis.Brukas@slu.se*), Kavaliauskas, M. (*Aleksandras Stulginskis University, Lithuania; marius.kavaliauskas@asu.lt*).

This study explored methodological as well as applied aspects of linking qualitative methods of scenario planning with forestry decision support tools, via modeling the behavior of involved private forest owners and state forest managers. The study is illustrated with results from two case study areas in Lithuania that are part of the EU FP7 project "Future-oriented integrated management of European forest landscapes" (INTEGRAL). The case areas differ substantially in biophysical and social characteristics, e.g., trees species distribution, ownership structure, and role of forests in the local economy. Four alternative possible future scenarios will be developed for each case area, envisioning different trajectories of multiple factors, including forest product markets, European and national policies, and silvicultural paradigms. Next, the Lithuanian large-scale forestry scenario model "Kupolis" will be adapted to perform a kind of agent-based modeling, reflecting potential behaviors of different types of forest owners or managers. Even though wood products currently have a very high market value, the potential values of carbon sequestration, recreation, environmental protection, and water will be assessed. Outcomes under the various scenarios will allow potential combinations of ecosystem services as well as alternative mixes of forest policy instruments to be evaluated.

GIS and monitoring of urban forests in Boa Vista, Roraima, Brazil. Neto, E.L., Reisq, F., Pinheiro, F. (*State University of Roraima, Brazil; everaldo.limaneto@gmail.com; flr_77@hotmail.com; flavia_abreu@hotmail.com*), Batista, D.B. (Federal University of Paraná*, Brazil; dbiondi@ufpr.br*).

The lack of planning for urban forests is common in Brazilian cities. The objective of this research was spatially registering the existing trees on the streets of the city of Boa Vista, through GIS. The authors traveled all the streets of the city, in order to collect points using GPS and measure the area of the tree canopy. It was observed that 73% of the streets have some type of pavement or urban infrastructure basic conditions. Use of GIS indicated that about 40% of the streets and blocks analyzed showed conditions suitable for trees along sidewalks. The area of the tree canopy was 0.15 mile^2. The relationship between crown area and the area of city sidewalks indicated that at least 7,000 trees could be planted along sidewalks, to meet aesthetic, ecological, and social needs. It was found that GIS provided spatial analysis of the distribution of trees in the municipality and provided information about neighborhoods with a deficit or surplus of trees. Thus, it is confirmed that the application of GIS is useful to support the implementation and monitoring of urban forests.

Determinants and global patterns of bushmeat hunting. Nielsen, M., Pouliot, M., Meilby, H., Smith-Hall, C. (*University of Copenhagen, Denmark; mrni@ifro.ku.dk; mapo@ifro.ku.dk; heme@ifro.ku.dk*), Angelsen, A. (*Norwegian University of Life Sciences, Denmark; arild.angelsen@umb.no*).

Bushmeat hunting is considered the main threat to conservation of biodiversity in tropical forests but simultaneously represents an important source of protein and income to innumerable rural households in the developing world. Many policy recommendations focus on creating alternative income-generating opportunities for hunting households as the main strategy for reducing the commercial bushmeat trade. However, results of existing studies are ambiguous, and the effect of the opportunity cost of labor on hunting has not been empirically investigated on a global scale. Similarly, there are contradictory results on how poverty, market access, and macro-economic conditions and stability influence bushmeat trade. Here the authors use the global Poverty and Environment Network (PEN) dataset containing more than 8,000 households in 35 tropical countries to investigate the socioeconomic, demographic, and geographical correlates of bushmeat subsistence and cash income and how the opportunity cost of labor affects bushmeat income. A probit model was used to examine household characteristics, and a mixed model was used to incorporate the panel data structure to analyze the relationship between bushmeat hunting and opportunity cost of labor. The results uncover information on the driving factors of the bushmeat trade, thereby facilitating design of management strategies without compromising rural livelihoods and food security.

Desired forest futures of forest sector stakeholders in Sweden. Nordin, A. (*Swedish University of Agricultural Sciences, Sweden; Annika.Nordin@slu.se*).

The Future Forests interdisciplinary research program explores pathways forward for the Swedish forest sector in a time characterized by change. During early 2014 this program will do a scenario-analysis involving four categories of stakeholders.

The methodology will be back-casting to explore desired forest futures for 2060 of four major categories of stakeholders. They are defined based upon differences in fundamental ideas of future forest use: (1) forest for production, (2) forest for conservation, (3) forest for indigenous people's heritage (e.g., reindeer herding), and (4) forest for recreational needs and rural tourism business opportunities. The back-casting methodology allows for decoupling futures from current trends, and enables definition of alternative pathways. Hence, stakeholders may move outside prevailing paradigms and ignore dominant trends. In the process, stakeholders' concepts, attitudes, and values will be studied. This presentation shows the four desired forest futures resulting from the back-casting analysis. In particular, similarities and differences of the desired futures will be highlighted. The presentation will also identify tradeoffs and choices that have to be made by society in a discussion of possible pathways forward to a common desired forest future.

Anchor forests: a multi-ownership pilot project in eastern Washington, USA. O'Laughlin, J. (*University of Idaho, USA; jayo@uidaho.edu*), Andringa, S. (*Yakama Nation, USA; steve@yakama.com*), Gervais, B. (*Northwest Advanced Renewables Alliance, USA; gervaisbreanna@gmail.com*).

An "anchor forest" is a multi-ownership land-based area capable of supporting sustainable long-term wood and biomass production levels backed by local infrastructure and technical expertise, and endorsed politically and publicly to achieve the desired land management objectives. It is a landscape-scale collaborative approach to active forest management with three main goals: restore infrastructure capacity, coordinate management across ownerships, and provide economic benefits. The Intertribal Timber Council, with U.S. Forest Service funding, is conducting a pilot project test of the concept in three areas of eastern Washington that include forest lands on four Indian reservations. The Yakama Nation, with 1.3 million acres of prime forest, grazing, and fertile farm lands in south central Washington state (USA), is the first part of the test. Team members include U.S. Forest Service and Washington Department of Natural Resources representatives and researchers from the University of Washington, The Nature Conservancy, and the University of Idaho. Progress to date will be highlighted, including resource assessment, collaborative cross-ownership strategies, and identification of barriers to meeting goals and management objectives.

Morphological assessment of *Parkia biglobosa* accessions from different agro-ecological zones in Nigeria. Onilude, Q., Akinyemi, O., Julius, A. (*Forestry Research Institute of Nigeria; omoonilu@yahoo.com; akinyemi77@yahoo.com; talktobayo247@yahoo.com*), Oduola, M. (*Federal College of Forestry, Nigeria; abilacrown@gmail.com*), Ogunremi, O. (*National Biotechnology Development Agency, Nigeria; sijiogunremi@yahoo.com*).

Twenty-nine accessions of *Parkia biglobosa* were collected from different agro-ecological zones in Nigeria to quantify the extent of morphological variation existing within the accessions. A completely randomized design was used with four replicates and five seedlings per pot for the 29 accessions. Morphological variations were evaluated by ANOVA, cluster analysis, principal component analysis (PCA), and Pearson correlation coefficients. Characters inferred showed differences across the accessions, except for a few variables, such as primary leaflets on cataphyll, stem girth, and root dry weight. Cluster analysis indicated the existence of three groups separating the species and revealing intra-specific variation within the accessions. An acceptable solution for PCA was reached when three dimensions of the model were found to be significant and explained 77% of the total variance of the original variables. Low genotypic and high phenotypic coefficient of variation was observed for all the characters measured. Overall highest value of genetic coefficient of variation was noticed in height of seedling, followed by average number of secondary and primary leaflets on seedling, average number of leaves on seedling, root dry weight, cataphyll length, cataphyll width, and fresh and dry weight of shoot.

Assessment of honey and its utilization on the rural livelihoods in the rainforest ecological zone of Nigeria. Onilude, Q., Oyeleye, B., Julius, A. (*Forestry Research Institute of Nigeria, Nigeria; omoonilu@yahoo.com; bolarinwa_oyeleye@yahoo.co.uk, talktobayo247@yahoo.com*, Ogunremi, O. (*National Biotechnology Development Agency, Nigeria; sijiogunremi@yahoo.com*), Oniroko, N., Jegede, O. (*Forestry Research Institute of Nigeria, Nigeria; onirokoniyi@yahoo.com; opeyemijegede@yahoo.com*).

The objective of this paper was to assess the impact and utilization of honey as a non-timber forest product on rural livelihoods in Iwo local government areas of Osun state situated in the tropical rainforest ecological zone of Nigeria. A pre-tested questionnaire was administered to 20 household heads from five villages selected using simple random sampling technique. Information collected included level of awareness of and willingness for successful adoption and integration. Results obtained indicated that the respondents' occupation included farmers (38.5%), civil servants (18%), traders (38%), and traditional healers (6.5%). The result of the descriptive and inferential test statistics showed that the perception of respondents on importance and uses of honey in the study areas varied. The major constraint discovered was that the traditional healers lacked quality control measures and did not have a standard way of measuring how much honey to use to treat different ailments. Honey production is predominantly an activity of rural people and can create employment, reduce poverty, and generate income, thus discouraging them from moving to urban areas for unavailable white collar jobs. Recommendations were also suggested based on the study.

Determinants of unwillingness in private forestry in the humid zone of Nigeria. Onyema, M. (*Federal University of Technology, Nigeria; mac-anthony.onyema@futo.edu.ng*), Azeez, I. (*University of Ibadan, Nigeria; azeezismail2000@yahoo.com*).

Public sector dominance of forestry across the globe impedes realization of local and international forestry targets despite huge local and international investments in the sub-sector. Groups and individuals with stakes in forestry were identified through stakeholder analysis across selected rural and urban communities in the study area. Relevant information was obtained using a set of questionnaires and supplemented with focus group discussions. Baseline data on household forestry-based activities were presented in the form of a checklist, and further analyses of data used Chi-square test of independence and logit regression models. Unwillingness by indigenous residents and local-based farmers was significantly influenced by household size and conservation awareness. Traditional/religious leaders and landlords (landowners) in both communities surveyed correspondingly expressed resistance to promulgate or support forestry/conservation issues or practices. Local-based farmers and indigenous residents in rural areas manifested inherent fear of any land use change because of prevalent local norms and institutionalized

practices in these areas. A robust and integrated grassroots approach towards a review of institutions and orientations of different categories of stakeholders is a step to develop an adaptable plan and synergy to encourage private sector forestry entrepreneurship.

Community perspectives for cacao-based agroforestry development in Camalig, Albay Province in the Philippines: an application of Q methodology. Paras, F. (*University of the Philippines, the Philippines; fdparas@gmail.com*), Rahman, S. (*Center for International Forestry Research (CIFOR), Indonesia; sumonsociology@yahoo.com*).

Albay province is considered to be the "Vatican of Disasters" in the Philippines due to the frequency of natural phenomena like typhoons, landslides, and volcanic eruptions in the area. However, amidst the threats aggravated by climate change, the province has a local government that is one of the most progressive in climate change mitigation and adaptation. As an adaptive management mechanism, a proposal for establishing a cacao-based agroforestry project in the community of Camalig, Albay, is being piloted in order to simultaneously address reforestation, climate-change adaptation, and poverty in the area. In this paper, the suitability of cacao-based agroforestry as a social enterprise, an adaptive management mechanism, and livelihood opportunity for the local community is assessed through key informant interviews, focus group discussions, and the application of Q methodology in analyzing community perspectives.

Valuing recreation for New Zealand's planted forests: moving beyond traditional timber economics towards achieving multi-purpose forests. Pizzirani, S., Yao, R., Lerouxdebretagne, F., Harrison, D. (*Scion, New Zealand; stefania.pizzirani@scionresearch.com; richard.yao@scionresearch.com; fanny.lerouxdebretagne@scionresearch.com; duncan.harrison@scionresearch.com*).

Forest recreation in New Zealand is a growing, multi-million dollar industry. Yet there is limited understanding of the economic value of a forest recreational visit for the tens of thousands of forest users in New Zealand. This study aims to examine the values and preferences of recreationists in New Zealand forests with high visitation rates. The objectives of the study were to: (1) estimate the economic value of recreation in forests; and (2) identify recreational preferences. To achieve these objectives, this research developed and implemented a nationwide survey using the travel cost method, the contingent behaviour method, and the Delphi method. Survey results indicated that for planted forests with high visitation rates, the economic benefits of recreation can exceed timber revenue. Furthermore, using identified recreational preferences, a matrix of potential economic value was developed which can be used when considering the development of a new forested area. This matrix was integrated with GIS to spatially identify land area suitable for both timber production and recreation. This research has allowed the authors to assess not only current economic benefits of forest recreation but also to optimise the socioeconomic potential of developing new forests.

Efficient and effective control of bark beetle outbreaks in a community forest of Oaxaca, Mexico. Poloni, A. (*Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional Unidad Oaxaca, Mexico; adrian_poloni@live.com*), Duran, E. (*Instituto Politecnico National (CIIDIR-Oaxaca), Mexico; eduran3@hotmail.com*), Cruz Avilés, J., Maldonado Arango, O. (*Comisión Nacional Forestal, Región V-Oaxaca, Mexico; jucruz@conafor.gob.mx; olivia.maldonado@conafor.gob.mx*).

In recent years climate change has appeared to increase forest pest outbreaks, which can cause economic impact to the timber industry and alter the capacity of forests to provide environmental services. Current management models around the world for controlling forest pest outbreaks, such as those for *Dendroctonus* species, include varying levels of participation from government, industry, and other actors. Between 2007 and 2012 Mexico's National Forestry Commission (CONAFOR) detected 210 forest pest outbreaks throughout the state of Oaxaca; CONAFOR and 64 communities collaborated effectively to carry out forest management measures that reduced and almost eliminated many of the damaged forest patches. The governing institutions of community forests are essential in facilitating rapid, effective, and relatively economical forest health measures that address and control forest pest outbreaks. The community forests in Oaxaca have been recognized for their contribution in avoiding deforestation and promoting conservation; however, their crucial role in facilitating forest health measures goes unacknowledged. These cases offer successful examples of multi-scale governance, where local communities in forest resources are assisted by forestry professionals and state and federal agencies to execute efficient and effective management that promotes forest health. With the potential increase of forest pest outbreaks, more attention and support must be given to this trio of stakeholders.

Risnjak National Park: visitor vulnerability on the Leska educational path and suggestions to avoid unfortunate outcomes. Poštenjak, F. (*Independent, Croatia; fran.postenjak@gmail.com*).

National parks are places of significance that preserve natural landmarks. Risnjak National Park in Croatia was established mainly to protect its forests, which need to be preserved in unaltered form for future generations. Almost all (>98%) of the Leska educational path in the park goes through forest communities that have not been managed in any way over the past few decades. As a result trees representing a variety of hazards, such as deadwood, rotten trees, lightning-damaged trees, fungi-infected trees, and drywood, are found along the path. Visual tree assessment was conducted along the same portion of the path on two occasions in summer 2011 and in summer 2013. Most hazard trees found along the path were in zone A (50%), and the fewest were found in zone B (23%). Trees in the "3" hazard category were most common (40%) and those in the "2" hazard category were least common (27%). Contingent valuation method-willingness to pay was conducted between April and October 2013. Based on survey results it would be acceptable to raise the entrance fee for Risnjak National Park if the additional income would ensure visitor safety, infrastructure enhancement, and establishment of new activities. The visual tree assessments conducted on the Leska educational path indicate that visitor safety is at risk and that hazard sources should be removed.

Relevance of REDD initiatives for local communities in a low biomass forest: case of tapia woodland, central part of Madagascar. Rakoto Ratsimba, H., Rabemananjara, Z., Rabefarihy, A. Rabenilalana, F (*Université d'Antananarivo, Madagascar; rrharifidy@moov.mg; zorabema@hotmail.com; yrihat@gmail.com; rmihajamanana@yahoo.fr*), De Haulleville, T. (*Université de Liège-Gembloux Agro-Bio Tech, Belgium; tdehaulleville@doct.ulg.ac.be*), Bastin, J., Bogaert, J., Ramamonjisoa, B.

The success of the REDD initiative will depend on full involvement of local communities in the sustainable management of forest resources. In this sense, four key points need to be analyzed: (1) how to determine the available biomass in the *tapia* woodland, (2) trends of deforestation and degradation, (3) locations of these processes, and (4) needs of local communities in forest resources. This study combines multi-temporal remote sensing analysis integrating high resolution sensors combined with an inventory of biomass in the field with a stratified systematic random sampling at the forest level (forest class), and a socioeconomic study to identify the actors of deforestation/degradation and analyze their consumption practices of forest timber products. These analyses demonstrated that the *tapia* is a low biomass forest with an average of 20 ± 2 Mg/ha of dry biomass. Anthropogenic pressure on *tapia* woodland is high and is characterized by a continuous deforestation (a rate of 3% between 1990 and 2000 and 7% between 2000 and 2005). The surveys confirmed this trend and showed that local communities are the major actors of deforestation, mainly by firewood harvesting, charcoal production, construction, and conversion of forest land to cultivated land.

Integrating social science research class into the forestry curriculum: a case study of Forestry Engineering Program in Colombia. Rodriguez, S. (*Universidad Autónoma de Chihuahua, Mexico; sandra_osu@yahoo.com*), Villarraga, L. (*Universidad Distrital, Colombia; lizfvf@yahoo.es*).

Community-based sustainable forest management implies a commitment to understanding local sociocultural and economic aspects associated with resource management. Studies have shown that traditional knowledge is essential for forest management. Consequently, efforts have been done to encourage participatory practices to strengthen collaborative outcomes. However, little has been said about the challenges facing facilitators or professional foresters when communicating with forests' owners and indigenous populations of the forests. This study aims to investigate to what extend is the social dimension included in the forestry curriculums. An in-depth review of the undergraduate curriculums and class's syllabus with social component is conducted to determine the state of the art of the social dimension in those curriculums. A survey of 27 questions is administered to senior undergraduate students, professors, and professionals to explore the challenges faced when working with small-scale forests' owners and to assess perceptions about the importance of including formal classes on qualitative and quantitative social research. Data collection is in progress.

Forest research institutions and Caçador Model Forest: integrating local knowledge and scientific approaches to enhance rural livelihoods in Southern Brazil. Rosot, M. (*EMBRAPA, Brazil; augusta_rosot@hotmail.com*), Kellermann, B. (*National Council for Scientific and Technological Development* (*CNPq), Brazil; kdbetina@hotmail.com*), Radomski, M., Lacerda, A., Garrastazu, M. (*EMBRAPA, Brazil; maria.radomski@embrapa.br; andre.biscaia@embrapa.br; marilice.garrastazu@embrapa.br*), Cardoso, D. Mattos, P., Muñoz-Braz, E., Rosot, N., Oliveira, Y.M.

Though very restrictive, environmental laws—which prohibit any kind of management for timber production in Araucaria forest in southern Brazil—fail to prevent its conversion to other more profitable uses, mainly agriculture and livestock. Therefore, EMBRAPA Forestry, the forest branch of the Brazilian Agricultural Research Corporation, is putting much effort into demonstrating that the management of native forests can not only rehabilitate ecosystem functions but also contribute to increased rural incomes through alternative uses of forest resources. As a strategy to implement this paradigm shift, EMBRAPA has undertaken a 5-year process to create a model forest in the region of Caçador (Santa Catarina State), which features the typical landscape pattern of Araucaria forest remnants, including forest patches, crops, pasture, industrial areas, and urbanized areas as well as forest plantations. Despite an economy based on the service sector, commerce, agriculture, and a strong forest-based industry, the region has a low Human Development Index, poor income distribution, and environmental liabilities. Aiming at enhancing rural livelihoods within the model forest, EMBRAPA and other research institutions are developing projects that integrate the community's practical knowledge and scientific methods concerning sustainable forest management through participatory field-level methodologies, as well as facilitating cross-sector relationships involving forestry and agriculture.

Forest offenders become the protector of the forest: a case study from inland Sal forest, Bangladesh. Sadath, M. (*Khulna University, Bangladesh & Georg August University, Germany; mnsadath@yahoo.com*), Islam, M. (*University of Queensland, Bangladesh; wasiulislam7@yahoo.com*).

Forest encroachment by local forest users and indigenous people has been the root cause of inland Sal forest destruction in Bangladesh. The Madhupur National Park and adjacent forest areas have lost biodiversity and vegetation cover. Until 2008, frequent burning and illegal logging were common under the policing type of traditional forest management by the forest administration. This study examined the change in forest biodiversity and number of forest offences in the Madhupur region before and after implementation of the innovative Bangladeshi co-management model. Quantitative and qualitative content analysis, followed by interviews of relevant stakeholders, was used to analyse the social and political aspects of this forest area. Regeneration and forest biodiversity were assessed in 2006 and 2013. The study found that the status of forest vegetation and biodiversity improved, and the number of forest violations has decreased, dropping from 276 offences in 2003–2004 to only 23 in 2011–2012. This study shows that when the forest offenders were made the protector of the forest in the Madhupur region, the co-management strategy was successful.

Evaluation of the tree mortgage system in traditional agroforestry management in Moluccas, Indonesia. Salampessy, M. (*Pattimura University, Indonesia; meis_forester@yahoo.com*), Febryano, I. (*Lampung University, Indonesia; indragumay@yahoo.com*), Suharti, S. (*Ministry of Forestry, Indonesia; suharti23@yahoo.co.id*).

The agroforestry system in land management has been carried out traditionally by the societies in Maluku, Indonesia. The practice is known as "Dusung," and one of the plants cultivated is nutmeg. Although currently world demand for nutmeg is extremely high, this demand has no effect on farmers' welfare. Farmers face a number of problems, one of which is a system of debt bondage that causes heavy losses to farmers. This study aims to explain the involvement of farmers with the debt bondage system, namely "the tree mortgage system." The method used in this research is a case study, where data are collected by interviewing and observing participants. The collected data were analyzed using principal agent theory. The results showed that

nutmeg farmers have a high risk of debt bondage due to exploitive and unethical treatment by bond agents. This can occur, for example, when agents use their knowledge of nutmeg marketing prospects (i.e., prices) to pay unfairly low prices to farmers. Farmers are also required to mortgage the nutmeg tree with a particular agent, through loans provided by the agent, which puts farmers in a weak and disadvantaged position.

Promoting community forestry in a REDD+ context: a global analysis of small-scale forestry enabling environments in 44 developing countries. Sanchez Badini, O. (*University of British Columbia, Canada; olivia.sanchez@alumni.ubc.ca*).

Small and medium forest enterprises, including community forestry, are common business models in the context of forest-dependent economies in developing countries. Because these enterprises can contribute to the achievement of REDD+ goals through conservation and sustainable use of forests while simultaneously improving local livelihoods, it has been proposed to use a portion of the REDD+ readiness efforts to promote national enabling environments for fostering the development, growth, and success of these enterprises. Using an evaluative framework created from an extensive literature review on the subject of small-scale forestry enabling environments, this work used qualitative content analysis to explore the breadth and depth of national-level support for external and internal elements of success for small and medium forest enterprises. The study focused on 60 REDD-readiness Forest Carbon Partnership Facility (FCPF), Climate Investment Funds (CIF), and UN-REDD documents from 44 different developing countries in Latin America and the Caribbean, Africa, and Asia-Pacific. By understanding the role of these REDD+ schemes in the direct and indirect promotion of small-scale forestry development in various countries, the authors aim to understand the global trends in this area and point out gaps in the enabling environment found in the current strategies and actions proposed under REDD+.

Management of regeneration on hurricane-affected forests and its implications for the development of indigenous communities in the North-Atlantic Region, Nicaragua. Sánchez Correa, J. (*Colombia; jeanbap563@hotmail.com*), Ordoñez, Y. (*Independent; yadido@hotmail.com*).

In the first half of 2011, an ecological characterization of forests affected by Hurricane Felix, 3 years earlier, was performed in the North-Atlantic Autonomous Region, Nicaragua. In addition to use of the livelihoods approach, resources of Miskito communities were described and information on forest management in the study area was compiled. The results were shared with both the local community and the forestry advisory body of the region. Based on the results, guidelines for forest management, mainly for regeneration, were defined to enable local indigenous people to develop skills and potential leverage for obtaining benefits. From an ecological perspective, a recovering forest with abundant regeneration of useful species—*Calophyllum brasiliense, Symphonia globulifera, Terminalia amazonia, Vochysia ferruginea, Vochysia guatemalensis*, and *Carapa guianensis*— was found. From a social perspective, communities with strong natural, social, and human resources were also found, represented by recovering forests, organizational structures, and skillful and specialized labor, respectively. Based on the degree of forest recovery and environmental conditions, and taking into account community resources, silvicultural treatments have been proposed—release of species and desirable individuals, sprout management, seed production, and gap enrichment with species of commercial interest—to manage the forest and get a desired species composition that meets community expectations.

Eradicating an invasive species: landowner perceptions of impacts to ecosystem services. Santo, A., Sorice, M. (*Virginia Polytechnic Institute and State University, USA; anna.santo@vt.edu; msorice@vt.edu*), Anderson, C. (*Centro Austral de Investigaciones Científicas, Argentina; chrisa1@vt.edu*).

Originally brought to the Tierra del Fuego (TDF) archipelago in Argentina to start a fur trade in 1947, the North American beaver (*Castor canadensis*) has spread throughout the region. Despite binational support for eradication, *estanciero* (private landholder) participation in beaver control has been very low. The authors conducted 40 semi-structured interviews on the main island of TDF to examine *estancieros*' mental models of how beaver-caused changes influence riparian area ecosystem services. The authors further examined the influence of these perceptions on the willingness of *estancieros* to assist with beaver eradication. Individual mental models were aggregated into an overall cultural model to examine the degree of shared understanding about beaver impacts to ecosystem services. Many landowners perceived beaver as a threat to provisioning, cultural, supporting, and regulating services; however, a minority of landowners in the arid north perceived significant personal provisioning and cultural service benefits. Lack of cooperation among neighboring landowners, especially public lands, was frequently mentioned as the largest barrier to participation in beaver control efforts. The authors suggest areas where targeted communication, regulation, or voluntary incentives might facilitate effective and cooperative beaver eradication strategies.

Small-scale private forests provide increased structural diversity and carbon storage in Germany's Swabian Alb biosphere reserve. Schaich, H. (*University of Freiburg, Germany; harald.schaich@landespflege.uni-freiburg.de*), Plieninger, T. (*University of Copenhagen, Denmark; tobias.plieninger@ign.ku.dk*).

In European cultural landscapes, forest area is subdivided into a mosaic of stands of different ownership types and sizes. This study hypothesizes that forest ownership is an indirect determinant of forest management approaches and is therefore relevant for biodiversity conservation and carbon sequestration. The authors compared structure and species composition of mixed deciduous forest stands in clusters of different ownership types, namely state-owned, municipal, and small-scale private forests, in south-western Germany. Although close-to-nature management has been practiced in public forests for years, this study demonstrated that tree species diversity does not differ significantly between ownership types. However, small-scale private forests comprise significantly higher levels of structural diversity, more dead wood, and greater carbon storage capacity than either public forest type. This finding is contrary to other studies, where publicly owned lands were found to host higher biodiversity, and differs from the global trend, where continued fragmentation of private lands threatens forest sustainability. The importance of small-scale private forests, e.g., for the conservation of old-growth and dead-wood-dependent species, appears to stem from less intensive and more diverse forest management. To maintain diversity in small-scale private forests, remuneration and consulting programs to promote forest biodiversity and ecosystem services should be advanced.

AgriCarb: an option for rural development in Gabon. Schmid, C. (*University of Natural Resources and Life Sciences (BOKU), Austria; carmen_schmid@gmx.at*), Niedermayr, J. (*University of Natural Resources and Life Sciences, Italy; julia.niedermayr@gmail.com*), Stanzl, P. (*VMS, Gabon; stanzl225@aon.at*), Pietsch, S. (*University of Natural Resources and Life Sciences (BOKU), Austria; stephan.pietsch@boku.ac.at*).

The AgriCarb project in Gabon, Africa, promotes a sustainable land-use scenario by linking smallholder low-input agroforestry with forest preservation and small-scale carbon offset projects. High transaction costs of carbon offset projects, along with low CO_2 prices and related risks and uncertainties, are major obstacles to smallholder project implementation. The aim of this study was to assess whether the implementation of an agroforestry system supported by carbon offset payments is likely to provide higher net income to farmers than their current shifting cultivation practices. A survey of the socioeconomic background and carbon stock measurements of forests as well as existing plantations was conducted to determine the baseline scenario of shifting cultivation. The current land areas used for shifting cultivation were found to be five times higher than the project scenario. Moreover, carbon stocks under the agroforestry scenario are estimated as at least 20% higher than the baseline carbon stock. Analysis of the economic performance of agroforestry implementation using net present value calculation, demonstrated additionality of the AgriCarb project: Higher initial costs of agroforestry implementation are estimated to be covered by offset payments and revenues from agroforestry production. Thus, carbon offset payments have been identified as a viable incentive for farmers to switch to agroforestry.

Subsistence strategies and means of the river populations of the Luki Biosphere Reserve in the Democratic Republic of Congo. Semeki Ngabinzeke, J. (*University of Kinshasa, Democratic Republic of the Congo; jeansemeki@gmail.com*), Meyanga Tongo, Y. (*Ministry of Scientific Research and Innovation- Yaoundé Cameroon, Cameroon; meyanga_yves@yahoo.fr*).

The Luki Biosphere Reserve, the last remnants of the Mayombe forest in the Democratic Republic of the Congo, is under severe anthropogenic pressure. Since independence, "Zairisation" has led to a cascade of bankruptcies in the agricultural and food industries in the region. Seeking a new livelihood, the people went to the forest, where slash and burn agriculture, charcoal production, timber exploitation, and hunting have been their means of subsistence. To understand these means of subsistence, surveys were carried out in four villages (Kinzua-Mvuete, Kikalu, Kiyalala, Kiyangala) located along the river in the Reserve. Results show the people's strong dependence on forest resources. In the context of a growing population, general impoverishment, and bad environmental governance, the people developed strategies of intensification, extensification, diversification, and migration. These activities result in insufficient fallow time, land conflicts, felling of small-diameter trees, and land use change, which together with deforestation and degradation strongly contribute to the people's state of misery. With a view to reconciling the objectives of development and conservation, recommendations include increasing the use of agroforestry, fish farming, and apiculture, and raising raise awareness.

Undergraduate enrollment in forestry and related areas of natural resources in the United States with respect to gender and race/ethnicity. Sharik, T. (*Michigan Technological University, USA; tlsharik@mtu.edu*), Lilieholm, R. (*University of Maine, USA; roblilieholm@gmail.com*), Richardson, W. (*U.S. Department of Agriculture, USA; billrich@vt.edu*).

Enrollments of women and minorities in forestry and related areas of natural resources in the United States are substantially lower than their numbers in the college population as a whole and in most other fields of study. When all areas of natural resources are examined, forestry shows the lowest enrollments of women and minorities. Interdisciplinary degree programs exhibit the highest numbers and are also the fastest growing programs overall. These trends have important implications for the future of the forestry profession in the United States.

Impact of socioeconomic circumstances on forest management and forest cover in Java Island, Indonesia. Shiga, K. (*University of Tokyo, Japan; shiga@anesc.u-tokyo.ac.jp*), Damayanti, E., Wachyuni, M., Prasetyo, L. (*Bogor Agricultural University (IPB), Indonesia; e11yn.d4mayanti@gmail.com; mardiana.why@gmail.com; lbprastdp@yahoo.com*), Masuda, M. (*University of Tsukuba, Japan; masuda.misa.gm@u.tsukuba.ac.jp*).

Deforestation constitutes the main problem in developing countries. Some proximate causes are agricultural expansion and forest exploitation. Driving forces include population increase, debt, government policies, and price of export commodities. Given these factors, deforestation would be expected to be a site-specific process and to differ based on biophysical and demographic characteristics of the site. Java Island is the most populated island in Indonesia with almost a quarter of the island in forestland. Java has a very long history of deforestation that started in the Dutch colonial era, but through forest management by *Perhutani* (State Forestry Corporation) and several other central-government programs, some provinces in Java have been attempting to extend the forest cover. The shift from deforestation to reforestation is called "forest transition." Among provinces in Java, West Java Province, where the forests are managed by *Perhutani* Unit III West Java & Banten, is the only province that has already experienced forest transition. This study was aimed at clarifying whether socioeconomic conditions affect forest management and forest cover in Java. Using statistical data and the annual report of *Perhutani*, the authors address the effects of (1) a change in forest management (including collaborative forest management between the community and *Perhutani*) and (2) offensive activities by local people caused by economic development and by changes in industrial structures, demographics, and local community relationships.

Local community resource management of the mangrove forest ecosystem at Kalitoko, Mayalibit Bay, and Raja Ampat, West Papua, Indonesia. Sihotang, B. (*Indonesia; godbless.binsar@gmail.com*), Yunita, S. (*Gadjah Mada University, Indonesia; yunitasekar95@yahoo.com*).

The mangrove forest ecosystem in Kalitoko in Indonesia has high biological productivity and also provides socioeconomic benefits to the community. This research aimed to determine the activities of the community affecting the ecosystem, describes socioeconomic conditions and community interaction in utilizing the mangrove forest, and evaluates the condition of the mangrove forest. The research was conducted from July to August 2012 in Kalitoko, Mayalibit Bay, and Raja Ampat. Data were

collected using purposive sampling by interviewing several people who have many activities within and near the forest. In addition, secondary data were obtained from a literature review. Results showed that fishing was the occupation of 71% of the community; fishermen utilized the resources of mangrove for their survival. Most people (53%) were aware of the importance of the mangrove in protecting flora and fauna to support the preservation of mangrove ecosystems. The diversity of species in this mangrove forest was relatively high. Sixty-five species of mangrove (56 genera and 35 families) were identified, of which 21 species were classified as rare species in accordance with their listing as "threatened" on the IUCN Red List. Tree density was 549 individuals/ha with basal area of 18.6 m^2/ha.

Linking mitigation and adaptation: learning from the first Indonesian community-based afforestation/reforestation Clean Development Mechanism project between Korea and Indonesia. Siregar, C. (*Forest Research and Development Agency, Indonesia; siregarca@yahoo.co.id*), Siregar, U. (*Bogor Agricultural University, Indonesia; siregaruj@gmail.com*), Jin, S. (*Korea International Cooperation Agency, Republic of Korea; spforest@gmail.com*), Lee, K. (*Korean Forest Service, Republic of Korea; jyakt@hotmail.com*).

Lombok Island, Indonesia, has the characteristics of a small island, such as low carbon emissions, but is highly vulnerable to climate change impacts because of limited natural resources, infrastructure, and human capital. The island has undergone massive deforestation under recently drier climate conditions. Agricultural productivity on the limestone-based soil is low and the local community is poor. In order to mitigate climate change in Lombok Island the governments of Indonesia and Korea conducted their first small-scale joint afforestation/reforestation Clean Development Mechanism (AR CDM) project under REDD+. From project implementation it was learned that mitigation alone was not sufficient to restore ecosystem services, such as water availability, while alleviating local poverty at the same time. Some adaptation measures are needed, such as building water reservoirs for plantation maintenance, establishing an agroforestry system that consists of a 1:1 planting ratio between forest and fruit tree species, and developing new market initiatives for agroforestry products linked to ecotourism.

Best practices for enhancing communication skills of forestry majors in U.S. institutions of higher learning. Storer, A., Sharik, T. (*Michigan Technological University, USA; storer@mtu.edu; tlsharik@mtu.edu*), Bullard, S. (*Stephen F. Austin State University, USA; bullardsh@sfasu.edu*), Allen, J. (*Northern Arizona University, USA; James.Allen@nau.edu*).

Communication skills have been identified by employers of forestry graduates as the top priority among all desirable skills in their employees ever since surveys of desirable skills have been administered. Moreover, communication skills typically show the greatest gap between desired and actual skill levels, both in our students and in our graduates in the workplace among an array of skills examined. In response to this problem, educators from the more than 70 institutions of higher learning offering forestry degrees in the U.S. have been developing best practices for enhancing communication skills. Here we report on these best practices, along with methods of measuring/assessing gains in these skills and the magnitude of these gains.

Conserving endangered species of high economic value through the participatory cultivation model. Suharti, S. (*Ministry of Forestry, Indonesia; suharti23@yahoo.co.id*).

Intensive and massive forest exploitation along with frequent forest fires in Indonesia has resulted in the immense decline of many tree species, including several of high economic value. At the same time, many conservation efforts have not had satisfactory results because programs have lacked focus and good planning. Furthermore, there are different perceptions about conservation terminology. Some people interpret conservation of rare plants as not allowing plants to be disturbed or cultivated for harvest at all. This perception needs to be modified because several conservation efforts through partnership models, such as that for aloes (*Aquilaria malaccensis*), have yielded positive and significant results. Research reveals that communities in various regions are quite enthusiastic about aloe cultivation because it could lead to many benefits. Some of the factors supporting success of aloe conservation through the participatory model are the widespread adoption of techniques for aloe, high economic value of aloe products, relatively short cultivation period (8 years), and availability of required technology for inoculation. Aloe tree conservation programs through the participatory model could be replicated for other endangered species with high economic value.

Merging gaps between forest conservation and agricultural production in protected areas: case study of southern Bakundu in Cameroon. Suka, E. (*Protection of Nature and Sustainable Development, Cameroon; emmanuelsuka@yahoo.com*).

The Southern Bakundu Forest Reserve was established in 1940. Today, in a search for arable farmland, communities near the forest boundaries have converted 7 000 ha out of the original 19 425 ha to cropland through slash and burn. Illegal chainsaw felling of timber and harvesting of non-timber forest products have further degraded the forest and increased carbon emissions. Land tenure conflicts are rife among stakeholders. Surrounding villages claim ownership of the land despite exclusive state ownership of forest reserves. Government met stiff resistance when it attempted to evict farmers from the reserves because the established farms have cash and subsistence crops. Despite rising demand for food, the government rejected requests to declassify the reserves and hand over the already occupied portions for agricultural production. To ensure that forest reserves continue to provide much-needed environmental goods and services, deforested areas were rehabilitated and standing forest improved to enhance carbon storage. Agroforestry systems and the consensual natural resource governance approach were implemented. Stakeholders jointly drafted and implemented management plans for forest and agricultural resources. Analysis of data showed a tremendous increase in agricultural productivity and stabilized forests. Results were used to develop REDD+ projects. Further damage to the forest was halted, thus stabilizing local climate and supporting food security and sustainable development goals.

Alternative livelihoods and biodiversity conservation. Sunderland, T. (*Center for International Forestry Research (CIFOR), Indonesia; t.sunderland@cgiar.org*), Roe, D. (*International Institute for Environment and Development (IIED), UK; dilys.roe@iied.org*), Redford, K. (*Archipelago Consulting, USA; redfordkh@gmail.com*), Kumpel, N. (*Zoological Society of London, UK; Noelle.kumpel@zsl.org*), Booker, F. (*International Institute for Environment and Development (IIED), UK; francesca.booker@iied.org*), Day, M. (*Center for International Forestry Research (CIFOR), UK; m.day@cgiar.org*).

Considerable investment has been made in strategies designed to provide alternative livelihoods for people living in and around protected areas or other areas of biodiversity. The primary aim of such interventions is to alleviate a threat to biodiversity; a strong secondary outcome is to improve the well-being of the targeted communities. The donor community has invested in alternative livelihood activities for decades as part of both poverty alleviation programmes and tied development and conservation projects. Despite these investments, very little is known about what has worked, and what has not worked and why. There is also very little information about how more effective new programmes can be developed for both conservation and sustainable livelihoods. This systematic review provides an overview of the state of the evidence base on the effectiveness of alternative livelihood projects and illuminates the strengths, weaknesses, and prevailing knowledge gaps. The primary research question for the systematic review is: "Are alternative livelihood projects effective at reducing local threats to defined elements of biodiversity and/or improving or maintaining the conservation status of those elements?"

What makes community forest management successful in Myanmar? Thu, P., Park, M., Koo, J. (*Seoul National University, Republic of Korea; phyothu@snu.ac.kr; mpark@snu.ac.kr; sele78@snu.ac.kr*).

In Myanmar, the forests and forest land are controlled by the state, and land can be converted to other land uses. Community Forestry Instructions issued by the Forest Department in 1995 represented an innovative approach to decentralization of forest management and became a path to more secure land tenure. According to the Forest Master Plan (2001), 2.27 million acres must be handed over to forest user groups (FUGs) by 2030–2031, but only 4.5% had been handed over after 15 years (by 2010). This paper aimed to determine whether community forests are functioning well and to identify the wide range of challenges that FUGs encounter. Based on the theory of public participation in natural resource management, the social factors that determine the function and progress of community forest management were identified in the two Myanmar cases. The roles of stakeholders and their relationship and formal or informal rules were examined in the process of community forest management. Hence, this paper will be helpful when considering reforms in the policies and institutions of community forest management in Myanmar as well as in other developing countries.

Analysis of different community-based forestry in relation to employment and local livelihood in Nepal. Uprety, D. (*Multi Stakeholder Forestry Programme (MSFP), Nepal; dharam.uprety@gmail.com*).

Community-based forestry (CBF) in Nepal is attracting international attention. CBF in this paper encompasses community forestry, collaborative forest management, leasehold forestry, and buffer zone forest management, where the sustainable management of forest resources and their sustainable utilization rights are handed over to local communities under an approved operation plan, and users' constitution. Data shows that there are about 29 000 community-based forestry groups managing about 1.9 million ha of forest across the country. A recently updated report from Department of Forest of Nepal shows that the number of community forest user groups (CFUGs) reached 18 133, with 2.2 million membership households managing 1.7 million ha of forest land. The community-led forests and forestry sector as a whole contribute to generating jobs, thereby providing different livelihood options. A study found that the forestry sector employs 9.2% of Nepal's total economically active population (23 million) and contributes to 9.4% of the national GDP. The paper is based on studies between 2011 and 2013 commissioned by the Multi Stakeholder Forestry Programme, of which the author of this paper is the climate change and forestry manager.

Building climate resilience in communities by integrating community practices into the local planning process in Nepal. Uprety, D., Subedi, R. (*Multi Stakeholder Forestry Programme (MSFP), Nepal; dharam.uprety@gmail.com; r-subedi@msfp.org.np*).

About 25% of the total population in Nepal lives below the poverty line (less than US$1.25/day). Most of the population living in poverty is forest- and agriculture-dependent and is the most vulnerable in the face of climate change. With the inevitable impacts of climatic change, poor and vulnerable communities in Nepal have started preparing strategies to cope with the climate-induced hazards through adoption of community-based adaptation plans. This paper is based on the review of 420 community adaptation plans (CAPs) prepared between 2009 and 2012 at 12 different districts and covering approximately 33 600 rural households in Nepal. Preliminary analysis shows that incidence of landslides, drought, and forest fire, has increased sharply in the last few decades. The most common adaptation strategies for local communities to cope with these events were plantations (364 communities), raising awareness (362), water management (366), income diversification (302), alternative energy promotion (271), crop diversification (217), establishment of an emergency fund (319), and forest management activities (318 communities).

Tourism activities and biodiversity conservation within protected areas in West Africa. Vodouhe, G. (*Laboratory of Applied Ecology, Benin; vodouhefifanou@gmail.com*).

Local community support for management of protected areas is essential for their sustainability. Support is often linked to the benefits that communities receive from the protected areas, and tourism development is a means of providing such benefits. However, very few studies have attempted to analyze the link between the receipt of tourism benefits and local people's support for biodiversity conservation. The present study carried out around Pendjari National Park (PNP) in West Africa examined local people's attitudes towards tourism activities, their perception of sharing tourism benefits, and the effects of this perception on local support for biodiversity conservation. Data were collected from 293 residents regarding tourism and biodiversity conservation in PNP. Results revealed that 70% of respondents were positive towards tourism and support biodiversity conservation within the park. Twenty-four percent of respondents participated in different tourism-related activities, such as tour guide (11%), hunting guide (8%), and host to tourists (6%) during their visits. About 97% of respondents support the principle of returning a part of benefits generated by tourism activities to local communities, but they are frustrated by the total amount returned (73% of respondents). Gender and compensation methods used are the two most important factors distinguishing residents' perception of the inequalities in tourism benefits sharing ($c^2_{(8)} = 72.65$; $p = 0.0001$).

Does participation in non-profit urban tree-planting programs improve neighborhoods? Examining the impact of collective action on neighborhood residents. Watkins, S. (*Indiana University, USA; shawatki@indiana.edu*).

Collective action between neighbors has been found to build community capacity and to build connections, trust, and reciprocity among individuals. Urban tree-planting nonprofits in many U.S. cities often require neighborhoods to be involved in tree planting and maintenance and often these nonprofits articulate program goals that include social outcomes like improved community capacity. The purpose of this research was to evaluate whether neighborhood participation in these urban forestry efforts increases community capacity, including the level of trust that neighbors have for one another, the ties between them, and cohesion in the community. This research leverages a unique dataset that includes both ecological and social information about tree-planting neighborhoods and matched comparable neighborhoods in five cities. The data include survey responses from residents and participants; interview responses from neighborhood leaders and nonprofit employees, and a suite of neighborhood spatial and sociodemographic characteristics. Hierarchical regression techniques will account for spatial clustering of individuals within neighborhoods. Preliminary results suggest that nonprofit tree-planting programs that require neighborhood involvement have positive effects on the community, including helping neighbors to meet and communicate.

The Komet Programme, a public-private partnership in forest protection. Widman, U., Sandström, C., Eckerberg, K. (*Umeå University, Sweden; ulrika.widman@pol.umu.se; camilla.sandstrom@pol.umu.se; Katarina.eckerberg@pol.umu.se*).

There is growing worldwide reliance on voluntary agreements such as public-private partnerships (PPPs) as a means for forest protection. In Sweden, such partnership characterizes the approach in nature conservation agreements (NCAs). These agreements are negotiated between the County Administrative Board/the Forest Agency and a landowner. However, assessments made by the Swedish Forest Agency show rather inefficient implementation of set goals, even if there are regional variations. Hence, another PPP, the Komet Programme, was established in 2010 in selected regions to increase the interest for nature conservation and NCAs among landowners. The Komet Programme differs from top-down protection, as it gives the initiative in nature conservation to the individual landowner and not to the authority responsible. However, the forms of protection and payment in the programme are the same as in traditional formal protection. This paper intends to explore, through interviews with key actors, what factors on a local level affect the process and formation of PPPs. The analysis focuses on the process among the actors and their incentives for collaboration on a voluntary basis. The results may decrease the knowledge gap regarding the process-related aspects of PPPs and how they differ from those of formal protection.

Joint forest management in Western Uganda – impacts of internal governance on local livelihoods and conservation. Wilms-Posen, N., Murer, C., Egas Cadena, J., Brandao, L. (*University of Copenhagen, Denmark; n.wilmsposen@gmail.com; carlo.murer@yahoo.com*, *jegas@aldhea.org; lu.rb.br@gmail.com*).

Joint forest management (JFM) has been promoted widely in Uganda. Outcomes of this approach have mostly been analyzed with regard to livelihood and conservation; therefore, this paper aimed to examine (1) how different governance aspects of JFM affected developments of community-based organizations (CBOs), and through which channels these developments affected (2) local livelihoods and (3) conservation outcomes. The paper applied a mixed method approach and collected data in two CBOs managing considerable areas of the Budongo Forest Reserve. Results show that internal governance is a critical determinant for performance of CBOs. Elite capture and poor conservation outcomes were observed in a CBO that experienced difficulties in building trust and effective internal communication. Internal governance also limited the possibility of poor community members to participate in JFM activities, as it reduced the expected net benefit of joining the CBO through the perceived high risk of misinvestment. A comparison between wealth of households and their date of joining the CBO underlines this relationship as poor households joined the CBO only after expecting to receive tangible benefits. The authors conclude that internal governance and social capital formation can affect distributional outcomes and the achievement of the overall objectives of JFM.

The role of dryforests in livelihood resilience: experience from the pastoral and agro-pastoral production systems in the drylands of Ethiopia. Worku Gizaw, A. (*Forestry Research Center of Ethiopia, Ethiopia; adefires@yahoo.com*), Pretzsch, J. (*Dresden University of Technology, Germany; pretzsch@forst.tu-dresden.de*), Kassa, H. (*Centre for International Forestry Research (CIFOR), Ethiopia; habtekassa@yahoo.com*).

Dryforests are the largest components of the landscapes and gene pool of the continent of Africa. Lack of data on their socioeconomic significance has hinder integration of dryforests into development planning and hence they have undergone massive deforestation. Guided by social-ecological co-evolution theory framework, mixed quantitative and qualitative research design was used to examine the significance of dryforest income and factors affecting dependence on it, in the context of the pastoral and agro-pastoral production systems in the drylands of Ethiopia. Results showed that dryforests were a vital part of households' income portfolio, contributing 34.5% of the annual income and 42% of the cash income. Dryforests were the largest income sources for 47% of the respondents, and contributed up to 63% of the annual income of the poor, mainly female-headed households. Income from dryforests helped 24% of the households remain above the poverty line and reduced income disparity (Gini coefficient) by 13.7%. Income from dryforests is increasingly becoming a key strategy in households' risk management planning and in their coping with drought episodes. Various factors influence dependence on dryforest income. Implications of these findings could be relevant to similar dryland ecoregions in the Horn and could contribute to promoting multi-level accountability in managing the diminishing dryforests. Adaptation of livelihoods could thereby be enhanced, combating desertification and biodiversity conservation.

Rural development with non-timber forest products: the case of Qiannan Buyi and Miao Autonomous Prefecture, Guizhouin, China. Xun, H. (*International Centre for Bamboo and Rattan, China; xunhang@icbr.ac.cn*), Matsuoka, S. (*Waseda University, Japan; smatsu@waseda.jp*), Yue, Y., Tang, F. (*International Centre for Bamboo and Rattan, China; yueyd@icbr.ac.cn; fengtang@icbr.ac.cn*).

In the remote and mountainous areas of western China, it is common to find poverty existing side by side with abundant forests. Development of utilization of non-timber forest products (NTFPs) would make a great contribution to rural development in China.

The general objective of the paper is to assess the contribution of NTFPs to rural livelihoods and to identify potential development interventions for the future improvement in the Qiannan area. Data was collected via a semi-structured household survey, focus group discussion, and informant interviews. The research findings suggested that the livelihoods of forest-adjacent people in the Qiannan area are directly connected to various types of forest products. Of all NTFPs, sea buckthorn (*Hippophae rhamnoides* Linn (Sha Ji)) and bamboo shoots provided the highest market value. However, forest farmers have poor awareness of biodiversity, and they usually manage forests and collect NTPFs in an unsustainable way. To make natural resource utilization sustainable, there are three types of policy approaches: command and control, market-based approaches, and voluntary approaches. A combination of these approaches would be an ideal way to maximize sustainability. Some recommendations for relevant social actors are made in this research.

General health condition of forest species in three parks in Mexico City: crown condition. Zaragoza Hernandez, A., Cetina-Alcalá, V., López-López, M. (*Colegio de Postgraduados, Mexico; zara407@hotmail.com; vicmac@colpos.mx; lopezma@colpos.mx*), Chacalo-Hilú, A. (*Universidad Autónoma Metropolitana-Azcapotzalco, Mexico; lchacalo@yahoo.com.mx*), Isla-de Bauer, M., González-Rosas, H. (*Colegio de Postgraduados, Mexico; libauer@colpos.mx; hectorgr@colpos.mx*).

The crown condition indicator is used to know the proportion of trees with a crown dieback or a foliage density considered lower than normal. Thick and large crowns relate to high growth rates whereas small ones suggest sites with unfavorable conditions. The crown condition indicator can provide adequate reliable information to diagnose the general health condition of urban trees. The sites chosen were parks within Mexico City known as Alamedas. Samples were collected on three occasions during the rainy season (May–October) and once during the dry season (November–April) of 2011. Variables recorded were crown density (DNC), crown dieback (MR), and foliage transparency (TRPF) in 5% intervals on a scale of 0 to 100. Normality tests, variance analysis, and a non-parametric Kruskal-Walis analysis were carried out to find the distribution of data and significant differences in the values of the three variables at the level of $\alpha = 0.05$. Results indicated that species in better health were those with the highest DNC values and the lowest TRPF and MR values. Species in the best health were *Cupressus sempervirens*, *Ligustrum lucidum*, *Populus alba,* and *Fraxinus uhdei.*

Forestry higher education facing social and economic changes. Zasada, M. (*Warsaw University of Life Sciences (SGGW), Poland; Michal.Zasada@wl.sggw.pl*), Małek, S. (*University of Agriculture in Cracow, Poland; rlmalek@cyf-kr.edu.pl*), Skorupski, M. (*Poznań University of Life Sciences, Poland; maskorup@up.poznan.pl*), Gruchała, A. (*Warsaw University of Life Sciences (SGGW); Arkadiusz.Gruchala@wl.sggw.pl*), Frankowicz, M. (*Jagiellonian University, Poland; marek.frankowicz@gmail.com*).

The last two decades have brought many legal, economic, and social changes that have led to a new situation for forestry. Globalization, demographics, economic crisis, global changes, and increased emphasis on nature conservation bring new challenges both for the forest sector and for forestry education. Now more than ever, higher education in forestry has to be based on deep and innovative scientific research, both basic and applied. At the same time, a trend of discontinuing programs that offer forestry degrees has been observed, along with the combining of agricultural and forestry universities and faculties with the more general "life sciences" institutions. The mismatch between graduates' skills and the demands of the contemporary, rapidly changing labor market is discussed. Current trends in higher education in Poland are presented. Entrance requirements for programs, the need to develop soft skills, the promotion of foreign language literacy, and mobility and the ability to work on international teams are addressed. These new capabilities are becoming as important as the in-depth knowledge and skills directly related to the major field of study.

Exclusion of low-income households from forestry management: a study on forestry specialized cooperatives in China. Zhu, R. (*National University of Singapore, Singapore; a0086261@nus.edu.sg*).

Existing literature on forest management has extensively examined factors that affect participation and collective action in decentralized forest management. Exclusion of the poor is generally considered to be a result of inefficient government regulation and the inherent heterogeneity of communities. However, few systematic studies have identified the factors that affect common elite capture in community-based forest management. The exclusion of low-income households is by no means a static story. To explicate circumstances that exacerbate or mitigate effects of exclusion, it is necessary to explore institutional conditions at national as well as local levels. Therefore, this research will highlight the multi-level institutional factors that influence the issue of exclusion, specifically in the Forestry Specialized Cooperatives (FSCs) in China. Even though the Chinese central government has praised FSCs as a crucial means of promoting farmers' interests and rights, there is growing criticism that FSCs are marginalizing low-income citizens. Building on the multi-level institutional perspective, the research will provide a multi-level theoretical framework to explain the causes of internal exclusion in FSCs. This issue is important because it focuses on the most marginalized people in China—the rural poor. It also contributes to the global experiences of decentralized forest management. This study will be one attempt to link the FSC experience to international debates on community-based forest management.

GENERAL POSTER SESSIONS

IUFRO Division 7: Forest Health

Natural occurrence and pathogenicity of *Metarhizium anisopliae* obtained from Peninsular Malaysia forest soils against *Atteva scidoxa* larvae. Ahmad, M. (*Forest Research Institute Malaysia; mohdfarid@frim.gov.my*).

Atteva sciodoxa is a major threat to plantations of the herbal plant *Eurycoma longifolia* in Peninsular Malaysia. Control of this pest is difficult as application of chemical pesticides is not encouraged in the plantations. In addition, *A. sciodoxa* larvae are robust because they can withstand high daytime temperatures, have few natural predators, and are present throughout the year. Thus, development of a biological control method using entomopathogens could be an alternative approach in controlling the pest infestations. Soil samples were collected from 25 natural forests in Peninsular Malaysia and the presence of *Metarhizium anisopliae* was evaluated via the Galleria bait method with modification. Of the 25 samples studied, 96% were positive for *M. anisopliae* regardless of soil texture, organic content, soil moisture, pH, and elevation. However, they were isolated more frequently from lowland dipterocarp forests than upland dipterocarp forests. Pathogenicity assessment conducted on 3–4 instar stages of *A. sciodoxa* larvae revealed that all the fungal isolates were relatively pathogenic. The average mortality recorded was 85.6% and it occurred within 4.5 days of inoculation. However, only four isolates, namely, FRIM874, FRIM875, FRIM587, and FRIM862, were highly pathogenic against the larvae with 100% mortality. These isolates have potential for further study in developing a mycoinsecticide against the insect pest.

Emerging insect pest and disease in *Cedrela odorata* plantations in Ghana. Apetorgbor, M. (*Council for Scientific and Industrial Research, Ghana; mapetorgbor57@gmail.com*), Bosu, P. (*Forestry Research Institute of Ghana, Ghana; paul_bosu@yahoo.com*), Roux, J. (*FABI-University of Pretoria, South Africa; jolanda.roux@fabi.up.ac.za*).

Large-scale planting of high value indigenous tree species in Ghana was unsuccessful as a result of insect pest and disease problems. These failures, together with the urgent need to establish plantations to meet demand in the face of decreasing timber from naturally managed forests, partly account for the widespread planting of Cedrela (*Cedrela odorata*) and other exotic species. Insect pest and disease outbreaks in tree plantations, which used to be generally low, have been reported to be increasing with expansion of plantations. The purpose of this study was to identify insect pests and diseases occurring in Cedrela plantations and evaluate management strategies. A field survey was undertaken in 2- to 4-yr-old-plantations in three ecological zones of Ghana, and root and stem samples were collected. Diseased trees were heavily infested with bark borers (*Apate* spp.), whose attack triggers the flow of brownish gum, resulting in dieback in the plantations. White mycelia were observed in cambial layers between the bark and wood of basal stems in the moist evergreen forest zone. Morphological observations and DNA sequence data indicated *Armillaria hemii* was the cause of the root rot. These insect pests and diseases inflicted serious economic losses of 82–89% on farmers' plantations. Sustainable integrated pest management strategies are discussed.

Diagnosis of forestry pests and diseases in Costa Rica. Arguedas, M. (*Instituto Tecnológico de Costa Rica, Costa Rica; marguedas@itcr.ac.cr*).

Costa Rica has been reported to have 75 000 ha of forest plantations, mainly of species such as *Tectona grandis, Gmelina arborea, Acacia mangium, Cupressus lusitanica, Alnus acuminate, Vochysia* spp., and *Cordia alliodora.* As the Payment for Environmental Services Program was implemented over the last decade, other forest species gained importance for propagation for protection and urban forests. Plantations of these species have been found to have economically significant phytosanitary problems. Since 1984, the Costa Rica Institute of Technology has been performing a national diagnosis of forest pests and diseases. A total of 594 insect species (75% of all pests and diseases diagnosed), 154 pathogens (19%), 32 vertebrates (4%), and 13 mistletoe species (2%) have been reported in 170 tree species. The main problems are: *Hyblaea puera* and various Chrysomelidae and Geometridae species in *Tectona grandis*; *Rifargia* spp. and *Caviria vinasia* in *Vochysia guatemalensis*; rust on foliage and twigs of *Puccinia cordiae, Melampsoridium alni, Olivea tectonae, Prospodium* spp., and *Uredo cupressicola*; shoot borers (*Hypsipyla grandella* and *Cosmopteryx* spp.) and the bark beetle *Scolytodes alni* in *Alnus acuminate*; and various Cerambycidae species and cankers (*Chrysoporte cubensis, Erythricium salmonicolor*, *Nectria* spp., and *Seiridiun cardinale*) on the stem of and vascular wilt (*Verticillium* sp.) in *Calophyllum brasiliense*.

Trophic interactions between vertebrate insectivores and a climate-driven expanding forest moth. Barbaro, L. (*National Institute for Agricultural Research (INRA), France; luc.barbaro@pierroton.inra.fr*), Battisti, A. (*University of Padova, Italy; andrea.battisti@unipd.it*), Charbonnier, Y. (*Institut National de la Recherche Agronomique, France; yohan.charbonnier@pierroton.inra.fr*), Dulaurent, A. (*Institut Polytechnique LaSalle, France; Anne-maimiti.DULAURENT@lasalle-beauvais.fr*), Jactel, H. (*Institut National de la Recherche Agronomique (INRA), France; herve.jactel@pierroton.inra.fr*).

The pine processionary moth (*Thaumetopoea pityocampa*) is a key defoliating moth of European pine forests, exhibiting cyclic outbreaks and currently expanding its range northwards and upwards in elevation due to warmer winters. Although vertebrate predators are known to influence insect outbreak dynamics, the evolution of predator-prey interactions under ongoing climate change is still subject to considerable uncertainty. For example, spatial and temporal mismatches between predators and prey may impede biocontrol efficiency. Here, the authors question the potential influence of insectivorous birds and bats on this climate-driven expanding moth, which displays many morphological and behavioural adaptations to avoid predation: eggs are protected by scales, late-instar larvae release urticating setae and hide during daytime in silk winter nests, pupae are buried in the soil and imagos emerge at night. The authors successively quantify numerical and functional responses of specialist birds, generalist birds, and generalist bats to *T. pityocampa* density for all life stages, i.e., eggs, late-instar larvae, pupae, and imagos. The authors suggest that sustaining long-term biological control of the pine processionary moth would require the maintenance of high functional diversity of vertebrate insectivores at the landscape scale, including both generalists and specialists.

Improving mass rearing techniques for *Cleruchoides noackae* (Hymenoptera: Mymaridae). Barbosa, L. (*EMBRAPA, Brazil; leonardo.r.barbosa@embrapa.br*), Beltramin, F. (*EMBRAPA Florestas, Brazil; fabiele_belt@yahoo.com.br*), Rodrigues, A. (*EMBRAPA, Brazil; aperufforodrigues@gmail.com*), Martinez, G. (*Instituto Nacional de Investigación Agropecuaria, Uruguay; gmartinez@tb.inia.org.uy*), Wilcken, C. (*São Paulo State University, Brazil; cwilcken@fca.unesp.br*).

The bronze bug, *Thaumastocoris peregrinus*, is an important pest affecting Eucalyptus plantations. The egg parasitoid *Cleruchoides noackae* was introduced in Brazil in 2012 for biological control of this pest. A mass rearing of *C. noackae* was established at EMBRAPA Florestas. This paper summarizes the main techniques developed to date in order to maximize the production of adult *C. noackae*. The use of eggs laid on towel paper strips increased the number of emerging parasitoids when compared to cutouts of Eucalyptus leaves. Host eggs 2 days old are preferred by *C. noackae* over 3- or 4-day-old ovipostures. Eggs can be stored at 5 ºC for 30 days after being parasitized without significant effects on parasitoid emergence; such storage is a convenient strategy. The mean parasitoid emergence varies significantly with the density of host eggs; an increase in the number of host eggs offered reduced the number of parasitoids that emerged. These improvements have played a significant role in the production of *C. noackae* that has made possible mass release of *C. noackae* in Brazil and the establishment of natural populations of the parasitoid, as recently confirmed.

Evaluation of mortality in natural stands of *Pinus oocarpa* in Nicaragua. Bauman, T., Eckhardt, L. (*Auburn University, USA; tab0032@auburn.edu; eckhalg@auburn.edu*), Menard, R., Ward, J. (*U.S. Forest Service, USA; rmenard@fs.fed.us; jward@fs.fed.us*), Sediles, A. (*Universidad Nacional Agraria, Nicaragua; albertosediles@yahoo.com*).

Evaluations were conducted to determine the cause of mortality in sapling pine stands in the Nueva Segovia region of Nicaragua. These stands were natural regeneration in areas that had been devastated by *Dendroctonus frontalis* 10 years earlier. Approximately 10–20% of individual stands were affected. Mortality of individual trees occurred within 6–12 months after symptoms were observed. Observed symptoms included chlorotic and wilting foliage, black stained and resinous tissue in the roots and butt that extended into the stem, and insect galleries and feeding areas. Root samples of symptomatic trees were collected and traps for insect vectors were established. Material from insect galleries was also collected to determine species of fungi present. Galleries of a larger scolytid beetle were observed and *D. approximatus* was found. *Ips* spp. were present in some of the trees but were considered secondary. The objectives of this project are to determine the cause of this mortality, identify the insect and fungal associations, and describe the disease syndrome.

***Ninus taeda* roots represent a suitable host substrate for developing *Hylastes* spp. of bark beetles in Alabama, USA.** Bauman, T. (*Auburn University, USA; tab0032@auburn.edu*), Matusick, G. (*The Nature Conservancy, USA; gmatusick@tnc.org*), Menard, R. (*U.S. Forest Service, USA; rmenard@fs.fed.us*), Zeng, Y., Eckhardt, L. (*Auburn University, USA; yzz0015@auburn.edu; eckhalg@auburn.edu*).

During an investigation into premature mortality in *Pinus taeda* stands in Alabama, *Hylastes salebrosus* and *H. tenuis* bark beetles were observed colonizing the roots of affected trees. To further understand the role of beetles in tree death, two primary lateral roots were selected for excavation from six trees in the stand. Root samples were taken from two trees with healthy green crowns, two trees with chlorotic and dying crowns, and two trees with red, dead crowns. *Hylastes* beetles were found to colonize the roots of dying and dead trees. Both larvae and pupae of *H. salebrosus* were identified in collected roots, providing direct evidence of beetle breeding within the roots of *P. taeda*. Adult beetles were rolled onto media and roots containing brood galleries were plated onto media to identify any fungi associated with these beetles. Of the beetles recovered, 47% were found to be transporting up to five species of ophiostomatoid fungi. The fungi were identified as *Leptographium terebrantis*, *L. procerum*, Grosmannia huntii, and *G. alacris*. In addition, one undescribed Ophiostoma species was isolated. These findings indicate dying and dead *P. taeda* roots provide suitable host material for *Hylastes* brood development

Paper mulberry invasion in Ghana. Bosu, P., Apetorgbor, M., Nkrumah, E., Bandoh, K. (*Council for Scientific and Industrial Research, Ghana; paul_bosu@yahoo.com; mapetorgbor57@gmail.com; enkrumah@csir-forig.org.gh; pbandoh@csir-forig.org.gh*).

Broussonetia papyrifera [family Moraceae] is a highly invasive woody perennial introduced to Ghana from its native Southeast Asia. Regeneration of the species after forest clearing occurs by stumps, root sprouting, and seedlings from the seed bank. A recent study to assess the impact of *B. papyrifera* invasion in forest and forest-savanna transition sites has increased our understanding of its invasive patterns. In a comparative assessment of species composition in invaded and uninvaded stands, relative percent cover of resident species/guilds that included indigenous broadleaved species and grasses was significantly lower in invaded plots. Seven months after *B. papyrifera* was experimentally removed from invaded plots, indigenous broadleaved species increased significantly in removal plots at the forest site. At the forest-savanna transition site, however, the increase in percent cover of indigenous species was not significantly different from control plots. These results led to the conclusion that *B. papyrifera* may favour indigenous species communities in the transition zone, whereas its removal is more likely to favour regeneration in a forest zone. Studies have been planned to determine whether paper mulberry invasion alters soil physical and chemical properties and whether its competitive ability is mediated through allelopathic effects.

An economic comparison of prevention strategies against forest pathogens. Brunette, M., Caurla, S. (*National Institute for Agricultural Research (INRA), France; marielle.brunette@nancy.inra.fr; sylvain.caurla@nancy.inra.fr*).

This paper analyses strategies for prevention of forest pathogenic risks from an economic perspective. A forest economics methodology was developed within a cost-benefit framework in order to compare existing treatments to prevent the invasion of three pathogens (*Hylobius abietis*, *Dothistroma septospora* and *Dothistroma pini*, and *Heterobasibion annosum*) in Landes forest, in the southwest of France. Results show that for *Hylobius abietis*, prevention, either through self-insurance (Foster solution) or self-protection (fallow), appears to be more cost-effective than taking no preventive steps. For *Dothistroma septospora* and *Dothistroma pini*, results indicate that the treatment analysed, i.e., self-protection (*Diathane paysage*), is never economically feasible for the forest owner because it induces a negative land expectation value (LEV). The authors computed the threshold

value of the treatment for which the LEV becomes positive and thus the treatment could be considered. This value is 45% lower than the current one. Finally, for *Heterobasibion annosum*, various self-protection activities were analysed, and local stump removal just after contamination is shown to always be more profitable than a systematic preventive treatment and that a fallow period at the end of rotation performs better than local stump removal if and only if the contamination occurs during the second thinning, when the forest is mature. Beyond the specifics of the case study, the paper proposes a methodology to analyse such problems.

Climatic change and insect outbreaks in Canada's boreal forests. Candau, J. (*Canadian Forest Service, Canada; Jean-Noel. Candau@nrcan.gc.ca*).

Insects are the world's most diverse class of organisms and as such they play a major role in the dynamics of most natural and human-managed ecosystems. Their impacts can be both positive and negative, direct and indirect, and generate positive or negative feedbacks, so understanding how climate change might influence insect impacts in forests is a daunting task. Insects as a whole represent the dominant natural disturbance factor in Canada's forests where, during outbreaks, host trees are often killed across extensive areas. This presentation considers how climate change might influence insect outbreak regimes in Canada's boreal forests. Also discussed are the direct and indirect effects of climate change on Canada's forest insects and the challenges associated with forecasting insect outbreak regimes in a changing environment.

Impact of soil moisture, humidity, and climatic conditions on Scots pine (*Pinus sylvestris* L.) damage in Lithuania. Čapkauskas, G., Žemaitis, P., Stakenas, V., Varnagiryte-Kabasinskiene, I. (*Lithuanian Research Centre for Agriculture and Forestry, Lithuania; gediminas.capkauskas@gmail.com; povilaszemaitis@gmail.com; v.stakenas@mi.lt Aleksandras Stulginskis university., Lithuania; i.varnagiryte@mi.lt*).

Increases in mean temperature, frequency of summer droughts, and dry episodes during periods of active growth of tree components have been discussed in recent decades as the primary climatic factors affecting forest health in Europe. The aim of this research was to investigate the correlation between forest health (main indicators: crown defoliation and frequency of biotic and abiotic tree damage) of Scots pine (*Pinus sylvestris* L.) stands, climatic factors (mean temperature and amount of precipitation) in forest site types with different humidity. Meteorological data from the network of meteorological stations and tree condition data from the Forest Monitoring (Level I) databases for the period 1991–2012 were analysed (3 000 of Scots pine trees annually). The De Marton dryness index was used in evaluation of the effect of drought on Scots pine health. The frequency of Scots pine damage was found to be significantly correlated with the climatic conditions. During the period analyzed, three different stages of mean annual temperature trend were revealed: decreasing (1991–1996), stable or no change (1997–2004), and increasing (2005–2010). Tree damage occurred more often during periods with higher mean temperature and longer periods of drought.

Report of *Chrysoporthe cubensis* Bruner Gryzenhout & M. J. Wingf. in plantations of *Eucalyptus pellita* in the Colombian Orinoquia region. Chocontá, A., Pinzon, O. (*Universidad Distrital Francisco Jose de Caldas, Colombia; victornieto@conif.org.co, Colombia; anagibeth73@hotmail.com; oppinzon78@hotmail.com*), Nieto, V. (*Corporación Nacional de Investigación y Fomento Forestal (CONIF), Colombia; victornieto@conif.org.co*).

Eucalyptus canker is one of the most limiting diseases for *Eucalyptus* cultivation worldwide. In order to characterize the causal agent of the canker observed in commercial stands of *E. pellita* in the Casanare department of Colombia, samples were collected from bark of diseased trees for further study in the laboratory. Several isolates of the fungus were obtained on malt extract agar medium incubated at a constant temperature of 27 °C. The fungus was identified as *Chrysoporthe cubensis* Brunes Gryzenhout & M. J. Wingf. The strains obtained were preserved using the techniques of cryopreservation and lyophilization at the microbiology ceparium of the Universidad Distrital for further molecular characterization. Canker symptoms were observed in the field from the base of the tree to 165 cm high in trees from 7 months to 3 yr old. Although not considered an epidemic attack, this is the first record of *C. cubensis* in commercial plantations of *E. pellita*. Therefore, efforts are needed in breeding programs for *E. pellita* because this species is considered to have high economic potential in the region.

New records of insects associated with seedlings of some forest trees in Sabah, Malaysia. Chung, Y., Richard M., Ong, R., Kuina, K., Eyen, K., Hastie, A. (*Sabah Forestry Department, Malaysia; arthur.chung@sabah.gov.my; richard.majapun@sabah.gov.my; robert.ong@sabah.gov.my; Kuina.Kimjus@sabah.gov.my; eyen.khoo@sabah.gov.my; Alexander.YukLoongHastie@sabah.gov.my*).

Insects can cause considerable damage to their host trees, which may adversely affect tree health and growth. Hence, it is important that documentation of insects associated with various forest trees be continued to provide baseline information from which insect pest profiles of each individual economic tree species can then be compiled. This paper presents some of the new records of insects associated with some of the forest trees in Sabah, Malaysia. The new host plant records include commercial timber trees (*Shorea johorensis, S. ovalis, Vatica rassak*, and *Hopea nutans*), forest trees for restoration of riparian areas (*Nauclea subdita* and *Mitragyna speciosa*), peat swamp forest species (*Gonystylus bancanus*), Bornean endemic dipterocarp (*Shorea symingtonii*), and the Bornean ironwood (*Eusideroxylon zwageri*). All these were recorded at the nursery of the Forest Research Centre, Sepilok, in Sandakan. Life cycle of the insects was monitored and identification was based on the emerged adults.

CONFT-IR spectroscopy identifies coast live oak resistant to *Phytophthora ramorum* before infection. Conrad, A., Rodriguez-Saona, L. (*Ohio State University, USA; conrad.245@osu.edu; rodriguez-saona.1@osu.edu*), McPherson, B., Wood, D. (*University of California, USA; bam23@berkeley.edu; bigwood@berkeley.edu*), Bonello, P. (*Ohio State University, USA; bonello.2@osu.edu*).

Sudden oak death, caused by the introduced oomycete *Phytophthora ramorum,* can be deadly for coast live oak (*Quercus agrifolia*); nonetheless, naturally resistant trees, i.e. those that survive infection, are known to occur in nature. However, identifying resistant trees based on survival may take up to 7–10 years, making management of affected forests extremely challenging

and unpredictable. In this study, Fourier transform infrared (FT-IR) spectroscopy was used to analyze methanol extracts from healthy coast live oak phloem tissue. After tissue collection, trees were inoculated with *P. ramorum* and symptom development was monitored annually in order to classify trees as resistant or susceptible. Using soft independent modeling of class analogy (SIMCA) and partial least squares regression (PLSR), the authors found that spectral frequencies from FT-IR analysis could be used to both discriminate between resistant and susceptible trees, and corroborate qualitative and quantitative analyses of constitutive phenolics using HPLC. This is the first report of the use of FT-IR spectroscopy to identify coast live oak resistant to *P. ramorum* before infection. FT-IR may be a useful tool not only for the management of urban and natural forests affected by sudden oak death, but also for the management of other emerging forest pests and pathogens.

Critical thermal limits for the southern spread of the gypsy moth. Dattelbaum, K. (*Virginia Commonwealth University, USA; kdattelbaum@vcu.edu*), Parry, D. (*State University of New York, USA; dparry@esf.edu*), Tobin, P. (*U.S. Forest Service, USA; ptobin@fs.fed.us*), Agosta, S., Johnson, D. (*Virginia Commonwealth University, USA; sagosta@vcu.edu; dmjohnson@vcu.edu*).

Determining the factors that drive the extent of spatial spread in invasive species is fundamental for mitigating the negative impacts of damaging insect pests to forest ecosystems. For invasive species, climate change could open new habitats to invasion or impose environmental barriers to further spread. The gypsy moth (*Lymantria dispar*) is an invasive folivore in North American hardwood forests and represents one of the best documented biological invasions in the world. Over twenty years of trapping data has revealed extremely dynamic spread rates, with some regions experiencing range expansion while the invasion front in other regions, such as the southeast, is static or contracting. Our work tests the lethal and sublethal effects of maximum temperatures on gypsy moth development and life history traits. We measure the potential for adaptation to novel climates, as well as inherent plastic responses, by testing populations from across the invasion front. This biophysical information will be incorporated into distribution models to explicitly link functional traits with both present and projected environments. Incorporating physiological limits into species distribution studies establishes the mechanistic relationship between climate and species' tolerances and results in more robust predictive models.

Patterns and processes affecting stem borers in subtropical eucalypt plantations. Debuse, V. (*Queensland Department of Agriculture, Fisheries and Forestry, Australia & University of the Sunshine Coast, Australia; vdebuse@usc.edu.au*), Lawson, S. (*Queensland Department of Agriculture, Fisheries and Forestry; Simon.Lawson@daff.qld.gov.au*); Smith, T. (*Queensland Department of Agriculture, Fisheries and Forestry, Australia & University of the Sunshine Coast, Australia; tim.smith@daff.qld.gov.au*), Carnegie, A. (*University of the Sunshine Coast, Australia; angus.carnegie@fcnsw.com.au*).

Longicorn beetles (Coleoptera: Cerambycidae) and cossid moths (Lepidoptera: Cossidae) are insect borers that are major global pests of eucalypt plantations. In Australia, damage from borers and associated fungal invasion can reduce sawlog timber value by up to 90%. Despite this, there has been little research to date on determining the major predictors of the incidence or severity of borer attack. The authors examined site- and landscape-scale drivers of borer damage from both insect families in two plantation species, *Corymbia citriodora* subsp. *variegata* (CCV) and *Eucalyptus grandis*, in Queensland and New South Wales, Australia. Twenty CCV and 19 *E. grandis* plantations were assessed for incidence, severity, and bole height of borer attacks, representing 4 200 CCV and 3 990 *E. grandis* trees in total. Landscape and site predictors were collected for each site through field surveys and from databases and analysed with the borer data to determine the relative importance of each variable in predicting the extent of borer attack. The authors demonstrate the extent to which the risk of borer attack can be mitigated by the grower through improved management protocols and discuss the relative importance of other extrinsic influences that are beyond industry control.

***Phytophthora plurivora*, a new species causing collar rot on *Alnus glutinosa* in Spain.** Diez-Casero, J., Martín-García, J., Martínez-Álvarez, P., Haque, M., Lomba, J. (*University of Valladolid, Spain; jdcasero@pvs.uva.es; jorgemg@pvs.uva.es; pmtnez@pvs.uva.es; mhaque@pvs.uva.es; josemalomba@gmail.com*).

In a survey of *Phytophthora* associated with alder mortality in Castilla y León, Spain, several isolates of a new *Phytophthora* sp. were consistently recovered from necrotic bark of the collar and lower stem of *Alnus glutinosa* by direct plating onto a selective agar medium. The *Phytophthora* species displayed a radiate and slightly chrysanthemum-like growth pattern on V8 juice agar. Mycelial growth of the isolates was optimal at 25 °C; no growth was observed at 32 °C. The isolates were homothallic and produced smooth-walled spherical (very rarely elongated) oogonia with paragynous antheridia, and both plerotic and aplerotic golden brown oospores on V8 juice agar. In non-sterile soil extract, the isolates produced sporangia which were non-caducous, semi-papillate, mainly ovoid and obpyriform, and obovoid to limoniform but sometimes distorted with two apices. The isolates were highly pathogenic to the seedlings of *A. glutinosa* and resulted in wilting and mortality following the under-bark inoculation. The ITS region of the rDNA was amplified, sequenced, and compared with the reference sequence of *Phytophthora plurivora*, showing 100% identity with it and confirming its morphological and physiological identification. This is the first record of *P. plurivora* affecting *A. glutinosa* in Spain.

Status of forest tree diseases in Turkey. Dogmus-Lehtijarvi, T. (*Çankırı Karatekin University, Turkey; tugbadogmus@sdu.edu.tr*), Lehtijarvi, A. (*Bursa Technical University, Turkey; asko.lehtijarvi@btu.edu.tr*), Aday Kaya, G., Oskay, F. (*Çankırı Karatekin University, Turkey; guldenaday@sdu.edu.tr; fundaoskay@sdu.edu.tr*).

Forests in Turkey occupy 21.7 million ha. As a result of afforestation and rehabilitation efforts the total area of forest is increasing while the area of degraded forests is decreasing. Biotic and abiotic stress factors such as disease, drought, windstorms, and wildfire periodically affect forests or specific tree species, leaving dead or weakened trees. The effects of these stresses may be manifested locally or over a larger area, but they do not cause species extinction. Mycological studies of Turkish forests were first started in the 19th century in Istanbul, and this tradition was continued during the 1960s. The first ecological and forest pathological studies were published in the late 1970s. During the last 10–20 years there has been a considerable increase in the number of mycological studies, especially in floristic surveys, which have been carried out in different forest ecosystems. This review aims to summarize the current knowledge about most common forest tree diseases reported in Turkey. Currently, Annosum root rot, European pear rust on juniper, Armillaria root disease, *Phytophthora* dieback on oaks, red band needle blight, Dutch elm disease, Diplodia shoot blight, box blight, chestnut blight, and stem rots are considered the most important forest diseases.

To know a bark beetle: ecophysiological implications for mathematical modeling of bark beetle population dynamics. Dolezal, P., Miklas, B., Bartosova, E., Davidkova, M., Okrouhlik, J. (*University of South Bohemia, Czech Republic; dolezal@entu.cas.cz; b.miklas@centrum.cz; bartyk@seznam.cz); marketadavidkova@seznam.cz; okrouhl@entu.cas.cz*).

In the last three decades, predictive models of bark beetle population dynamics shifted from simple linear models to complex ones that use numerous ecophysiological variables. The authors summarize results of 17 years of research on bark beetle physiology, which not only explain phenomena commonly observed by foresters, but also ensure precise prediction of bark beetle population dynamics in a globally changing environment. Key studied aspects included changes in bark beetle physiology during late summer (related to imaginal diapause), overwintering, flight ability, energy status, reproductive biology (sister-broods), and influence of temperature and day length on voltinism. First, the authors identified the critical day length for diapause induction and temperature threshold preventing beetles from entering diapause regardless of day length. The authors' recent studies describe changes in chemical composition of bark beetles (cold resistance, lipid and carbohydrate reserves), dispersal abilities, and estimated energy used during flight. Finally, a large-scale field study on sister-brood development and comparison of recent and historical data from the 1950s and 1960s has helped to identify the influence of temperature on reemergence rate, reproductive success, and gonadal physiology. Inclusion of all these aspects led to a PHENIPS-based model which increases the efficiency of protective measures against bark beetles.

Two new ophiostomatoid species isolated from soil on snouts of feral hogs damaging pine roots in Georgia, USA. Eckhardt, L., Ditchkoff, S. (*Auburn University, USA; eckhalg@auburn.edu; ditchss@auburn.edu*), Duong, T., de Beer, W., Wingfield, M. (*FABI-University of Pretoria, South Africa; Tuan.Duong@fabi.up.ac.za; wilhelm.debeer@fabi.up.ac.za*, *Mike.Wingfield@up.ac.za*).

The role of wild pigs in dispersing pathogenic fungi during rooting activity is poorly understood in terms of forest pathology. In this study to consider this question, fungal isolates were obtained from soil on the snouts of feral hogs trapped in *Pinus palustris* and *P. taeda* stands in Fort Benning, Georgia. Micromorphology and DNA sequences of the ITS, elongation factor, and beta-tubulin gene regions were used to identify the fungi. Three ophiostomatoid species were identified, of which only one**,** *Ophiostoma sparsiannulatum*, was of a known species**.** The remaining two species will respectively be described as novel taxa in *Ophiostoma sensu lato* and the *Leptographium procerum* species complex. In addition to the discovery of new fungal species, this study shows that wild pigs may reduce tree vigor by causing wounds for soil-borne or insect-vectored pathogen infection, predisposing trees to bark beetle attack and perhaps incidentally introducing phytopathogens during rooting activity.

Winter moth: biological control and population dynamics in the northeastern United States. Elkinton, J., Boettner, G. (*University of Massachusetts, USA; elkinton@ent.umass.edu; boettner@psis.umass.edu*).

The winter moth (*Operophtera brumata*)*,* a leaf-feeding geometrid native to Europe, has recently invaded eastern New England (USA) and is causing widespread defoliation. Previous invasions by this species in Nova Scotia and British Columbia have been suppressed by the introduction of two parasitoids from Europe, the tachinid *Cyzenis albicans* and the ichneumonid, *Agrypon flaveolatum*. As a result of these introductions, low-density populations of winter moth now persist indefinitely in these regions similar to those that exist in Europe. Over the past 8 years the authors have introduced *C. albicans* at 22 locations in Massachusetts, Rhode Island, and Maine. These efforts are focused on *C. albicans* because it specializes on winter moth and it is thought to be the agent primarily responsible for the decline of winter moth densities in Canada. As of this year the authors have established *C. albicans* at seven sites and parasitism levels have been increasing steadily at these sites. The authors have also documented yearly changes of density and survival of winter moth life stages at these sites so that they can explain the yearly fluctuations of density that they have observed and the impact of *C. albicans* with respect to the other sources of mortality in this system.

Evidence of widespread ozone-induced visible injury on plants in Beijing. Feng, Z. (*Chinese Academy of Sciences, China; zhzhfeng201@hotmail.com*), Calatayud, V. (*Fundación CEAM, Spain; calatayud_viclor@gva.es*), Wan, W., Sun, J. (*Chinese Academy of Sciences, China; wan.wx1972@126.com; sunjingsong1@163.com*).

One of the most evident ways to document ozone effects on vegetation is the assessment of ozone-induced visible injury in leaves of sensitive species. Despite the high ozone levels measured in China and in Beijing in particular, impacts on vegetation have scarcely been reported. Several field surveys were conducted in July and August 2013 in the main parks, forests, and agricultural areas of Beijing. Ambient ozone levels were high enough to induce foliar symptoms in more than 25 different species. Ozone symptoms were more frequent in rural areas and mountains in northern Beijing, and less frequent in city gardens. Injury to different types of beans, belonging to different genera, was common and widespread in all the areas. Other affected crops were watermelon, grape vine, and several species of gourds. Among native species, visible injury was common in ailanthus, and it was also observed in pines, ash species, and climbing shrubs such as *Ampelopsis humulifolia*. Ornamental plants such as the black locust (*Robinia pseudoacacia*), the rose of Sharon (*Hibiscus syriacus*), and Japanese morning glory (*Ipomoea nil*) also exhibited ozone symptoms in different Beijing areas.

Photosynthesis and growth response of *Metasequoia glyptostroboides* seedlings to elevated ozone. Feng, Z., Zhang, W., Wang, X. (*Chinese Academy of Sciences, China; zhzhfeng201@hotmail.com; zwwno_1@163.com; wangxk@rcees.ac.cn*).

High ambient ozone (O_3) concentration has frequently been observed in southeast China, especially in the developed subtropical region of the Yangtze River Delta. *Metasequoia glyptostroboides* (Hu and Cheng) is a rare deciduous "living fossil" conifer species widely distributed in subtropical regions not only as a natural forest stand but also an important greening species planted in southern cities of China. In this study, *M. glyptostroboides* was exposed to ambient air (NF) and elevated ozone (E-O_3; NF+60 ppb) for 2 years in open-top chambers, in order to determine whether rising O_3 concentration in the future might negatively affect the growth of this rare species. Results indicated that E-O_3 significantly reduced photosynthetic pigment contents, net photosynthetic rate, maximum carboxylation capacity, and electron transport in both 2009 and 2010. In contrast, E-O_3 only

significantly reduced stomatal conductance (g_s) in 2009; it did not change g_s in 2010. E-O_3 inhibited whole-plant carbon accumulation and distribution over two growing seasons, and significantly decreased leaf dry mass per area and the increments of branch number. The data suggested that the net photosynthetic rate of *M. glyptostroboides* has been significantly decreased by E-O_3 mainly due to reduced carboxylation capacity and electron transport.

Effects of elevated ozone on the injury, growth, and photosynthesis of 10 woody species widespread in Beijing. Feng, Z., Zhang, Y. (*Chinese Academy of Sciences, China; zhzhfeng201@hotmail.com; 373862305@qq.com*), Yuan, X. (*Beijing Technology and Business University, China; windy_yuan0904@126.com*), Calatayud, V. (*Fundación CEAM, Spain; calatayud_viclor@gva.es*), Yang, T. (*Beijing Technology and Business University, China; sdjdytt@126.com*), Gao, F.

Tropospheric ozone (O_3) is considered one of the most critical air pollutants for forests due to its detrimental effects on carbon sequestration and forest health. Very little is known about the effects of O_3 on forest species from Asia. Due to rapid urbanization in China, ambient O_3 concentrations in some cities reach phytotoxic levels, causing visible injury in many herbs and woody species. The study of responses to O_3 of representative woody species from suburbs and cities is therefore important in order to assess effects on carbon sequestration in the urban forest ecosystem. For this study, 1-year-old seedlings were selected from 10 woody species: *Acer truncatum, Ailanthus altissima, Fraxinus chinensis, Hibiscus syriacus, Koelreuteria paniculata, Platanus orientalis, Prunus davidiana, Robinia pseudoacacia, Sophora aureus,* and *Ulmus pumila*. Plants were exposed in open-top chambers to five O_3 treatments: non-filter ambient air (NF), NF+20 ppb, NF+40 ppb, NF+60 ppb, and NF+80 ppb for 4.5 months. During fumigation, visible injury evolution was assessed every week, and growth and chlorophyll content were measured each month. Foliar photosynthesis was measured in August and October. At the end of fumigation, all plants were harvested and separated into root, stem, leaves, and branches. These results will be presented.

Variation in susceptibility of native Scottish Scots pine populations to infection by *Dothistroma septosporum*. Fraser, S. (*University of Aberdeen, UK; sfraser@abdn.ac.uk*), Brown, A. (*Forest Research UK, UK; anna.brown@forestry.gsi.gov.uk*), Woodward, S. (*University of Aberdeen, UK; s.woodward@abdn.ac.uk*).

Artificial inoculations and field infections were used to determine the relative susceptibility of six Scottish *Pinus sylvestris* populations to infection and damage by the needle blight pathogen *Dothistroma septosporum*. Field infections were monitored for 2 years (2012 and 2013) on trees planted at two sites, Culbin in north-east Scotland and Torrs Warren in south-west Scotland. In field experiments, site, year, and population significantly affected disease severity. There was also a significant interaction between site and population. In both years the greater disease severity was seen at Torrs Warren, the site with the higher level of summer precipitation. At both sites, disease severity was significantly greater in 2012, a year with an abnormally wet summer. Population had a significant effect on disease severity in 2012, when overall disease levels were high, but different patterns of relative susceptibility were seen at the two sites. At Culbin, trees from Benn Eighe showed the most infection; however, at Torrs Warren, plants sourced from Glen Carrich, Glen Loyne, and Abernethy were most severely affected. Results of the artificial inoculations were similar to those seen at Torrs Warren in 2012, the greatest disease severity being observed on plants from Glen Cannich and Glen Loyne.

Socioeconomic assessment of the impact of the red palm mite on the Nariva Swamp of Trinidad and Tobago. Garcia, M., Seepersad, G. (*University of the West Indies, Trinidad and Tobago; marc.garcia@sta.uwi.edu; govind.seepersad@uwi.sta.edu*), Bossenbroek, J. (*University of Toledo, USA; jmbossen@gmail.com*).

In 2006, the red palm mite (*Raoiella indica* Hirst) was marked as officially established in Trinidad and Tobago. The mite is a great threat to terrestrial biodiversity and is of particular concern in palm populations. Locally, the coconut palm (*Cocos nucifera*) has been the most affected. The Nariva Swamp in Trinidad, a designated Ramsar site, is home to a large population of palms. The impact of the red palm mite on this ecosystem is both direct and indirect. Its direct impact includes declining yields of coconuts and resulting increased market prices. Indirect impacts of this invasion include the loss of non-market ecosystem goods and services, such aesthetic value, biodiversity, and demand for recreational services. This study was aimed at estimating the indirect costs of invasion by the mite. Two methods were used to estimate its non-market impacts: contingent valuation and travel cost method of valuation. These data were collected through questionnaires, both on and off the study site. Most of the population was unaware of the mite and its effect but willing to pay to conserve the swamp's biodiversity. The authors suggest increased spending on awareness campaigns and removal efforts.

Population genetics reveals the origin of the *Coryphodema tristis* host expansion to *Eucalyptus nitens* in South Africa. Garnas, J., Degefu, D., Hurley, B., Wingfield, M., Slippers, B. (*FABI-University of Pretoria, South Africa; jeff.garnas@fabi.up.ac.za; dawit.degefu@fabi.up.ac.za; brett.hurley@up.ac.za*, *mike.wingfield@fabi.up.ac.za; Bernard.Slippers@fabi.up.ac.za*).

Emerging pests resulting from novel host associations between native pests and nonnative, commercially propagated trees represent a growing threat to global plantation forestry. Population genetics offers opportunities to better understand the patterns and processes linked to host use and range expansion. The source of the *Coryphodema tristis* (Lepidoptera:Cossidae) infestation of *Eucalyptus nitens* was investigated using mitochondrial cytochrome oxidase I (COI) sequence and amplified fragment length polymorphism (AFLP) data. Individuals of *C. tristis* collected from *E. nitens* plantations in Mpumalanga and *Vitis vinifera* in the Western Cape were analyzed together with museum specimens (COI only) from across South Africa. Fourteen COI haplotypes were obtained from 135 sequenced individuals, including two from contemporary *E. nitens* populations that showed high sequence similarity to a dominant haplotype collected throughout South Africa. AFLP analyses revealed minimal genetic diversity from samples on *E. nitens* with no structure among seven subpopulations spanning 90 km. Samples from *V. vinifera* were clearly distinct based on AFLP markers and COI. Results suggest that the infestation of *E. nitens* reflects recent movement from local populations, and that such events of host range expansion are rare. Host expansion onto Eucalyptus was independent of the colonization of grapevine in South Africa.

Impacts of variation in resource quality for larvae of the European woodwasp (*Sirex noctilio*) in South African *Pinus patula* plantations. Garnas, J., Termer, K., Hurley, B. (*FABI-University of Pretoria, South Africa; jeff.garnas@fabi.up.ac.za; katie.termer@fabi.up.ac.za; brett.hurley@up.ac.za*).

Variation in resource quality can influence oviposition choice, growth and survival, and ultimately population dynamics. The authors examined biotic and abiotic determinants of body size and sex ratio in *Sirex noctilio,* the globally invasive European pine woodwasp. Sex ratio has been observed to be highly male biased (>10:1) with female adult body size varying up to fourfold. Careful dissections of *S. noctilio*-infested logs collected at three time points during the larval developmental period were examined to understand how natural variation in factors hypothesized to correlate with resource quality may influence age and gender-specific larval growth and survival. Specifically, the authors investigated the role of wood moisture, tree section, larval density, sapstain abundance, and density of co-occurring insects on larval growth rate, survival, and resource use efficiency. Preliminary analyses indicate that larval mass is uniformly low at high larval densities, consistent with intraspecific competition. Growth rate increased as moisture increased, and male bias decreased. Effects on sex ratio appear to result from female oviposition choice as larval mortality was low. Larval resource use efficiency does not appear to be influenced by any of the factors considered. These findings form part of a more comprehensive understanding of resource quality from the perspective of *Sirex* larvae.

Linking phylogeographic history, niche divergence, and biological invasion risks: the case of North American *Dendroctonus* bark beetles. Godefroid, M., Rasplus, J., Rossi, J. (*National Institute for Agricultural Research (INRA), France; martin.godefroid@supagro.inra.fr; rasplus@supagro.inra.fr; jean-pierre.rossi@supagro.inra.fr*).

Species often display geographically structured intra-specific diversity resulting from past geologic and climatic events. Such phylogeographic histories may—or may not—have led to actual intra-specific niche divergences. Species distribution models (SDMs) depict the realized niche by linking species occurrences to environmental descriptors and are widely used to assess the risk of biological invasion. However, these SDMs are usually constructed at the species level without considering the potential differences between phylogeographic lineages. In the present work, the authors investigate how much their estimation of risk changes as the phylogeographic structures are accounted for while elaborating the SDMs. They tackle the question at a continental scale and consider five bark beetle species of the genus *Dendroctonus* which are among the most destructive organisms of North and Central American conifer forests. The focus is on their potential distribution in Europe and the associated risk. Results reveal that distinct phylogeographic lineages correspond to partially non-overlapping potential distributions in Europe. As a result, species-level niche models generally underestimate the potential range of *Dendroctonus* species in Europe. The authors conclude that risk assessment should rely upon SDMs incorporating phylogeographic structures whenever possible.

Updated list of Scolytid species occurring in commercial tree plantations in Uruguay. Gómez, D., Martinez, G. (*Instituto Nacional de Investigación Agropecuaria, Uruguay; dgomez@tb.inia.org.uy; gmartinez@tb.inia.org.uy*).

Commercialization of wood packing and plant materials, together with climate change, has led to an increased dispersion of pests and diseases worldwide, causing the colonization of new areas by bark and ambrosia beetles. In this context, it becomes necessary to work toward identifying new invasive species of scolytids. A dramatic increase in tree plantations began in Uruguay in the 1990s after a new forestry law went into force in the country, leading to more than 1 million ha forested with exotic trees (mostly *Eucalyptus* spp. and *Pinus* spp.) to date. In December 2009, after a severe drought episode, high mortality was recorded on pine tree stands during the first economically significant outbreak of bark beetles recorded in the country. Here the authors present an updated list of bark and ambrosia beetles recorded in commercial tree plantations in Uruguay, after 3 years of surveying. Bark and ambrosia beetles are part of the fauna commonly occurring in pine tree and eucalyptus plantations in Uruguay. Beetle species mainly belong to Dryocoetini, Ipini, Hylesinini, and Xyleborini.

Modeling stomatal ozone deposition in Mediterranean annual pastures using a multilayer-multispecies model. González-Fernández, I., Calvete-Sogo, H. (*Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Spain; ignacio.gonzalez@ciemat.es; hector.calvete@ciemat.es*), Büker, P., Briolat, A. (*University of York, UK; patrick.bueker@york.ac.uk; alan.briolat@york.ac.uk*), Elvira, S., Sanz, J. (*Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Spain; susana.elvira@ciemat.es; j.sanz@ciemat.es*), Emberson, L., Bermejo, V., Alonso del Amo, R.

Risk assessment of ozone effects on vegetation within the framework of the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) is increasingly being based on modeled stomatal ozone deposition. Current models used to calculate ozone deposition fluxes represent the vegetation surface as a big leaf placed at the top of the canopy. However, this approach presents some limitations when used in species-rich plant communities with complex canopies like those of pastures. Species coexisting in the pasture have different gas exchange rates and sensitivity to ozone, affecting the deposition of ozone to individual components and its potential effects for sensitive species. A multilayer-multispecies model designed at the Stockholm Environment Institute, University of York, based on the existing deposition of ozone for stomatal exchange (DO_3SE) model used within the CLRTAP, has been parameterized using a 3-year-long database of meteorological variables, ozone concentration, and pasture physiological measurements on a Mediterranean annual pasture in Spain. Ozone fluxes were also calculated using the same approach for an ozone fumigation experiment in open-top chambers aiming at relating ozone stomatal fluxes to effects observed in the experiments. The ultimate goal of this study is deriving improved methodologies and novel ozone critical levels useful for risk assessment.

Characterizing Great Basin bristlecone pine tree chemistry. Gray, C., Jenkins, M. (*Utah State University, USA; curtis.gray@aggiemail.usu.edu; mike.jenkins@usu.edu*), Runyon, J. (*U.S. Forest Service, USA; jrunyon@fs.fed.us*).

Great Basin bristlecone pine (GBBP) typically co-occur with other similar pine species in the same ecological niche, such as Limber pine. Limber pine may be infested with mountain pine beetle (*Dendroctonus ponderosae* Hopkins), yet pine beetle has not been observed to infest GBBP. The authors hypothesize that the attraction of beetles could be due to differences in monoterpenes

between the two species. Terpenes are the main constituents of plant essential oils and resins and include all chemically modified forms such as terpenoids. Terpenes have a wide array of uses both ecologically and commercially and are known to play important roles in plant defenses against insect herbivory. Tree chemistry from temporal and spatial gradients at two sites in Nevada, USA, were quantified and compared at 2-hr increments once per month throughout summer 2013. Results revealed peaks in certain airborne volatile terpene compounds emitted from the trees needles. Preliminary analysis of airborne terpenes showed the presence of beta-myrcene, 3-carene, and beta-phellandrene in Limber pine, which previous studies have shown may be bark beetle attractants. These terpenes were all absent in the sampled GBBP.

Biotic and abiotic factors associated with large-scale die-off of a Eucalyptus clone in Zululand, South Africa. Greyling, I. (*FABI-University of Pretoria*, *South Africa; izette.greyling@fabi.up.ac.za*), van den Berg, G., Harrison, I., da Costa, D. Pienaar, B. (*Mondi, South Africa; gert.vandenberg@mondigroup.co.za; ian.harrison@mondigroup.co.za; dean.dacosta@mondigroup.co.za; ben.pienaar@mondigroup.co.za*), Mphahlele, M., de Beer, W., Wingfield, M., Roux, J.

Large-scale death of a single plantation-grown *Eucalyptus grandis x urophylla* clone was first reported in 2010 from the Zululand region in South Africa. Mortality occurred in patches that expanded rapidly, with up to 90% mortality reported in some areas. Sites on which the die-off has occurred differ across age and site classification classes. Prior to tree death, symptoms include foliage yellowing and death, internal staining of the vascular tissue, presence of ambrosia beetle tunnels, or a combination thereof. Eight different species of ambrosia beetles have been identified and various isolation techniques have been used to identify potential pathogens that they might carry. Various fungi and bacteria have also been isolated from dying trees, where all tree parts have been thoroughly considered. Despite intensive sampling and investigation, no clear cause of the mortality has been found. For the present, there are indications are that mortality is due to a complex interaction between biotic and abiotic factors. The fact that this problem has occurred on only one of many clones cultivated is intriguing and emphasises how little is known regarding the long-term health prospects for intensively propagated *Eucalyptus* clonal hybrids.

The role of drought and stand density in Jeffrey pine susceptibility to the Jeffrey pine beetle. Grulke, N., Graves, A., Seybold, S. (*U.S. Forest Service, USA; ngrulke@fs.fed.us, adgraves@fs.fed.us*, *sjseybold59@gmail.com*).

Drought and stand density are cited repeatedly as the primary causes of bark beetle outbreaks. However, the level of physiological drought stress and competition experienced is typically inadequately defined and measured. This research tested the roles of physiological drought stress and stand density in Jeffery pine (*Pinus Jeffreyi*) in five national forests over 3 years along an 85-km north-south latitudinal gradient on the eastern slope of the Sierra Nevada and Transverse Range (USA). Metrics used for competition were stand density (standard) and distance to nearest neighbor (con- and interspecific). Metrics for drought stress included needle and phloem water potential (pre-dawn and noon total, osmoticum, turgor water potential). In addition, resin quality and resin exudation rates were evaluated in the context of attacks by Jeffrey pine beetle (*Dendroctonus jeffreyi*). Physiological drought stress of needles was correlated with bole phloem turgor potential and with attack by *D. jeffreyi* and woodborers, but inversely correlated with resin flow rates. At all sites, tree drought stress was correlated with low percentage of annual average precipitation, but was greater in dense stands only at the northernmost site. Overall, attacked Jeffrey pines were closer to another single tree (i.e., higher tree-tree competition), but had fewer trees within their spheres of influence (i.e., lower density stands).

A mobile application and citizen science to monitor incidence and severity of Marri *Quambalaria coyrecup* cankers in Australia. Hardy, G., Marbus, C., Burgess, T., Paap, T. (*Murdoch University, Australia; g.hardy@murdoch.edu.au; c.marbus@murdoch.edu.au; t.burgess@murdoch.edu.au; t.paap@murdoch.edu.au*).

The incidence and severity of cankers caused by *Quambalaria coyrecup* in marri (*Corymbia calophylla*) have increased significantly in southwestern Australia since the early 1990s. Marri is an iconic overstorey forest tree across a number of forest ecosystems. It is a major food source, habitat tree, and refugium for numerous fauna, including the endangered Carnaby's cockatoo (*Calyptorhynchus latirostris*), as well as a "staple species" for apiarists. Consequently, the impact of the pathogen on marri is causing widespread concern across the community for many reasons. The authors have developed an application that works across mobile platforms (e.g., IPhone and Android) that is being used by interested members of the public, local government agencies, foresters, and scientists to capture location (GPS), incidence, and severity of cankers on trees, and upload photographs and other site information to a central server. The "Marri App" also informs users on what a canker looks like at different stages of development. Importantly, it also provides information on how to establish and monitor trials including fungicide and other treatment trials that will be statistically robust and informative for scientific purposes. The importance and power of the "Marri App" for information dissemination, community engagement, and citizen science will be discussed.

Host colonization behavior of the walnut twig beetle, *Pityophthorus juglandis* (Coleoptera: Scolytidae): implications for the worldwide cultivation of walnut trees. Hishinuma, S., Flint, M., Bostock, R. (*University of California, USA; chlorinated@gmail.com; mlflint@ucdavis.edu; rmbostock@ucdavis.edu*), Seybold, S. (*U.S. Forest Service, USA; sjseybold59@gmail.com*).

Thousand cankers disease of walnut (*Juglans* spp.) is caused by the fungal pathogen *Geosmithia morbida*, which is vectored by the walnut twig beetle (*Pityophthorus juglandis*; WTB). The disease has been reported from walnut species throughout the United States and threatens walnut trees worldwide. Disease severity appears to be governed by susceptibility of trees to attack by WTB or to canker formation following *G. morbida* infection. The authors studied the early stages of WTB host colonization behavior in a walnut germplasm collection of 16 species and hybrids (1 500 trees) in Solano County, California. Landing rates were assessed on unbaited branches of live trees (May–October, 2012–2013) and on aggregation pheromone-baited cut branch sections (September–October 2013). In both cases, clear plastic sheets coated with Stikem Special were used as cylindrical traps. Higher landing rates were recorded on unbaited and baited branches of *J. californica* and *J. hindsii*, two black walnut species native to California. Both *J. regia* (unbaited), used for commercial nut production, and *J. nigra* (baited), a valuable timber species with extreme susceptibility to the disease, elicited lower landing rates than the California species. These results suggest visual, tactile, or chemical cues may allow WTB to distinguish hosts prior to fully penetrating the bark.

Eastern hemlock-dominated forest ecosystems of northeastern Ohio and possible changes with the impending infestation by the hemlock woolly adelgid. Hix, D. (*Ohio State University, USA; hix.6@osu.edu*), Macy, T., Goebel, C., Matthews, S. (*Ohio Department of Natural Resources, USA; thomas.macy@dnr.state.oh.us; goebel.11@osu.edu; matthews.204@osu.edu*).

Eastern hemlock (*Tsuga canadensis* (L.) Carr.) is a foundation tree species of forest ecosystems in the eastern United States. Since its accidental introduction in 1951, hemlock woolly adelgid (*Adelges tsugae* Annand; HWA) has caused widespread mortality of eastern hemlock in an expanding portion of its range; the adelgid is expected to reach northeastern Ohio within decades. To establish pre-infestation characterization of forest composition, the authors sampled the two main types of hemlock forests in that area, collecting vegetation and environmental data from seven mature stands. Principal components analysis showed clear separation between the two physiographic regions based on slope percent and slope position. Although multi-response permutation procedure (MRPP) detected a significant difference in the seedling stratum between physiographic regions, MRPP did not detect differences in the overstory, sapling, or ground-flora. Redundancy analysis revealed species-environment relationships consistent with species life-history traits and habitat requirements. The Forest Vegetation Simulator-HWA Event Monitor was then used as a forecasting tool, suggesting the potential for an 80% reduction in the basal area of eastern hemlock 30 years following HWA infestation in both regions. This research alerts forest managers to the potential loss of this foundation species, resulting in drastic alterations of forest composition, structure, and functional processes.

Nitrogen deposition and critical loads for Sierra Nevada (USA) forests: a comparison of measurement techniques and ecosystem responses. Hunsaker, C., Bytnerowicz, A. (*U.S. Forest Service, USA; chunsaker@fs.fed.us; abytnerowicz@fs.fed.us*), Johnson, D. (*University of Nevada, USA; forestrangesoils@gmail.com*), Fenn, M., Jovan, S. (*U.S. Forest Service, USA; mfenn@fs.fed.us; sjovan@fs.fed.us*).

Forest health is affected by nitrogen deposition and processing, and critical loads have been suggested for ecoregions of the United States. The Kings River Experimental Watersheds, run by the U.S. Forest Service, provides a long-term mountain research site for comparison of chemical sampling techniques and ecosystem responses, including stream water quality, soils, and lichens over a 10-year period. A lichen survey and 5 years of air-concentration sampling with passive filters provide an extensive sampling array. Wet deposition is sampled at one location as part of the National Atmospheric Deposition Program. More intensive sampling occurs within eight experimental watersheds that cover 990 ha; ion-exchange resin samplers provide annual N fluxes to the ground and shallow mineral soils at 460 points. At two locations, a different type of resin sampler provides comparison data for wet and dry season deposition. At 3–5 kg/ha/yr sensitive lichen species are adversely affected in the Sierra Nevada; at 17 kg/ha/yr N leaching is expected. Above-ground resin samplers indicate annual loadings of 5–11 kg/ha. Soil leachate fluxes range from 2–3 kg/ha in 2004 to 6–20 kg/ha in 2008. Both spatial and between-year variations have been large and will be discussed.

First releases of *Selitrichodes neseri*, a new biological control agent for the eucalyptus gall wasp, *Leptocybe invasa*. Hurley, B., Baffoe, K., Slippers, B., Garnas, J., Wingfield, M. (*FABI-University of Pretoria, South Africa University of Pretoria, South Africa; brett.hurley@up.ac.za; kwabena.baffoe@fabi.up.ac.za; Bernard.Slippers@fabi.up.ac.za; jeff.garnas@fabi.up.ac.za; mike.wingfield@fabi.up.ac.za*).

Selitrichodes neseri (Hymenoptera: Eulophidae), a recently described parasitic wasp of an invasive Eucalyptus pest, *Leptocybe invasa* (Hymenoptera: Eulophidae), was recently released in South Africa as a biological control agent. This was the first release of this wasp outside its native range of Australia. To assess establishment success, 10 release sites were monitored across the regions of South Africa where *Eucalyptus* spp. are extensively cultivated. Branches were collected from nine trees per site, radiating from the release tree. Surveys were repeated every 3 months. Collected material was stored in plastic emergence boxes and emergences of *L. invasa* and *S. neseri* monitored for 4 weeks. A year after the first releases, *S. neseri* adults were consistently recaptured from all the release sites. In addition, the sampling data reveal that *S. neseri* is gradually spreading farther outwards from the release trees. Parasitism rates were expectedly low, but have been increasing over time. Surveys are being continued to understand the rate of establishment and the factors that influence establishment.

Global patterns of diversity of the Sirex-Amylostereum-Deladenus symbionts and their implications for control. Hurley, B., Slippers, B., Mlonyeni, X., Fitza, K., Wooding, A. (*FABI-University of Pretoria, South Africa University of Pretoria, South Africa; brett.hurley@up.ac.za; Bernard.Slippers@fabi.up.ac.za; osmond.mlonyeni@fabi.up.ac.za; Katrin.Fitza@fabi.up.ac.za; amy.wooding@fabi.up.ac.za*), Garnas, J., Wingfield, M., Boissin, E., Postma, A.

A number of studies over the past 15 years have attempted to reconstruct the introduction and invasion history of *Sirex noctilio* and *Amylostereum areolatum*, as well as their parasites, which are used in biological control programs. These studies have been hampered by poor collection of the organisms from native areas, as well as by a lack of tools for studying their diversity and relationships. However, there has been considerable improvement in the quality of these collections and the tools for analyzing the associated data. It is now clear that there is a complex history of introduction, and reintroduction, of the woodwasp in many parts of the world, which is in contrast to the limited extent of introductions of parasitoids. There is consequently a broad discrepancy in diversity between the parasites and their hosts, which are important factors in biocontrol programs. The completion of the genome sequences of *S. noctilio*, *A. areolatum*, and the parasitic nematode, *Deladenus siricidicola*, offers unprecedented opportunities to better characterize the patterns and consequences of co-evolution and rapid evolutionary changes in non-native environments. Such insights promise to increase the understanding of the biology of these organisms and will likely offer novel avenues for control.

Genetic diversity of the deodar weevil, *Pissodes nemorensis* (Coleoptera: Curculionidae), in its introduced range in South Africa. Hurley, B. Wondafrash, M., Garnas, J., Slippers, B.(*FABI-University of Pretoria, South Africa; brett.hurley@up.ac.za; mesfin.gossa@fabi.up.ac.za; jeff.garnas@fabi.up.ac.za; Bernard.Slippers@fabi.up.ac.za*).

The deodar weevil (*Pissodes nemorensis*) is native to North America and has been introduced to Russia, Japan, and South Africa. It causes significant damage to pines, cedars, and spruces and has also been associated with various fungal pathogens of pines. In

South Africa *P. nemorensis* was first detected in 1942 on pine trees in the Port Elizabeth area. It has subsequently spread throughout the major pine-growing regions of the country and occurs on all commercially grown pine species, most likely because of the widespread movement of timber throughout the country and the capacity of the weevil to fly long distances. In this study the authors ask whether the current populations of *P. nemorensis* in South Africa are the result of a single or multiple introductions. These scenarios are expected to lead to different patterns of population genetic diversity, and might even have resulted in the introduction of cryptic species. To address these questions, cytochrome oxidase I (CO-I) gene sequence data and microsatellite markers are being used to characterize the genetic diversity of *P. nemorensis* samples collected across the major pine-growing regions in South Africa. The data collected during this study are important to consider when attempting to improve management of this pest.

Advances in the knowledge of *Eucalyptus* gall insects in Uruguay: current status and future prospects. Jorge, C. (*Universidad de la Republica, Uruguay; carolina.jorge@cut.edu.uy*), Gómez, D., Martinez, G. (*Instituto Nacional de Investigación Agropecuaria (INIA), Uruguay; dgomez@tb.inia.org.uy; gmartinez@tb.inia.org.uy*), Reyna, R. (*UPM-Forestal Oriental, Uruguay; rossana.reyna@upm.com*).

Uruguay has 1 million ha forested with exotic species, and 75% of this area is in *Eucalyptus* plantations. A national silvicultural practice characterized by large-scale plantations with monocultural stands makes it mandatory to carry out phytosanitary surveillance to prevent the entrance of new pests. A significant increase in insect invasions on *Eucalyptus* production areas has been observed in recent years. Gall-forming insects cause concern because of the risk they pose to young plantations. *Leptocybe invasa* Fisher & La Salle (Hymenoptera: Eulophidae) is considered one of the most invasive species reported in *Eucalyptus*. It colonized the region in 2008 when it was found in Brazil. It was officially reported in Uruguay in 2013. Although no economic losses have been recorded in Uruguay to date, it is considered a serious problem in Brazil and Argentina. Current studies on gall-forming insects in *Eucalyptus* are scarce in Uruguay. In order to develop management strategies for this species and others in this guild, a national survey has been implemented, and studies on bioecology and species distribution are ongoing.

Siberian pine mortality in the Southern Siberian Mountains. Kharuk, V. (*Sukachev Institute of Forest, Russian Federation; kharuk@ksc.krasn.ru*).

The causes and spatial patterns of Siberian pine mortality were analyzed based on satellite and dendrochronology data. Climate variables studied included temperature, precipitation, and drought index. Stand mortality was first detected in the year 2006 at an elevation of 650 m, and extended up to 900 m by the year 2012. The area of dead stands and the upper mortality line were correlated with increased drought. The uphill margin of mortality was limited by elevational precipitation gradients. Greatest mortality occurred on southern slopes within a 10–30° slope range and on convex terrain. Tree radial increment was correlated with drought index ($r^2 = 0.37$). The results showed the primary role of drought stress on stand mortality. A secondary role was played by bark beetles and root fungi attacks. The observed Siberian pine mortality is part of a broader phenomenon of "dark needle conifer" (DNC: Siberian pine, fir, and spruce) decline in European Russia, Siberia, the Russian Far East, and Belorussia. In addition, birch mortality was documented in the Trans-Baikal area. All locations of stand mortality coincided with areas of observed increases in drought. With increased aridity, DNC within the southern part of its range may be replaced by drought-resistant *Pinus silvestris* and *Larix sibirica*.

Heavy economic damage due to rot pathogen *Heterobasidion annosum s.l.* in close-to-nature managed Norway spruce forests in the Italian Alps. La Porta, N. (*Edmund Mach Foundation (MOUNTFOR), Italy; nicola.laporta@fmach.it*), Battistel, G., Gori, Y. (*Edmund Mach Foundation (FEM-IASMA); gianantonio.battistel@fmach.it; yuri.gori@fmach.it*).

Root and butt rot pathogens are important fungi that affect the forest carbon sequestration by destroying the root and stem wood of forest trees, by predisposing the forest to windfalls, and by limiting tree growth. *Heterobasidion annosum sensu lato* is the main pathogen affecting conifers in the Northern Hemisphere. The incidence of natural infection of *Heterobasidion* spp. and economic damage were recorded in Norway spruce (*Picea abies*) forests in the Central-Eastern Italian Alps. About 1 900 trees were sampled from 63 transects in pure stands of Norway spruce or mixed stands dominated by Norway spruce. Results showed that the pathogen was present in most of the transects, though with different incidence. All three species of *Heterobasidion* were found in the study, but only one or two species were found in any given transect. The percentage of trees infected in each transect differed remarkably, ranging from 39 to 100%. The average percentage of infected stump surface differed between transects, ranging from about 10 to 49%. This study shows the recurrent and heavy presence of *H. annosum* in Alpine forests and the surprisingly heavy damage caused by this fungus. The ecological role of this pathogen and its economic impact are discussed.

***Cephalcia arvensis* defoliation on Norway spruce: a case study analysis by tree-rings and stable isotopes approach.** La Porta, N. (*Edmund Mach Foundation (MOUNTFOR), Italy; nicola.laporta@fmach.it*), Gori, Y., Camin, F (*Edmund Mach Foundation (FEM-IASMA), Italy; yuri.gori@fmach.it; federica.camin@fmach.it*), Carrer, M. (*University of Padova, Italy; marco.carrer@unipd.it*), Battisti, A. (*University of Padova, Italy; andrea.battisti@unipd.it*).

This paper focuses on carbon and oxygen stable isotopes in conjunction with tree-ring chronologies to investigate the short- and long-term effects of *Cephalcia arvensis* defoliation on *Picea abies*. The authors found massive growth loss and significantly different carbon and oxygen stable isotope patterns associated with insect feeding; while carbon isotope values increased, oxygen isotope values decreased in the defoliated trees. Depletion of $\delta^{18}O$ reached its peak of –22.8‰ (1989), coinciding with the year of highest growth loss. The values in defoliated trees were close to those in control trees (1990), 2 years before complete growth recovery (1992). The depletion of $\delta^{18}O$ started 1 year ahead of growth reduction, whereas ^{18}O enrichment started 1 year before growth recovery. The authors hypothesized that a period of severe drought in the outbreak area before the insect attack may have caused the trees to mobilise reserve starch, which made trees more susceptible to *Cephalcia* attack as a result of increased soluble sugars and aminoacids concomitant with the direct effect of high temperature and dry weather on the insect populations. Moreover, the carbon and oxygen isotope patterns could be explained by both an increase in photosynthetic rate and a resort to starch reserves following insect feeding.

Responses of urban forests to environmental stress. Liu, Z., He, X., Chen, W. (*Chinese Academy of Sciences, China; forestry83@gmail.com; forestry63@gmail.com; fangbing_219900@163.com*).

Environmental stress, such as heavy metal contamination and greenhouse gas emissions, is becoming increasingly serious as urbanization intensifies. More attention is being paid to the influence of environmental stress on urban forests, because it poses a great risk to the sustainability of the urban environment and to human health. The present study, which is based on previous studies by this research team, reviews control of contamination sources, chemical speciation, and distribution of environmental stress. The physiological and biochemical responses of different urban forest plants to environmental stress are studied. Different methods and principles of remediation technologies for urban environmental stress are proposed.

Modeling forest insect distributions in Europe under climate change scenarios. Lyytikäinen-Saarenmaa, P., Saarenmaa, H. (*University of Helsinki, Finland; paivi.lyytikainen-saarenmaa@helsinki.fi; hannu.saarenmaa@uef.fi*), Fetyukova, Y. (*University of Eastern Finland, Finland; yuliya.fetyukova@uef.fi*), De Giovanni, R. (*Reference Center on Environmental Information, Brazil; renato@cria.org.br*), Williams, A. (*University of Manchester, UK; alan.r.williams@manchester.ac.uk*), Kulawik, R., Obst, M.

Climate change effects on distributional shifts of forest insects are still unclear. A predictive approach is a key to estimate the effect on forest ecosystems. Ecological niche modeling (ENM) is a technique for analysing distributional changes of organisms, such as spread of invasive species. Less work has been carried out on economically important species, such as forest pest insects. Such analyses require modeling the effect of host tree species, which is still difficult with current ENM tools. The authors present an analysis of distribution shifts of major European forest pest insects under climate change scenarios. This involves modeling their historical and future distribution, and using the predicted host tree distributions as environmental layers. Both Global Biodiversity Information Facility (GBIF) occurrences and forest damage reports from the European Forest Institute (EFI)-Alterra Database of Forest Disturbances in Europe were used. Workflow tools of the BioVeL project (see www.biovel.eu) were used. The predictions showed that damage by most major forest pests will spread about 500 km towards the northeast with extended occupation of suitable habitats by the year 2050. However, much uncertainty lies in how far the host trees will actually be capable of moving or being planted, and in the role of other drivers affecting forest insects.

Impact of nitrogen fertilizer factory pollution on ground vegetation of pine forests in Lithuania. Marozas, V., Augustaitis, A. (*Aleksandras Stulginskis University, Lithuania; vitas.marozas@asu.lt; algirdas.augustaitis@asu.lt*).

The present study aimed at an evaluation of species composition and abundance of understory vegetation of pine-dominated forests affected by nitrogen fertilizer factory pollution (JSC Achema, Lithuania). Ten sampling plots were established at different distances from the factory in the direction of the prevailing wind. Mature stands of Scots pine (>100 yr old) on fresh, low-fertility soils were selected for sampling of vegetation. Assessment of herbaceous plants was done in early July 2011. Ellenberg indicator values were used to evaluate how vegetation differed with distance from the fertilizer plant. Results showed that the total number of species of herbaceous plants decreased from 37 to 28 species as distance from the fertilizer factory increased. In the study plots located closest to the factory (3 and 5 km) the dominant species were *Oxalis acetosella* L., *Rubus idaeus* L., *Impatiens parviflora* DC., and *Chelidonium majus* L. Farther from the factory abundance of nitrophilic species declined; and at 9.2 km from the factory species characteristic to pine forests, such as *Vaccinium myrtillus* L. and *V. vitis-idaea* L. dominated. Moss species such as *Hylocomium splendens* (Hedw.) Schimp. and *Pleurozium schreberi* (Brid.) Mitt. dominated in all study plots. Ellenberg indicator values for nitrogen and pH decreased with increasing distance from the factory.

Seasonal dynamics of the bronze bug (*Thaumastocoris peregrinus*) on *Eucalyptus* spp. plantations after 4 years of monitoring. Martinez, G., Gómez, D. (*Instituto Nacional de Investigación Agropecuaria, Uruguay; gmartinez@tb.inia.org.uy; dgomez@tb.inia.org.uy*), Centurión, C., Reyna, R., (*UPM-Forestal Oriental, Uruguay;rossana.reyna@upm.com*), González, A., Amaral, L. (*Montes del Plata, Uruguay; alejandro.gonzalez@montesdelplata.com.uy; laura.amaral@montesdelplata.com.uy*), Regusci, A.

The bronze bug is a major pest of Eucalyptus tree plantations worldwide. The first outbreak of this species in Uruguay was reported in summer 2008. Soon after that, a monitoring network was installed throughout the country by using yellow rectangular sticky traps (10 cm × 12.5 cm) attached to a tree trunk at 1.80 m and replaced monthly. Five to nine traps were established in more than forty monitoring stations on forestry plantations covering different ages, densities, and Eucalyptus species. Here results are shown for 4 years of monitoring in two permanent monitoring stations. Captures start to increase by the end of October, reaching a peak in late summer (March–April) and then decrease to almost disappear by July–September. This seasonality is consistent with temperature, although peaks differ slightly among Eucalyptus species. *Eucalyptus benthamii* presented earlier and higher captures than the extensively planted species *E. grandis* and *E. dunnii*. Local rainfall during summer also affected abundance of the bronze bug. The authors discuss the implications of these finding for the development of an integrated management strategy for the bronze bug.

***Sirex noctilio* host searching behavior: use of reliable infochemicals emitted by fungal symbiont.** Martinez von Ellrichshausen, A., Fernandez Ajo, A., Corley, J. (National Agricultural Technology Institute (*INTA-CONICET), Argentina; andmarv77@gmail.com; afernandezajo@gmail.com; elmallin@gmail.com*).

The woodwasp *Sirex noctilio* is considered a major pest of pine plantations worldwide. Female wasps establish a symbiosis with the basidiomycete *Amylostereum areolatum*. Arthrospores of the fungus, carried in special sacs, are deposited into living trees at the moment of oviposition. Fungal growth within the wood is fundamental for larval nutrition. Previous studies have established a strong spatial aggregation of *S. noctilio* attack, with females favoring previously attacked trees because multiple fungal insertions help weaken the tree and increase larval survival. Therefore, the authors hypothesize that host-searching females will rely on fungal volatiles (in addition to pine infochemicals) as a reliable indication of host suitability. The volatile emissions of fungal growth were investigated, and electrophysiological and behavioral assays were used to establish the relevance of these volatile compounds in the context of female host searching behavior. The authors suggest that some of the fungal volatiles are used as cues during the host searching process, and their potential use in pest monitoring programs is discussed.

Infestation patterns of *Phoracantha semipunctata* (Coleoptera: Cerambycidae) corresponding with a drought-induced dieback event in native host trees in southwestern Australia. Matusick, G., III., Seaton, S., Hardy, G. (*Murdoch University, Australia; G.Matusick@murdoch.edu.au; g.hardy@murdoch.edu.au*).

An outbreak of the native Eucalyptus longhorned borer (*Phoracantha semipunctata*, Coleoptera: Cerambycidae) coincided with a severe drought-induced dieback event in the Northern Jarrah Forest of southwestern Australia in 2010–2011. Although the behaviour of *P. semipunctata* is well known where it is exotic, little is known about its ecology in its native habitats within Australia. Intensive whole-tree sampling was used to investigate population levels, host preference, and within-tree infestation patterns in *Eucalyptus marginata* and *Corymbia calophylla* trees during the outbreak. The density of oviposition sites was similar between host tree species, whereas infestation levels were significantly greater in marri compared to jarrah, including 20% more larval galleries per oviposition site and 46% more emergence holes/m^2. Larval damage in sapwood was extensive (mean of 48%) in both species. Significant positive correlations were found between density of oviposition sites, larval galleries, and emergence holes with stem diameter. This study is the first to establish the association between drought and outbreak levels of *P. semipunctata* in southwestern Australia, raising questions about the future impact of *P. semipunctata* with continued climate change in this region. It is also first to describe the within-tree distribution of the beetle in susceptible hosts in its native environment in Australia.

Interactive effects of white pine needle damage and climate change on forest health and carbon-water dynamics across the northeastern United States. McIntire, C., Asbjornsen, H., Broders, K. (*University of New Hampshire, USA; cameron.d.mcintire@gmail.com; heidi.asbjornsen@unh.edu; kirk.broders@unh.edu*), Munck, I. (*U.S. Forest Service, USA; imunck@fs.fed.us*), Livingston, W. (*University of Maine, USA; WilliamL@maine.edu*).

White pine needle damage (WPND) is a complex of fungal pathogens currently affecting forests in the northeastern United States. Since 2010, white pine chlorosis and defoliation caused by WPND have been observed in Maine, Massachusetts, New Hampshire, and Vermont. Warmer temperatures and higher-than-average spring precipitation in the region are thought to be exacerbating WPND, and the potential exists for positive feedback driven by interactive effects of the needle cast on water and carbon cycling, yet empirical data are lacking. This research addresses the impacts of these defoliations on forest health. The goals of this study are to (1) monitor the severity and spread of WPND, (2) determine to what extent defoliations are affecting the dynamics of transpiration and soil moisture of infected white pine stands, (3) measure annual changes in growth rates, and (4) develop a climate-based model for predicting disease outbreaks. The effects of WPND are measured through variation in sap flow rates to derive whole tree transpiration rates and dendrochronological analysis between healthy and diseased individuals. Shifts in both transpiration and carbon sequestration of this economically important and widespread species may have significant implications for managing New England forests for both ecological health and hydrologic services.

Climate change-induced shift in voltinism of eastern larch beetle (Dendroctonus simplex) associated with increased tree-killing behavior. McKee, F., Aukema, B. (*University of Minnesota, USA; mcke0620@umn.edu; bhaukema@umn.edu*).

The eastern larch beetle (*Dendroctonus simplex*) occasionally erupts and kills large numbers of mature tamarack (*Larix laricinia*). In Minnesota (USA), sustained epidemic behavior of the beetle has been noted since 2000, which deviates from historic patterns in this southern extent of its range. Biotic factors that predispose trees to attack, such as defoliators, have been noticeably absent. The authors examined trees over a 2-year period in northern Minnesota, and measured colonization and development throughout the growing seasons. Several lines of evidence suggested that additional insect generations were not sister broods as commonly understood from the limited body of literature on this insect, but rather F1 progeny that were attacking new trees in late summer. These progeny were able to successfully complete reproduction, overwinter, and emerge en masse the following spring. Laboratory studies demonstrate that this insect does not have an obligatory reproductive diapause. The authors postulate that bivoltine reproduction is the reason for enhanced outbreak activity in Minnesota in the absence of normal predisposing factors.

Effects of air pollution and climate change on forest growth in the Southern Carpathians (Retezat and Bucegi-Piatra Craiului Mountains). Neagu, S., Badea, O., Silaghi, D. (*Forest Research and Management Institute, Romania; badea63@yahoo.com; dianamicasm@yahoo.com*).

Forest ecosystem condition is mainly influenced by the negative action of air pollution and climate change as well by other stressors (biotic and abiotic). Tree growth and forest dynamics are considered as the primary indicators of stability, function, and productivity of forest ecosystems. Since the year 2000 interdisciplinary research at long-term ecological research sites at Retezat and Bucegi – Piatra Craiului in the Southern Carpathians has collected data provided by successive, permanent, and continuous measurements. Results showed different average annual growth in volume related to specific conditions of vegetation, air pollution, climate, and site by comparing healthy trees (crown defoliation 25%) versus damaged trees (crown defoliation >25%). Healthy trees recorded higher values of mean annual growth in comparison with the damaged trees with differences of 0.5–7.1 m^3/ha/yr (*Picea abies*), 0.8–6.9 m^3/ha/yr (*Fagus sylvatica*), and 0.9–5.4 m^3/ha/yr (*Abies alba*). Mean annual growth in damaged trees was up to 40–45% less than that recorded by healthy trees. Knowing the annual volume growth losses due to cumulative effects of air pollution and climate change along with other biotic and abiotic factors allows managers to better predict forest health impacts and to develop mitigation efforts.

Effects of tree species biodiversity on foliar fungal pathogen regulation: understanding the spread of the ash dieback pathogen, *Hymenoscyphus pseudoalbidus*. Nguyen, D., Cleary M., Stenlid, J. (*Swedish University of Agricultural Sciences, Sweden; diem.nguyen@slu.se; Michelle.Cleary@slu.se; jan.stenlid@slu.se*).

The fungal pathogen *Hymenoscyphus pseudoalbidus* has been causing widespread decline of European ash (*Fraxinus excelsior*) across Europe. Recent studies that showed lower genetic variability in European *H. pseudoalbidus* populations compared with that found in a Japanese population of the fungus suggest that the pathogen in Europe likely originated from East Asia. Population

genetic investigations have been performed to determine the population structure of *H. pseudoalbidus* across Europe and the fungus was found to be without any genetic population structure. These studies focused on fungal isolates throughout Europe, but no work has been done to determine the finer-scale resolution within one locality across a tree species diversity gradient. In this study, the authors aim to address whether mixtures of ash with various broadleaved tree species can help regulate the impact of the pathogen by limiting the spread of fungal spores. In a 12 km × 5 km area in the Hainich National Park in Germany, ten 30-m^2 plots were chosen that consisted of ash in various mixtures with broadleaved tree species. Sclerotized ash petioles were collected from selected target trees and microsatellite analyses were performed directly from subsections of these petioles. The authors tested the hypothesis that less genetic variation would be found among fungal populations in mixtures than in pure stands of ash.

Life cycle, survivorship, and control of an insect pest, *Trachys yanoi* (Buprestidae, Coleoptera). Ohsawa, M. (*Yamanashi Forest Research Institute, Japan; oosawa-ujk@pref.yamanashi.lg.jp*).

Trachys yanoi is a well-known and widespread insect pest of *Zelkova serrata*. The life cycle and survivorship of this insect were studied by field observation and breeding in laboratory in order to find methods of controlling the damage caused by this insect. Adults came out of hibernation and started feeding on Zelkova leaves from the outside of the leaves in April. After mating, they laid eggs on the Zelkova leaves. Eggs hatched and larvae as leaf miners started eating the interior of the leaves. Zelkova trees shed their leaves (early leaf abscission) together with the larvae. The larvae became pupae inside of fallen leaves and emerged as adult beetles from mid-July to early August. The adults of the new generation fed on Zelkova leaves in the crown. In October, they hibernated under the tree bark. Survival rate of this insect was relatively low in the egg stage. Parasitic wasps killed the insect in the larval stage, and *Beauveria bassiana* (insect disease) killed the adult beetles during hibernation. The removal of fallen leaves together with larvae or pupae of this insect in late July was found to be the most effective control method tested.

Nursery pest management of *Phytolyma lata* Walker (Scott) attack on Iroko (*Milicia excelsa* Welw C. C. Berg) seedlings. Olajuyigbe, S. (*University of Ibadan, Nigeria; lekito2001@yahoo.com*).

The establishment of plantations of *Milicia excelsa* has been constrained by the gall-forming *Phytolyma lata*, which causes extensive damage to young plants. This study aimed to prevent *Phytolyma* attack on *Milicia* seedlings in the nursery using chemical control and a physical barrier (screen house). Ninety 6-month-old seedlings of uniform growth were selected from a population of seedlings obtained from the same seed source. Thirty seedlings were placed in a screen house (SHS), and 30 seedlings (TRT) were placed in the open nursery and treated fortnightly with a low concentration (0.05%) water-based insecticide (Lambda-Cyhalothrin). Thirty untreated seedlings (UNT) were also placed in the open nursery as a control. The survival rate, height, and collar diameter were measured fortnightly for 24 weeks. After 10 weeks, only the untreated seedlings were attacked by *Phytolyma* insects, but no mortality was recorded during the study. There was no significant difference in the collar diameter growth of seedlings in all treatments. However, there were significant differences in the total height with an increase of 22% and 58%, in TRT and SHS, respectively, whereas UNT seedlings had a height growth of –0.27%. The provision of a physical barrier proved to be the most effective management strategy to prevent *Phytolyma* infestation, and chemical control was a successful alternative.

Biogenic VOC emission from silver birch under ozone and nitrogen stress. Paoletti, E., Carriero, G. (*National Research Council, Italy; e.paoletti@ipp.cnr.it; carriero@ipp.cnr.it*), Mills, G., Hayes, F., Brunetti, C. (*Centre for Ecology and Hydrology, UK; gmi@ceh.ac.uk; fhay@ceh.ac.uk; c.brunetti@ipp.cnr.it*), Tattini, M.

Silver birch grows in cold climates and farther north than any other tree species. It is a monoterpene and sesquiterpene emitter (Vuorinen *et al.*, 2005). This emission of volatiles from plant leaves may be altered under environmental stress (Beuchamp *et al*., 2005; Loreto and Schnitzler, 2010;), and contribute to the formation of aerosols and ozone (Fehsenfeld *et al.*, 1992). The main objective was to explore whether *Betula pendula* changes quality and quantity of volatile organic compound (VOC) emissions when exposed to two typical climate change stressors, i.e., elevated ozone and nitrogen availability. Trees were exposed to two levels of ozone in the air and three levels of nitrogen in the soil in solardomes. The emission of monoterpenes decreased as much as 45% by increasing nitrogen fertilization from 10 to 70 kg/ha/yr under low levels of ozone in the air. In contrast, nitrogenreduced the emission of monoterpenes by just 8% in plants exposed to high ozone levels. The effects were compound-specific, with the most abundant α-pinene and limonene showing the most significant variations. These results are discussed in the light of future scenarios involving global climate models and atmospheric VOC budgets.

Ozone-induced differences in phenology and antioxidants of poplar trees treated and untreated with ethylenediurea (EDU). Paoletti, E., Pignattelli, S., Carriero, G., Bartolini, P., Vettori, C. (*National Research Council, Italy; e.paoletti@ipp.cnr.it; sara.pignattelli@gmail.com; carriero@ipp.cnr.it; cristina.vettori@igv.cnr.it*), Paffetti, D.

Ozone (O_3) is an important phytotoxic air pollutant and a significant greenhouse gas (Bytnerowicz *et al.,* 2007). Chronic O_3 injury mimics other environmental stressors, such as pathogen attacks. Ozone may weaken freezing tolerance (FT) and predispose trees to frost injury (Ranford and Reiling, 2007). Plant FT develops in autumn as a response to shortening of photoperiod and low temperatures; therefore, autumnal warming may affect the developing of FT in plants. Both O_3 and freezing stress can increase the production of reactive oxygen species (ROS) such as O_2^- and H_2O_2, and antioxidants such as glutathione (GSH) and ascorbate (AsA) (McKersie *et al*., 1997; Castagna and Ranieri, 2009). To prevent ozone injury, ethylenediurea (EDU) has been widely used (Manning *et al*., 2011). The objective of this study was to understand whether ambient ozone exposure is affecting the ability of plants to overwinter, by investigating acclimation/de-acclimation to cold stress and freezing tolerance in an O_3-sensitive poplar clone (Oxford clone) treated and untreated with EDU as soil drench. This study presents the result of phenology, foliar content, and gene expression of ROS and antioxidants. Preliminary results show that spring flushing is delayed and shoot lengthening is decreased in untreated poplars.

Ozone fluxes and epidemiology of ozone injury to forests. Paoletti, E. (*National Research Council, Italy; e.paoletti@ipp.cnr.it*), Sicard, P. (*ACRI-ST, France; pierre.sicard@acri-st.fr*), De Marco, A. (*National Agency for New Technologies* (*ENEA), Italy; alessandra.demarco@enea.it*).

Although tropospheric ozone is an important greenhouse gas and phytotoxic air pollutant (Bytnerowicz *et al*., 2007), quantification of its effects on real-world forests is challenging. Ozone, in fact, is a strong oxidant and does not accumulate in the environment. Effects on forest indicators are thus not specific. In addition, effects depend on the amount of ozone entering through the stomata (flux) rather than the amount of ozone in the air (exposure) (Paoletti and Manning, 2007). Epidemiology is the study of patterns, causes, and effects of diseases. Large-scale epidemiological investigations focused on ozone impacts on plant indicators may provide a quantitative assessment of ozone injury. A complication is that ozone co-varies with beneficial (air temperature, solar irradiation) and detrimental (soil water stress) factors. Most of the previous epidemiological evaluations of the environmental impacts of ozone focus on ozone exposure only. Here novel results are reported from cross-comparing soil, meteorological, ozone, and plant databases for Italian and French forests, where stomatal ozone fluxes were investigated. The results were obtained within the FO3REST Life+ ENV/FR/208 project.

Flight activity, life history, and host selection behavior of the walnut twig beetle in its native range in the southwestern United States. Parker, C., Flint, M., Nadler, S. (*University of California, USA; corwin.parker@gmail.com; mlflint@ucdavis.edu; sanadler@ucdavis.edu*), Graves, A., Seybold, S. (*U.S. Forest Service, USA; adgraves@fs.fed.us; sjseybold59@gmail.com*).

The walnut twig beetle (*Pityophthorus juglandis* (Coleoptera: Scolytidae); WTB) is native to the southwestern United States, where historically it has fed with little impact on the phloem of the branches and main stem of Arizona walnut, *Juglans major*. However, in recent decades, the beetle has substantially increased its range, carrying with it a fungus, *Geosmithia morbida*, which infects the phloem of many species of walnut. In 2013, the authors conducted comparative studies of the biology of WTB in California and New Mexico. Aggregation pheromone-baited *J. major* branches and flight traps were used to document WTB flight patterns and life history. Host selection behavior was assessed with pheromone-baited branch sections of *J. major*, *J. microcarpa*, *J. hindsii*, *J. nigra*, and *J. regia*. In these experiments, the branch sections were suspended on poles for 2–3 weeks in infested locations in both states. The attack densities varied by species with *J. hindsii* and *J. nigra* the most heavily attacked in both states; *J. microcarpa* was attacked at the lowest density. Rearing studies in the lab to assess productivity in the various hosts showed that branch sections of *J. hindsii* yielded far more brood than branch sections of *J. major* and *J. microcarpa*.

Optimal control strategies of forest pathogens in a heterogeneous landscape: a French case study. Petucco, C. (*National Institute for Agricultural Research* (*INRA), France; claudio.petucco@nancy.inra.fr*).

Forest pests are the most evident signs of an "unhealthy" forest. Certain management practices such as the extensive use of monoculture plantations favor emergence of pests. Moreover, global climate change can lead to decline of forest ecosystems and their capacity to satisfy human needs. Yet monocultures continue to be implemented and are considered to be the most profitable option. This work aims to evaluate the optimal pest control strategy in a heterogeneous landscape under different climate scenarios. First analysis is focused on a heterogeneous landscape divided into grid cells characterized by monoculture plantations for which the number of trees, standing volumes, and number of infected trees are known. The pest spatial and temporal dynamics depend on climate conditions (winter minimum temperature and sunshine duration) and on the density of host trees. Optimal control techniques were used to determine the intensity of monitoring and control in order to minimize total damage and pest control costs within a rotation period. Second, the analysis explores the profitability of having a mixed forest by replacing the dominant species with a second one not affected by the pathogen. The model is applied to the pine processionary moth (*Thaumetopoea pityocampa*) infection in the Landes region, France.

The good and the bad: tradeoffs between disease resistance and symbionts in loblolly pine. Piculell, B., Hoeksema, J. (*University of Mississippi, USA; bjpicule@go.olemiss.edu; hoeksema@olemss.edu*), Eckhardt, L. (*Auburn University, USA; eckhalg@auburn.edu*).

Pine decline and fusiform rust disease are major antagonists in the southeastern United States, negatively affecting crops and causing substantial economic and ecological damage yearly. Interest in addressing the detrimental effects of these pathogenic fungi has inspired extensive investigations into patterns of resistance in dominant pine species, such as loblolly pine (*Pinus taeda*). Little work, however, has focused on the role of pervasive below-ground symbionts of these pines, mycorrhizal fungi. A growth chamber experiment was conducted to investigate genetic variation and trait correlations within loblolly pine as it interacts with both pathogenic and ectomycorrhizal fungi. The experiment uses families of loblolly pine previously determined to be either resistant or susceptible to pathogenic fungi that cause either pine decline or fusiform rust disease. Variation was found among loblolly families in compatibility with different mycorrhizal species. Correlations found between susceptibility to pathogenic fungi and compatibility with symbiotic mycorrhizal fungi, indicate tradeoffs between fungal symbionts and fungal pathogen resistance.

Insect problems: a challenge for reforestation in the Colombian Orinoquia region. Pinzón Florian, O. (*Universidad Distrital Francisco José de Caldas, Colombia; opatriciap@udistrital.edu.co*).

Commercial plantations are increasing in the Colombian Orinoquia region mostly because of the availability of extensive areas previously dedicated to livestock. Most of this area is planted with introduced fast-growing species like *Pinus caribaea*, *Eucalyptus* spp., and *Acacia mangium.* Although forest commercial plantation activity in the region continues to expand, there is concern because of the occurrence of about 30 species of harmful insects. Currently, the main economic damage is caused by leaf-cutting ants (*Atta* spp., *Acromyrmex* sp.) and by beetles (Chrysomelidae : Eumolpinae) in eucalyptus and acacia. Infestations of the sap-sucking insect *Glycaspis brimblecombei* Moore (Hemiptera: Psyllidae) have also been recorded in eucalyptus in the region. A greater number of harmful insects have been found in *A. mangium;* despite extensive plantations, the trees do not reach 10 years of age. The main damage observed in this species is caused by termites in nursery seedlings and young plantations, and holes in the bark and sapwood caused by platypodids with undesirable consequences for wood quality and predisposition to secondary attack by diseases. Reforestation in the Colombian Orinoquia faces challenges regarding health issues before it can be considered as a real economic alternative for local communities.

Climate change and silvicultural practices promoted the emergence of a novel pest of poplar stands. Pointeau, S., Robinet, C., Bankhead-Dronnet, S., Sallé, A., Lieutier, F. (*University of Orléans, France; sophie.pointeau@avignon.inra.fr; christelle.robinet@orleans.inra.fr; stephanie.bankhead@univ-orleans.fr; aurelien.salle@univ-orleans.fr; francois.lieutier@univ-orleans.fr*).

Climate change in recent decades has been directly or indirectly involved in changing the life-history and population levels of many endemic forest insect species, leading to unexpected and unprecedented outbreaks. In spite of difficulties in assessing the complex impact of climate on insect communities, evaluating the effect of climate warming on insect population dynamics remains fundamental to understanding and predicting global warming-induced insect outbreaks in forest ecosystems. To test the hypothesis that climate warming affects the emergence and spread of endemic insects, the authors assessed whether recent climate warming could explain the outbreaks of the woolly poplar aphid (*Phloeomyzus passerinii*), an emerging pest in French poplar stands since 1996. A model of population dynamics was developed to simulate the annual growth potential of *P. passerinii* populations under optimal conditions using a theoretical index based on temperature-dependent biological traits. When host tree data were taken into account, this model successfully indicated the history and current outbreak range of the insect, confirming the effect of climate warming on this emerging aphid pest.

Conserving plant diversity of Central European oligotrophic forest habitats requires goal-oriented management of nutrient cycles. Pyttel, P. (*Albert-Ludwigs-University Freiburg, Germany; patrick.pyttel@waldbau.uni-freiburg.de*), Ewald, J. (*University of Applied Science Weihenstephan-Triesdorf, Germany; joerg.ewald@hwst.de*).

Nitrogen eutrophication poses a major threat to biodiversity. In Central Europe's cultural landscape eutrophication is due to the additive effects of ecosystem recovery from preindustrial land use and of modern deposition from combustion and agriculture. Looking at the intersection of Red List and Ellenberg indicator values for nutrients for forest species reveals that 69% of Germany's threatened vascular forest plants depend on oligotrophic habitats. While forests present a reserve of oligotrophic habitats, their filtering capacity makes them particularly prone to N deposition. A review of management options to counteract eutrophication shows that, under current environmental conditions, the maintenance of oligotrophic forest habitats requires selective removal of nutrients through intensive harvesting of crown biomass or removal of soil organic matter. The arising conflict with other ecosystem functions calls for a careful, site-specific prioritization of goals and optimization of measures.

Invasiveness of *Uromycladium tepperianum* on *Falcataria moluccana* affected by pyroclastic cloud from Merapi Volcano, Yogyakarta, Indonesia. Rahayu, S. (*University of Gadjah Mada, Indonesia; tatarahayu@yahoo.com*).

The objectives of the research were to evaluate changes in the morphological characteristics, survival, and pathogenicity of *Uromycladium tepperianum* in sengon (*Falcataria moluccana*) trees affected by the volcanic cloud from the eruption of Mount Merapi, Indonesia. Inoculum samples were taken from trees that showed gall symptoms. Trees were located on the southern slope of Mount Merapi in the danger, alert, and warning areas, at distances of 3–7 km, >7–11 km, and >11–15 km, respectively, from the top of the volcano**.** Samples were taken at random distances within the sites: fire (directly affected by the pyroclastic cloud), border (indirectly affected), and green (completely uninfluenced). Based on the artificial inoculation test, pathogenicity of each sample including germination, penetration, and infection ability was observed. Severity of gall rust disease in *F. moluccana* planted around the mountain was also evaluated. Results showed that the spores of *U. tepperianum* from the border location, had higher pathogenicity and aggressiveness, indicated by a higher percentage of germination, faster penetration, and higher infection rate, as well as a greater ability to produce galls, compared to spores from the fire and green locations. The rust fungus also became very invasive and caused an epidemic in the recently planted *F. moluccana*.

Insect frugivores and their impact on the regeneration of mangrove species in the West Coast of India. Remadevi, O.K., Latheef, A., Chatterjee, D. (*Institute of Wood Science and Technology; okremadevi@gmail.com; lathifc@gmail.com; yuv.jyoti@gmail.com*).

The conservation and management of mangrove forests deserve great attention because of the well-known importance and utility of mangroves. Insect frugivores feeding on fruits, seeds, and also propagules, were found to have a sizable effect on regeneration of mangrove species. A study was undertaken to assess insect infestation of fruits, the intensity and nature of damage of the seeds and propagules, and the impact on regeneration of the mangrove species, *Rhizophora mucronata*, *Avicennia officinalis*, *Kandelia* sp., *Bruguiera gymnorrhiza*, and *Sonneratia* sp. in the West Coast of India. Considerable damage was found in the fruits of *Avicennia* (in 70% of samples), where three different types of larvae were found to inflict considerable damage to the fruit. Most of the damage was caused by two species of insects, *Calandra* sp. and *Callistomyia klugii*. A large percentage of the *Sonneratia* fruits (71%) were found to be infested by a noctuid moth and a curculionid beetle. *Coccotrypes* sp. was found attacking nursery-planted seedlings of *Bruguiera gymnorrhiza*. Sixty-four percent of all severely affected seedlings were not viable within 2 months. The impact of insect attack on the initial establishment and survival of mangrove plants is discussed in the paper.

A common foliar endophyte, *Hormonema* sp., suppresses seedling emergence of host species, *Pinus ponderosa*. Ridout, M., Newcombe, G. (*University of Idaho, USA; mridout@uidaho.edu; georgen@uidaho.edu*).

Numerous endophytic fungi inhabit needles of the genus *Pinus*. Both within their host and the greater environment, however, the biological and ecological functions of the greater portion of these organisms are largely unknown. Among the more common endophytes isolated from asymptomatic needles of *Pinus ponderosa* are *Hormonema* spp. In greenhouse germination trials, *H. dematioides* reduced emergence of ponderosa pine seedlings by as much as 66%. Seed from western U.S. provenances of two *Pinus. ponderosa* subspecies, var. *ponderosa* and var. *scopulorum*, subjected to identical conditions had significant reductions in seedling emergence, by 14 and 30%, respectively. The same *Hormonema* isolate, however, failed to reduce emergence of a co-occurring western U.S. conifer *Pseudotsuga menziesii* var. *glauca*. Seedling germination and emergence are critical points for survival and establishment of pines in naturally regenerating stands. Physical and chemical conditions in litter layers have long been implicated as factors in low recruitment of seedlings beneath parent species. The presence of endophytic fungi in senesced foliage presents another potential factor in poor conspecific seedling recruitment in naturally regenerating stands and supports the Janzen-Connell hypothesis of biological diversity in forest systems.

Evaluating North American endophytic fungi for biological control of a coadapted pathogen *Dothistroma* needle blight in *Pinus* sp. Ridout, M., Newcombe, G. (*University of Idaho, USA; mridout@uidaho.edu; georgen@uidaho.edu*).

Red-banded needle blight of pines caused by the North American pathogens *Dothistroma* spp. has been devastating to radiata pine plantations in the Southern Hemisphere. However, the same pathogens are relatively benign in their North American ranges, where they infect a number of North American pines. This divergent response might indicate that some biotic or abiotic factor within the environment checks severity of infection across the native range of both the pines and their pathogens. In classical applications of biological control methods, the best source of biocontrol agents might be found within the natural range of the pathogen. Co-occurring communities of endophytic fungi found in pines within the native range of the pathogen provide a reservoir of potential biocontrol organisms. Seven single-endophyte treatments were applied to emerging needles of 7-year-old trees of *Pinus ponderosa* infected with red-banded needle blight. *Penicillium goetzii* isolated as an endophyte from root tissues of *Pinus ponderosa* reduced lesion extent by 7% on inoculated needles compared to untreated needles on *Dothistroma*-infected needles of *P. ponderosa*. Results from this study indicate that co-occurring endophytes present a potentially valuable tool for classical biocontrol of *Dothistroma* needle blight in intensive exotic pine plantations in the Southern Hemisphere and beyond.

Natural enemy recruitment to the Asian chestnut gall wasp, *Dryocosmus kuriphilus*, a highly invasive pest of chestnut, *Castanea* spp., worldwide. Rieske-Kinney, L. (*University of Kentucky, USA; lrieske@uky.edu*).

The globally invasive Asian chestnut gall wasp, *Dryocosmus kuriphilus*, continues to expand its range, affecting *Castanea* resources throughout invaded areas. Natural enemy recruitment to this globally invasive pest is being evaluated in the context of evolving trophic interactions (parasite – gall wasp and parasite – parasite), and applied biological control. In North America numerous adult parasitoids reared from galls collected throughout infested areas have been identified, but the presence of adult parasitoids is not necessarily indicative of parasitization. In order to determine which species are affecting gall wasp populations, identification of larval parasitoids dissected directly out of developing galls is necessary. But morphological identification of larval parasitoids is difficult. In this research a molecular approach is being used to definitively determine which parasitoids are affecting gall wasp populations. The ITS2 region of parasitoid larvae dissected from developing galls is being compared to adult insects identified morphologically. In this way specific parasitization activity and rates can be directly attributed to specific parasitoid species, opening the door for additional manipulations for biological control.

Colonization dynamics of mountain pine beetle in eastern and western pines: implications to range expansion. Rosenberger, D. (*University of Minnesota, USA; rose0675@umn.edu*), Venette, R. (*U.S. Forest Service, USA; rvenette@fs.fed.us*), Aukema, B. (*University of Minnesota, USA; bhaukema@umn.edu*).

The mountain pine beetle (*Dendroctonus ponderosae* Hopkins) is a disturbance agent native to western North America that intermittently undergoes large-scale outbreaks in *Pinus contorta* and *P. ponderosae*. This insect threatens eastern forests due to recent eastward spread from *P. contorta* forests of British Columbia into the *P. banksiana* forests of northwestern Alberta, and through transport of green pine logs from western states with populations of mountain pine beetle. Here the authors explore the colonization dynamics of this insect in naïve eastern hosts. Logs from two species of native hosts (*P. ponderosae* and *P. contorta*) and four naïve eastern pine species (*P. strobus, P. resinosa, P. banksiana,* and *P. sylvestris*) were harvested and transported to the Black Hills of South Dakota (USA), an area with epidemic populations of mountain pine beetle. There the authors investigated attraction of conspecifics in the field by tunneling beetles and host acceptance. Results indicate that eastern pine species may be susceptible to mountain pine beetle colonization. Differences in attraction among eastern pines and in host entry among regions may cause us to rethink our understanding of colonization dynamics from what is currently known in western forests. Implications to ongoing eastern range expansion of this eruptive herbivore are discussed.

Googling forest pests -Use of Google as a monitoring tool for delimiting the distributional range of forest pests. Rousselet, J., Robinet, C., Rossi, J. (*National Institute for Agricultural Research (INRA), France; jerome.rousselet@orleans.inra.fr; christelle.robinet@orleans.inra.fr; rossi@supagro.inra.fr*).

During the last decade, geospatial data have become increasingly accessible with the advent of new mapping technologies such as Google Earth™, Google Street View™, or Google Trends™. These technologies offer satellite imagery and aerial photos of most of Earth's land surface as well as real-time data documenting different types of outbreaks. The authors investigated how Google Street View could help in assessing the geographical distribution of species and how Google Trends could provide insight for real-time surveillance of pests. The authors worked with the pine processionary moth, the most important pine defoliator in southern Europe. They conclude that Googling forest pests is a promising tool although the approach is still in its infancy; more investigations are required to properly define its range of application and its limitations.

Trees outside forest strongly affect habitat connectivity for forest insects. Rousselet, J., Rossi, J. (*National Institute for Agricultural Research (INRA) France; jerome.rousselet@orleans.inra.fr; rossi@supagro.inra.fr*).

Some forest tree species are commonly used for ornamental purposes and therefore occur frequently in non-forest ecosystems. This paper presents the results of a modeling survey focused on the spatial distribution of trees outside forest (TOF) at the landscape scale. The authors deal with the tree species that host the pine processionary moth (PPM), a major pest for pine species in Europe. They modeled the spatial distribution of TOF by means of an inhomogeneous Poisson process and performed simulations across various landscapes. Results show the TOF constitute a major component of landscape connectivity with regards to PPM dispersal. In particular, large-scale ornamental tree distribution allows pest dispersal across non-forest habitat such as open-field agricultural landscapes.

Population structure and local adaptation of the pine cone weevil *Pissodes validirostris* (Coleoptera, Curculionidae): disentangling the role of the host plant from geography. Roux, G., Bertheau, C., Roques, A. (*National Institute for Agricultural Research (INRA), France; geraldine.roux@orleans.inra.frcoralie.bertheau@gmail.com; alain.roques@orleans.inra.fr*).

This study is focused on the palearctic species *Pissodes validirostris* Gyll. (Coleoptera, Curculionidae), the only known stenoconobionte *Pissodes* species. Whereas all but one species of *Pissodes* feed on the cambium and phloem of Pinaceae, the larval development of *Pissodes validirostris* occurs fully and only in cones and seeds of different pine species and the whole life cycle occurs in the same host species. Here the authors assess evidence for geographical host specialization within this weevil. Use of mitochondrial, nuclear DNA and morphometrical measures revealed that *Pissodes validirostris* probably incorporates five independent evolutionary lineages. No haplotype was shared between the lineages, which suggests the absence of gene flow between these groups. Allopatric fragmentation and colonization routes from distinct refugia during the post-glacial period of both the insect and its associated host pines may explain the present structuring of *P. validirostris* populations. However, given the geographic distribution of the pine species, it is difficult to unequivocally state whether geography or the host species is the main structuring factor.

Anatomy of gall rust in coppice sengon (*Paraserianthes falcataria*) infected by *Uromycladium tepperianum*. Rukhama, S., Fahrudin, F., Rahayu, S., Dwi Nugroho, W. (*Gadjah Mada University, Indonesia; aku.shofi@yahoo.com; fahrudinnanang941@gmail.com; tatarahayu@yahoo.com; wdnugroho@ugm.ac.id*).

Sengon (*Paraserianthes falcataria* (L.) Nielsen) is a fast growing species with short rotation period. However, it is susceptible to attack by the gall rust *Uromycladium tepperianum*. This disease inhibits growth, produces stem defects and even leads to the death of infected trees. This research aims to investigate the anatomy of gall rust in sengon and its wood anatomical changes. A completely randomized study design was used to evaluate two main factors were the condition of gall rust and wood. Gall rust condition included three diameter classes: large (> 1.1 cm), medium (0.8–1 cm) and small (< 0.8 cm), while wood condition was characterized as attacked wood or infected wood. The results showed that in gall rust anatomy, dark substrate contents and vessel elements increase with the size of gall rust. Furthermore, there was smaller diameter of fiber on the gall rust because of lack of giberelin, sclereids skin tumors as well as the wavy pattern on the composition of the callus. Results showed a decrease in the percentage and size of vessel diameter on infected wood as the effects of ethylene hormone. The increase of longitudinal parenchyma and ray cells as result of auxin and cytokinin, and a modification distribution parenchyma into band shape.

Reassessing critical load calculations by ecosystem feedback. Sanders, T., Fischer, U., Seidling, W., Lorenz, M. (*Thünen Institute of Forest Ecosystems, Germany; tanja.sanders@ti.bund.de; uwe.fischer@ti.bund.de; walter.seidling@ti.bund.de; martin.lorenz@ti.bund.de*).

Calculations of critical loads (CL) have been developed since the 1980s under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP). However, outcomes vary widely depending on the approach. Weathering rates and the gibbsite equilibrium greatly influence the allowable??endurable rates for sulphur and nitrogen deposition obtained, likely due to individual buffering capacities in the soils. The authors use different approaches to calculate CL for acidity and eutrophying nitrogen and compare them with the development of base cation leaching, the base cations–aluminium ratio, and acid neutralising capacity. Furthermore change in pH as well as potential changes in foliar magnesium, calcium, and potassium content are looked at to detect effects on or even shifts within ecosystem functioning. Data derived from the ICP Forests database provide a time-series on deposition, soil and foliar chemistry, growth, and tree condition. Initial results confirm significant variation in CL values due to methodological issues. Calculated CL exceedances are not necessarily manifested in a growth decline; on other sites a decline in tree health is observed even though no exceedances have occurred. The aim of this ongoing work is to modify CL calculations depending on forest ecosystem responses.

Climate alters interactions among bark beetles and symbionts, potentially altering geographic range. Six, D. (*University of Montana, USA; diana.six@cfc.umt.edu*), Addison, A., Powell, J. (*Utah State University, USA; audrey.smith@aggiemail.usu.edu; jpowell@usu.edu*), Bentz, B. (*U.S. Forest Service, USA; bbentz@fs.fed.us*).

Several bark beetles in the genus *Dendoctonus* are involved in obligate symbioses with fungi. The fungi, as well as the host beetles, are highly responsive to temperature, which determines their upper and lower bounds for growth and survival and their overall performance in a given habitat. These symbioses typically involve three partners: a beetle and two fungi. Each fungus provides nutritional benefits to the beetle; however, one fungus is typically superior to the other in supporting beetle fitness. The relative prevalence of the two fungi with a beetle, and subsequently, their effects on beetle population dynamics, is temperature dependent. The fungi possess different temperature tolerances, which leads one to dominate at cooler temperatures and the other at warmer temperatures. Thus, temperature influences beetle fitness, not only through direct effects on development, reproduction, and survival, but also indirectly, through its effects on fungal partners. The authors describe how temperature acts a stabilizing force for these three-way interactions as well as how climate change may act to disrupt stability and decouple one or both partners from the beetle host. The authors also discuss the need to incorporate the fungi into models predicting range expansions and contractions of bark beetle species to increase their accuracy.

Diversity of the parasitic nematode *Deladenus siricidicola* and its relevance as a biological control agent. Slippers, B., Fitza, K., Mlonyeni, X., Hurley, B., Wingfield, M. (*FABI-University of Pretoria, South Africa; Bernard.Slippers@fabi.up.ac.za; Katrin.Fitza@fabi.up.ac.za; osmond.mlonyeni@fabi.up.ac.za; brett.hurley@fabi.up.ac.za; mike.wingfield@fabi.up.ac.za*), Yek, S., Ayres, M., Lombardero, M., Dodds, K., Ahumada, R., Sopow, S.

Deladenus siricidicola is the primary biological control agent for the invasive woodwasp and pest of *Pinus*, *Sirex noctilio*. Although the genetic diversity of invasive populations of *S. noctilio* is relatively high, that of the nematode used in biocontrol programs is extremely limited. Little is known about the diversity of *D. siricidicola* in native populations. In order to investigate the diversity of *D. siricidicola* populations, mitochondrial and microsatellite markers from the whole genome were used. Populations of nematode were from Argentina, Australia, Canada, Chile, New Zealand, South Africa, and the United States, representing putative native and non-native areas. Preliminary results showed extreme homozygosity in the populations from the Southern Hemisphere compared to the Northern Hemisphere strains. The release of a highly efficient single strain of nematode throughout

the Southern Hemisphere has strongly influenced this pattern. To address the low genetic diversity available for biocontrol programs, the above-mentioned strains, and their hybrids, are being screened in culture for potential virulence. Furthermore, a selection of strains is being tested for effectiveness to parasitize the wasp after inoculation into logs. The results are expected to clarify the potential of diversity in a biocontrol agent to improve its use in biological control programs.

Global homogenization of forest insect pests—a case study of *Leptocybe invasa.* Slippers, B., Hurley, B., Wingfield, M., Dittrich-Schröder, G. (*FABI-University of Pretoria, South Africa; Bernard.Slippers@fabi.up.ac.za; brett.hurley@fabi.up.ac.za; mike.wingfield@fabi.up.ac.za; Gudrun.Dittrich@fabi.up.ac.za*).

Global travel and trade has resulted in an increased number of introduced insect pests worldwide, especially in plantation forestry where non-native tree species are planted. The "homogenization" of pests in these plantations around the world has consequently occurred. One of the most serious recent examples of such a pest is *Leptocybe invasa*, which is native to Australia. Since its discovery outside its native range and subsequent description in 2004, it has spread to all continents where *Eucalyptus* is planted. In order to trace the route and extent of *L. invasa* introduction around the world, the authors characterised the genetic diversity within and between populations of *L. invasa* from the origin and introduced environments. The cytochrome oxidase I (CO-I) region of the mitochondrial DNA, as well as simple sequence repeats, were used to determine the genetic diversity of the *L. invasa* populations. Preliminary results suggest that there is little genetic differentiation within the species regardless of geographic origin. Furthermore, distinct populations, or even cryptic species, have been independently introduced, and populations in some regions contain both these types. These data and the historical record of the *L. invasa* global invasion reflect the potential for plant-associated pests to move rapidly and repeatedly around the world.

Digestion in the spruce bark beetle (*Ips typographus* L.): cellulases present! Stefkova, K. (*University of South Bohemia, Czech Republic; kristef@seznam.cz*), Dolezal, P. Okrouhlik, J. (*Academy of Sciences of the Czech Republic & University of South Bohemia, Czech Republic; dolezal@entu.cas.cz; okrouhl@entu.cas.cz*), Miklas, B. (*University of South Bohemia, Czech Republic; b.miklas@centrum.cz*).

The spectrum of digestive enzymes, including glycosidases and proteinases, was investigated throughout the year in the foregut, midgut, and hindgut of the spruce bark beetle (*Ips typographus* L.). The study was primarily focused on the activity of digestive enzymes and determination of their pH optima. Gut fluids of fully feeding adults were positive on cellulase, xylanase, and amylase activity, i.e., enzymes responsible for phloem digestion. Activity levels of these enzymes were highest in the foregut and their pH optima were around 5. It is not clear whether the cellulase activity is of microbial origin or whether the beetles have cellulases of their own. Protease activity was also present, mainly in the midgut in highly alkaline pH, suggesting that the anterior part of the gut is the major site of polysaccharide digestion in mildly acidic pH, while midgut is the major site of protein digestion in highly alkaline pH.

Interacting disturbances in mixed-conifer forests of the United States: effect of bark beetles and wildfires on forest trajectories. Stevens-Rumann, C., Morgan, P. (*University of Idaho, USA; csrumann@uidaho.edu; pmorgan@uidaho.edu*).

Increasing wildfires and outbreaks of bark beetles in the western United States have led to concern about the impact of multiple disturbances. The objective of this research was to understand the effects of fuels and tree regeneration on large wildfires with and without prior bark beetle-caused tree mortality in mixed conifer forests of the interior northwestern United States. Data were collected from 180 plots across four wildfires that burned in 2007. Both tree seedling density and fuel abundance varied up to 6 years post-fire. Seedling densities were lowest on areas that experienced only wildfire, without bark beetle activity. The most coarse woody debris (logs >7.62 cm) was found on sites that experienced bark beetle activity 3–6 yr prior to study and on sites that experienced a wildfire and previous bark beetle attacks. Areas that experienced both bark beetle-caused tree mortality and a wildfire had higher mean tree seedling densities and woody fuel than areas with wildfires and no prior bark beetle mortality; however, fine woody debris (logs <7.62 cm) did not differ significantly between disturbances. Large snags that are beneficial for wildlife had the highest densities on burned sites, but all disturbances maintained significantly higher snag densities than control sites and well above minimum desired densities for these forest types.

Insect pest problems of Indian sandalwood (*Santalum album* L.) in the current scenario of its cultivation and possible management practices. Sundararaj, R. (*Institute of Wood Science and Technology, India; rsundariwst@gmail.com*).

Santalum album L. is a valuable tree that occupies a preeminent position in Indian forestry. India used to contribute 90% of the *S. album* output of the world, but its share has declined in recent years and sandalwood is now in the vulnerable category of the IUCN Red List. Recognizing this grim situation, state governments of sandalwood-growing states relaxed the rule in such a way that "every occupant or the holder of land shall be legally entitled to the sandalwood tree in his land." Relaxed regulation is encouraging community and private entrepreneurs to cultivate *S. album* in agroforestry, farm forestry, and various agri-silvi-horticultural and mixed plantation systems. Many insect pests of agricultural and horticultural importance were found affecting sandalwood in these new systems of sandal cultivation. Infestation of sucking pests, particularly scales and mealybugs, often causes 30% mortality of trees in the early stage of establishment, and severe infestation of stem borers often causes almost complete failure of plantations. Many pests were found increasing their host range on *S. album.* In light of these findings, the emerging insect pest problems on *S. album* under cultivation and its efficient management practices were discussed in this paper.

Record of two new insect pests on Indian rosewood (*Dalbergia latifolia* Roxb.). Sundararaj, R., Ragavendra, G., Nalini, R (*Institute of Wood Science and Technology, India; rsundariwst@gmail.com; gundi.raghava21@gmail.com; rnalinidsi@gmail.com*).

The rosewood (*Dalbergia latifolia* Roxb.) is an economically important timber species indigenous to India. The timber is used for fine furniture and cabinet making, musical instruments, turnery, and decorative veneers. Medicines and an appetizer are made from tannins in the bark. The species is planted as a shade tree. Thus far it has been reported to be infested by 16 species of wood feeders, 14 species of sap suckers, and one species each of a defoliator and seed feeder. In the present study on insect pests of trees in south India, the mealybug *Icerya* sp. and the weevil *Peltotrachelus pubes* were found infesting *D. latifolia.* The severe

infestation of *Icerya* sp. often resulted in drying and premature falling of leaves. Infestation of *P. pubes* often resulted in complete defoliation of young plants. This is the first report of these two insects being found on *D. latifolia*. In this paper the insect pests so far reported on *D. latifolia* are reviewed and the significance of the occurrence of two new pests on *D. latifolia* is discussed.

Status of the invasive spiraling whitefly *Aleurodicus Dispersus* Russell (Hemiptera: Aleyrodidae) in India along with new host records. Sundararaj, R., Revathi, T.G., Divya, K.P., Amuthavalli, T. (*Institute of Wood Science and Technology, India; rsundariwst@gmail.com; revathi.tg@gmail.com; divyakprabhakaran@gmail.com; t7amutha@gmail.com*).

Whiteflies are small phytophagous insects belonging to the family Aleyrodidae. They infest the leaves of plants, generally the undersurface; a few species are found on petioles and stems. They are mostly restricted to the Tropics and Subtropics. The spiraling whitefly *Aleurodicus dispersus* Russell is an invasive species to India, and the spread of this whitefly was successful mainly due to its polyphagous nature and prolific breeding. In India, it has been found breeding on 320 plant species belonging to 225 genera under 74 families. The major host plants of economic concern in India are banana, guava, avocado, papaya, coconut, cucurbits, dahlia, gerbera, gladiolus, tomato, mulberry, tapioca, and bell pepper, in addition to several species of shade trees in the urban and forest environment. *Tectona grandis, Michelia champaca, Eucalyptus camaldulensis, Eugenia jamboloana*, *Artocarpus heterophyllus*, *Bauhinia variegata*, *Thespesia populnea*, *Pongamia glabra*, and *Polyalthia longifolia* are some of the important tree species affected by this whitefly. Detailed surveys conducted during 2010–13 on the whitefly fauna of India resulted in the discovery of many new host plants and found that *A. dispersus* is increasing its host range. In the light of these findings the pest status and host range of *A. dispersus* in India are discussed.

A simple non-destructive method for detecting heart rot in standing trees using impact resonance frequency Suyama, H. (*Shimane Prefecture Mountainous Region Research Center, Japan; suyama-hiroshi@pref.shimane.lg.jp*).

The decay-area ratios inside the stems of 240 living Japanese black pines in a park in Matsue City, Japan, were estimated using the lateral impact vibration method. Estimates were obtained using the diagnostic index, *df*, which is the product of the diameter *d* of a stem and the resonance frequency *f*, resulting from laterally impacting the stem with a hammer. Initially, the following procedures were performed: (1) The *df* of 31 Japanese black pines was measured using the lateral impact vibration method. These trees were then subsequently cut down to confirm whether the trees had decay. The average *df* of the non-decayed pines was accordingly obtained. (2) Using artificial hollow disks, the relationship between the hollow-area ratios and the decreasing rates of *df* was determined. All the trees in the park were tested using this method. The decay-area ratios were calculated on the basis of the two abovementioned procedures. To evaluate the accuracy of the method, the actual decay-area ratios were measured by cutting. The decay-area ratios estimated by this method were highly positively correlated with the actual ratios ($r = 0.80$, $p < 0.001$). This method was thus shown to be effective in estimating the decay-area ratios inside the stems of Japanese black pine.

A field evaluation of *Metarhizium anisopliae* formulations for management of Ailanthus defoliator, *Eligma narcissus* Cramer. Theeyan Chari Othayoth, S. (*Ashoka Trust for Research in Ecology and the Environment, India; tosasi@atree.org*).

Many planters of South India are currently growing *Ailanthus excelsa* trees because of increasing demand in several wood-based industries. Recently, recurrent defoliation by a lepidopteran pest, *Eligma narcissus*, has been observed severely affecting the productivity of the trees. The efficacy of 25 *Metarhizium anisopliae* isolates against the pest larvae was evaluated through a laboratory bioassay. Two promising isolates, MIS7 and MIS13, were subsequently evaluated in two infested 4-yr-old *A. excelsa* plantations in Odagathur of Tamil Nadu state. Two formulations of the isolates, F1 (MIS7+MIS13 at 1 014 conidia ml/ in 0.08% Tween® 80) and F2 (MIS7+MIS13 at 1 014 conidia ml/1 in 0.08% Tween 80 with 0.5% *Pongamia pinnata* seed oil), were applied by spraying. The population counts of *E. narcissus* were recorded 1 day before and 7 and 15 days after the application. Reduction of pest population over control calculated using the Henderson and Tilton equation was 60.5% in F2 and 53.8% in F1. Results indicate the potential for application of the formulation with *P. pinnata* seed oil to manage *Ailanthus* defoliation risk.

Forest fire danger changes for the China mainland in the last 30 years. Tian, X., Shu, L., Hong, L., Wang, M., Zhao, F. (*Chinese Academy of Forestry, China; tianxr@caf.ac.cn; slfhxk@126.com; work_li@caf.ac.cn; oldchoff@163.com; zhaofengjun1219@163.com*).

It is necessary to identify the effects of climate change on fire regimes for adaptation to climate change. This paper classified fire danger zones for the China mainland based on wildfires detected by satellites in 2005–2012 and ecological zones. A dataset of 824 daily weather observations for 1980–2010 was interpolated into 0.25° × 0.25° grids, and fire danger indexes were calculated for all grids by using the fire weather index (FWI) system. Results showed that: (1) The China mainland can be divided into eight fire danger regions (R1–8) and no vegetation areas, such as the North Daxing'anling Mountains deciduous coniferous forest region (R1), and (2) In 1981–2010 the annual average temperature and precipitation of the China mainland were 6.4 °C and 620 mm, respectively. Precipitation in the 2000s decreased 3.8% and 5.1% compared to the 1980s and 1990s, and the temperature increased 0.9 °C and 0.4 °C, respectively. Precipitation for R1, R2, and R3 declined significantly (8.5–16.0%). (3) FWI showed an increasing trend for most areas, especially for R2, where the FWI in the 2000s increased 29.3% over the 1980s. FWI for R2, R4, R7, and R8 increased by 8.9–14.7%, but the index for R8 decreased by 10.3%.

Assessing the impacts of *Imperata cylindrica* (L.) Beauv on root-feeding bark beetle populations associated with southern pine decline. Trautwig, A., Brunson, B. (*Auburn University, USA; antrautw@gmail.com; bab0002@tigermail.auburn.edu*), Carter, E. (*U.S. Forest Service, USA; eacarter@fs.fed.us*), Eckhardt, L. (*Auburn University, USA; eckhalg@auburn.edu*).

The invasive grass *Imperata cylindrica* is an increasing threat to the diversity of native plant and wildlife species in the United States. Another issue facing landowners of southeastern forests is pine decline (PD). The factors associated with PD include a complex of abiotic and biotic stressors that cause economically significant mortality in *Pinus* forests. Root-feeding bark beetles, which are vectors for pathogenic ophiostomatoid fungi, are attracted to stressed pines. *I. cylindrica* could be contributing to pine decline by inducing additional stresses, leading to higher infestations of root-feeding bark beetles. Twenty plots were established

in a *P. taeda* pine plantation located in southeastern Mississippi (10 with *I. cylindrical* and 10 without *I. cylindrica*). Insect traps on each plot were checked biweekly to observe insect population trends. Data show that *Hylastes salebrosus* was the most abundant species and had consistently higher populations in *I. cylindrica* plots. *Hylastes porculus*, *Dentroctonus terebrans*, and *Hylobius pales* showed similar trends, but populations were not significantly different between treatments. Soil moisture was found to be significantly higher in the top 8 inches of the soil horizon for *I. cylindrica* plots. This result may indicate that *I. cylindrica* rhizomes altered moisture availability to *P. taeda* pine roots and caused additional stress to the trees.

Collaboration in managing the threat of *Sirex noctilio*: the South African experience. Upfold, S., Croft, P., Dyer, C. (*Institute for Commercial Forestry Research, South Africa; sally.upfold@icfr.ukzn.ac.za; philip.croft@icfr.ukzn.ac.za; colin.dyer@icfr.ukzn.ac.za*), Hurley, B., Slippers, B. (*FABI-University of Pretoria, South Africa; brett.hurley@fabi.up.ac.za; Bernard.Slippers@fabi.up.ac.za*), Verleur, M., Wingfield, M.

First detected in *Pinus radiata* in the Cape Province of South Africa in April 1994, the woodwasp *Sirex noctilio* has spread across the pine-growing areas of the country, posing a significant threat to commercial softwood plantations. The South African Sirex Control Programme (SASCP) was established by the forestry private sector to address this threat. The programme became a unique private-public partnership between the private forestry sector, government (Department of Agriculture, Forestry and Fisheries), and specialized research institutions (Forestry and Agricultural Biotechnology Institute (FABI) and the Institute for Commercial Forestry Research (ICFR)).This paper details the approach taken by the South African Forestry Industry, particularly the development of the SASCP, in managing the threat to commercial pine plantation forests from the *Sirex* woodwasp. The history of the programme through to current initiatives is presented, including an overview of operational processes developed to control *Sirex,* the deployment of biological control agents, monitoring to detect the extent and spread of *Sirex*, communication to and awareness by all stakeholders, and research to support the programme. The various roles of all public and private partners are highlighted as are the lessons learned that can be effectively used in the management of future risks.

***Quambalaria*: new reports from four continents, including a new species from Australia.** Wingfield, M., de Beer, W., Marincowitz, S. (*FABI-University of Pretoria, South Africa; mike.wingfield@fabi.up.ac.za; wilhelm.debeer@fabi.up.ac.za; Seonju.Marincowitz@fabi.up.ac.za*), Kolařík, M. (*Academy of Sciences of the Czech Republic; mkolarik@biomed.cas.cz*), Pegg, G. (*Agri-Science Queensland, Australia; geoff.pegg@dpi.qld.gov.au*), Duong, T.

The smut-like genus *Quambalaria* is associated with foliar diseases on myrtaceous trees. The aim of this study was to characterize new isolates from various host trees in Africa, Southeast Asia, the United States, and Australia based on DNA sequences from ITS and EF-1α gene regions. The phylogenies of the two gene regions corresponded well and revealed six monophyletic clades representing *Q. pitereka*, *Q. eucalypti*, *Q. cyanescens*, *Q. coyrecup*, *Q. pusilla* (with *Q. simpsonii* as synonym), and a new species from leaf spots on *Angophora costata* in Australia. The data revealed new host records for *Q. coyrecup, Q. cyanescens*, and *Q. pitereka* from *A. costata* in New South Wales, and *Q. pitereka* from *Corymbia tessellaris* and *C. ptychocarpa* in Queensland. New country reports from diseased *Eucalyptus* leaves include *Q. eucalypti*, *Q. pusilla*, and *Q. cyanescens* from Laos, and *Q. eucalypti* from Thailand. *Quambalaria cyanescens* was the only species on non-myrtaceous hosts and on all inhabitable continents. It is associated with several hardwood-infesting bark beetles from Colorado and California (USA), and from Tunisia. Australia is the only country where all six *Quambalaria* spp. have been reported, suggesting that this is the centre of origin of the genus.

Mapping susceptibility to large forest fires using MODIS in Washington and Oregon (USA). Yang, Z. (*Oregon State University, USA; zhiqiang.yang@oregonstate.edu*), Davis, R., Cohen, W. (*U.S. Forest Service, USA; rjdavis@fs.fed.us; wcohen@fs.fed.us*), Mildrexler, D. (*Oregon State University, USA; David.Mildrexler@oregonstate.edu*).

Mapping fire-prone areas, especially those susceptible to large forest fires, has important implications for forest management as well as wildlife conservation. For example, wildfire has been identified as the leading cause of habitat loss for spotted owl nesting and roosting. This study presents a framework for modeling the probability of large fires in forested areas of Washington and Oregon (USA). The analysis uses environmental gradient, forest successional status, and current forest conditions to map the pattern of large fire occurrence. In addition to static environmental variables, e.g., elevation, slope, and radiation, MODIS land surface temperature is included. It is hypothesized that a stressed forest is more prone to fire. In this analysis, areas with a long-term trend of decreasing vegetation vigor were identified using time series of Landsat images. MODIS surface reflectance and Normalized Difference Vegetation Index (NDVI) products were used to represent current vegetation condition. Random samples from fires as identified by Monitoring Trends in Burn Severity (MTBS) from 2002 to 2010 were used as training data, and predicted fire probability maps for 2011 to 2013 were used for validation. Two modeling methods were evaluated: MaxEnt and Random Forest.

Damage risk assessment of Norway spruce forests with different site and stand characteristics: towards sustainability assessment and sustainable management. Žemaitis, P., Stakenas, V., Čapkauskas, G., Varnagiryte-Kabasinskiene, I. (*Aleksandras Stulginskis University; povilaszemaitis@gmail.com; v.stakenas@mi.lt; gediminas.capkauskas@gmail.com*).

Tree health and frequency of tree damage are key elements influencing the sustainability of forest stands. Therefore, it is very important for forest managers to identify the site types and stand characteristics that can help to reduce the vulnerability of stands. Norway spruce (*Picea abies* (L.) H. Karst.), a dominant tree in the forests of Eastern and Northern Europe, were studied. Data from the Forest Monitoring Level I (1989–2010) data set with approximately 2 000 Norway spruce samples collected annually were used. Humidity and soil fertility were selected as site variables; tree species composition, stand structure, and age were selected as stand characteristics. Total risk index was calculated based on spruce crown defoliation, defoliation class, and frequency of identifiable biotic and abiotic damage (e.g., insects, fungi and diseases, wind, frost, drought). Results showed that site and stand characteristics are important factors in the condition of and damage distribution in spruce stands in Lithuania. The authors concluded that Norway spruce management could be optimized according to the lowest total risk index based on site and stand characteristics.

GENERAL POSTER SESSIONS

IUFRO Division 8: Forest Environment

The roles of protected areas to biodiversity conservation and carbon storage: case study of two developing countries. Adekunle, V. (*Federal University of Technology, Nigeria; adekunlevaj@rediffmail.com*), Nair, N. (*National Botanical Research Institute India; nairnbri@yahoo.co.in*).

The contributions of protected areas (PAs) in two developing countries (Katarnia Ghat Wildlife Sanctuary, India and Eda Strict Nature Reserve, Nigeria) to biodiversity and environmental conservation were assessed in this study. Inventory data were collected from 12 plots (25 m × 25 m) randomly located in each of the PAs. In each plot, all woody plants were identified and tree growth variables (DBH ≥ 10 cm) were measured. Biodiversity indices were used for species diversity, analytical formula for stand volume, and Brown's model for biomass estimation. The diversity and abundance, physiognomy, yield, and the family importance of the PAs indicated that they are mature, repository of biodiversity, and have potentials for continuous development. The biodiversity indices compared favorably with the results from other similar PAs. The above ground biomass and carbon estimation show the roles of forest landscape in climate change mitigation through CO_2 absorption. The difference in phytosociological characteristics and carbon values of the two PAs, higher values obtained for the Nigerian PA, was attributed to the variation in geographical location, climatic conditions, and soil properties. The challenges in developing countries with forest protection can be mitigated by introducing some institutional policies and involving rural communities in the management of PAs.

PES: the watershed services of tropical forest. Adnan`, N., Ahmad, I., Mohd Yusof, M. (*Forest Research Institute Malaysia, Malaysia; norliyana@frim.gov.my); ismariah@frim.gov.my; mohdfaridzul@frim.gov.my*).

Ecosystem services received attention in both the Millennium Ecosystem Assessment and The Economics of Ecosystem and Biodiversity (TEEB). One of the most important ecosystems provided by tropical forest is watershed. Tropical forest resources have been one of the major sources of revenue for the Malaysian economy, however it is decreasing every year due to activities such as commercial logging, shifting cultivation, and forest encroachment for other land uses. The sustainable management practices for watershed and land use have to apply in order to fulfill the demand between watershed and land use, where protecting water resources is communities demand and land use. This study uses both statistical and economic models to understand the impact and the value of tropical forest protection for watershed services. This study is based on 69 catchments of streamflow and sediment monitoring stations of 10 states in Malaysia. For each station we use a geographic information system (GIS) to determine catchment boundaries and to construct catchment-specific meteorological variables. Data on each forest are gathered from the National Forest Inventory from 1982, 1991, 1997, and 2002 while data on nonforest land use are derived from the land use survey maps for 1984, 1990, 1997, and 2004. For the hydrological analysis, we used multiple regression analysis to evaluate the effect of land use changes on water flow and sedimentation in the river basin.

Assessment of tree species diversity and growth analysis of trees species in Igbo-Olodumare, Ondo State, Nigeria. Agbelade, A. (*Federal University of Technology, Nigeria; aladesanmi2008@gmail.com*).

This research paper examines tree species diversity, abundance, and yield of trees species in Igbo-Olodumare, Ondo State, Nigeria. Basically, the objective of this research work was to assess the level of biodiversity and analyze the growth variables of the forest ecosystem. Data were collected from three temporary sample plots of 20 m × 20 m, laid systematically in the sites. Within each plot, trees with DBH ≥ 20 cm were identified and their DBH was measured. Biodiversity indices and growth variables were computed with biodiversity and growth variable equations. There was a total of 152 stems/ha of 17 families and 27 species. Shannon's maximum diversity index (Hmax) was 5.02, Shannon's equitability (EH) was 2.07, and Shannon-Wiener diversity index (H') was 2.66. Tree growth variables were obtained and indicated as mean diameter at breast height (17.82 m), mean basal area (14.0 m^2/ha), and mean volume (87.21 m^3/ha). The most abundant species was *Hildegardia barteri* in the family of Meliaceae (53 stems) followed by *Mansonia altisima* in the family of Sterculiaceae with 13 stems, and *Celtis zenkeri* in the family of Ulmaceae with 8 stems. It is therefore recommended that the forest estate within Igbo-Olodumare should be protected adequately and developed into a world class tourist attraction center with proper forest management in place.

Enhanced accumulation of Hg in aquatic biota: An effect from forestry and land use? Åkerblom, S. (*Swedish University of Agricultural Sciences, Sweden; staffan.akerblom@slu.se*), Eklöf, K. (*Pennsylvania State University, USA; kje15@psu.edu*), Bishop, K., Wu, P. (*Swedish University of Agricultural Sciences (SLU), Sweden; Kevin.Bishop@slu.se; pianpian.wu@slu.se*).

Field studies have been initiated in Sweden with the main focus being to estimate temporal trends of Hg in fish from lakes subject to forestry operations in their catchments. These forestry operations include clearcut as well as fertilization. Results from these studies were compared to temporal trends of Hg in fish from national monitoring stations. Forested catchments accumulate considerable amount of Hg compared to unforested catchments. This excess in stored Hg, primarily in soils, is a source of Hg available for transport and accumulation in freshwater ecosystems. In fact, higher Hg concentrations in fish were found in boreal forest lakes, even in remote areas, compared to unforested areas. Several studies have shown that Hg transport increases in stream runoff after forestry operations. This excess in exported Hg can potentially become available for accumulation in food chains in boreal lakes. It is shown that the direct transport of Hg does not directly promote higher bioaccumulation. Other chemical and biological effects due to forestry can also be induced that affect the potential of Hg to bioaccumulate.

Ethnobotany and structure of natural stands of plant toothbrush species in southern and central part of Benin. Akpona, T. (*Laboratory of Applied Ecology, Benin; ajeandidier@gmail.com*), Akpona, A. (*General Directorate of Forestry and Natural Resources, Benin; akpona@gmail.com*).

Plant toothbrush, wrongly named toothpick, is a shrub species that is considered as a secondary forest product that thrives in natural stands (savannas and forest). A structural description of the stands mainly composed of these species was done through a forest inventory of 19 square plots of 50 m per side. Data collected within plots were the diameter of each individual and the number of the species that were used to compute dendrometric and ecological parameters. Moreover, an ethnobotanical survey was conducted in some districts of south and central Benin through interviews of 105 randomly selected people. Data collected were related to their perception on the patterns of use of plant toothbrush species. The results obtained showed that the density of the plant toothbrush was significantly higher in savannas than in forest, and the species richness was higher in tree-savannah and forest than in shrub-savannah. The other structural parameters had almost the same value in savannas and forest. The most important and most used species were: *Anogiussus leiocarpa, Bridelia ferruginea, Combretum collinum, Hymenocardia acida, Malacantha alnifolia, Napoleona vogelii, Pseudocedrella kotschyi, Sorindea warneckei, Terminalia glaucescens* and *Zantoxylum zanthoxyloides.*

Where will forest loss occur? Identifying attractors of forest loss in temperate ecosystems of south-central Chile. Altamirano, A. (*Universidad de La Frontera, Chile; adison.altamirano@ufrontera.cl*), Miranda, A. (*Universidad de La Frontera, Chile; alejandro.miranda@ufrontera.cl*), Pinchiera, F. (*Corporacion Nacional Forestal, Chile; francoise.pincheira@gmail.com*), Cayuela, L. (*Universidad Rey Juan Carlos, Spain; luis.cayuela@urjc.es*), Orrego, R. (*Universidad de La Frontera, Chile; r.orrego@ufromail.cl*).

Temperate forests of Chile are one of the world's biological hotspots but they are being transformed at an unprecedented high rate. We investigated the attractors of forest loss in three physiographical zones of Chile. We analyzed satellite imagery from 1973, 1987, 1999, and 2008. Multiple logistic regression models were fitted to investigate the relationship between the main trajectories of forest loss and attractors of such change. Overall, a decrease of native forest cover associated to an expansion of agricultural land and establishment of forest plantations. Yet, the trajectories of forest loss were not homogeneously distributed across regions for the different time periods. Whereas in the Coastal and Andean Ranges native forests were mostly replaced by exotic plantations, in the Central Valley agricultural expansion was the main responsible of forest loss. In the Coastal Range, forest loss mainly occurred on flat slopes and next to villages. In the Central Valley, proximity to existing agricultural land was the most important attractor. Finally, forest loss in the Andean Range was associated to lower elevations and flat slopes. Our results highlight the need for new policies to reduce native forest loss that consider the spatial variability of the trajectories and attractors of deforestation.

Integrating data at multiple scales to assess national synergies between forest carbon and biodiversity in Colombia. Armenteras, D., Rodriguez, N., Molina, E. (*Universidad Nacional de Colombia, Colombia; darmenterasp@unal.edu.co; neraso2000@gmail.com; edumolgo@gmail.com*), Retana, J. (*Centre for Ecological Research and Forestry Applications (CREAF), Spain; javier.retana@uab.es*).

Few studies have analyzed the relationship of forest carbon (C) stocks and biodiversity at national and sub national levels in tropical countries. Part of the problem is the lack of adequate data for monitoring both carbon and biodiversity at the local levels. This can be overcome by undertaking a combination of a three tier approach proposed to integrating biodiversity concerns into assessment frameworks for national programs for reducing emissions from deforestation and forest degradation, thus combining globally derived data with nationally generated remote sensing data and ground based forest and biodiversity surveys. In the present study, we apply this combined approach with available datasets at different scales and assess the congruence between forest C storage and biodiversity, focusing on species richness at the national level in a tropical country such as Colombia. We also analyze the variation in this relationship within Colombian regions with highly contrasting geographical characteristics and explore factors that affect biodiversity and C patterns. We analyze areas of maximum biodiversity and of maximum carbon storage to find out geographical areas with overlaps. Finally, we identified those regions potentially to be the focus of either forest carbon or biodiversity focused policies.

Ecosystem response 20 years after intensive forest harvesting for bioenergy in *Betula papyrifera* stands in Central Newfoundland: a multidisciplinary approach. Arsenault, A., Titus, B., Thiffault, E., Baines, P. (*Canadian Forest Service, Canada; Andre.J.Arsenault@NRCan-RNCan.gc.ca; Brian.Titus@NRCan-RNCan.gc.ca; Evelyne.Thiffault@RNCan-NRCan.gc.ca; Patricia.Baines@NRCan-RNCan.gc.ca*), Sveshnikov, D. (*Memorial University of Newfoundland, Canada; dmitry.sveshnikov@grenfell.mun.ca*).

Bioenergy produced from biomass left behind from forestry operations is renewable, reduces fossil fuel use, and has economic potential in Canada. However, it is important to understand the environmental impacts of intensive forest harvesting and use this knowledge to guide policy and develop best management practices to ensure the sustainable management of our forests. We examined forest ecosystem response to conventional and whole-tree harvesting of white birch stands 20 years after treatment along a productivity gradient at three locations in Central Newfoundland. Clear-cutting significantly increased the diversity of vascular plants, most likely because of increased light levels, but the intensity of biomass removals did not appear to affect the abundance or diversity of vascular plant species. However, significant differences in the abundance of deadwood and associated nonvascular flora persisted 20 years after treatment. The combination of clear-cutting and intensive browsing by moose accelerated succession when conifers were abundant in the understory. Sites with low conifer regeneration developed into alder thickets. The intensity of biomass removal did not appear to influence this result, however, the whole tree harvest treatment was associated with lower conifer growth and volume at one of the sites. Relationships between forest structure, species diversity, forest productivity, and soil and foliar nutrients will be discussed within the context of intensive biomass harvesting.

Relation between soil type and potential of regeneration in vegetation pattern of Sudanian zone. Assede, E. Adomou, A., Sinsin, B. (*University of Abomey-Calavi, Benin; assedeemeline@gmail.com; adomouaristide@yahoo.fr; bsinsin@gmail.com*).

Regeneration of woody species has always been the major concern of ecologist in the process of ecosystems renewal. This work aims to determine the potential of regeneration in different vegetation units of the Sudanian zone and establish a relationship with the soil type. A total of 615 square plots of 25 m^2 were established inside of four vegetation patterns. We used Poisson regression

to model the regeneration potential across different soil types. Contrary to floodplains, the border of streams and the hills presented a positive effect on density of regeneration. The incidence rate ratio of floodplains, border of streams, and hills were respectively 1.01, 2.1, and 0.67 times the incident rate ratio of plains. Contrary to hills, floodplains and border of stream had a negative effect on the number of species in regeneration compared to plains. The incidence rate ratio of floodplain, border of stream, and hills were respectively 0.43, 0.6, and 1.2 times the incident rate ratio of plains. From the tree species studied, only *Terminalia macroptera* presented its best regeneration density in floodplains. Even if the soil type was a good predictor of the regeneration potential, it was not sufficient to predict the evolution of regeneration potential.

How to make burning of Chocolate Hills of Bohol, Philippines carbon neutral? Bantayan, N., Pulhin, F., Calderon, M., Predo, C. (*University of the Philippines Los Banos, Philippines; ncbantayan@gmail.com; yaybpulhin@yahoo.com; bargecal@yahoo.com; cdpredo@yahoo.com*), Barruga, R., Barruga, R. (*Ecosystems Research and Development Bureau Philippines, Philippines; roseannbarruga@yahoo.com; roseann_barruga@yahoo.com*).

This study was conducted to develop a carbon offset program for the Chocolate Hills Natural Monument (CHNM) in Bohol, Philippines. We found that the current scheme of burning to maintain the grass-covered (treeless) and brown hills in order to sustain tourist arrivals is environmentally unsound. The study estimated the carbon loss from burning and compared it with the tourism income of the Chocolate Hills. A comparison of the benefits and costs of the status quo and the proposed management regime was conducted. Also, the biomass analysis and the carbon assessment reveal that an estimated 153 ha of forest should be established to offset the carbon emission due to clearing of the hills. This means that the carbon offset project will require the establishment of one hectare of forest for every two hills cleared. The cost of forestation could be supported with income from tourism in a form and manner that directly involves the community. The study found that the present value of tourism income was much higher than the cost of carbon emission due to burning.

Ground beetles (Coleoptera, Carabidae) assemblage in forests plantations of the Colombian Orinoquia. Baquero Carvajal, L., Pinzón Florian, O. (*Universidad Distrital Francisco José de Caldas, Colombia; sptefannie@hotmail.com; opatriciap@udistrital.edu.co*).

Commercial forests plantations with fast growing species such as *Pinus caribaea*, *Eucalyptus pellita.* and *Acacia mangium* are replacing areas previously occupied by natural savannas or introduced pastures in the Colombian Orinoco region. Consequences of changing soil use over associated diversity and soil productivity are still unknown. Considering that Carabidae are sensitive to environmental and structural changes in the ecosystem, and therefore used as ecological indicators of disturbed areas, we compared their richness in stands of *Eucalyptus pellita* and *Pinus caribaea* of four different ages in which silvicultural management was crucial. Sampling was performed exposing 135 pitfall traps for 15 days at the beginning of the rainy season of 2013. Some environmental and dasometric variables were also recorded including closure of the canopy, litter accumulation, and basal area of the trees. A total of ten and nine morphospecies were found in eucalyptus and pine respectively, belonging to five genera of which the most representative was the genus *Tetracha.* In addition, Cicindelinae and Scaritinae were most representative subfamilies. Richness was higher in younger plantations disregarding the forest species.

Designing innovative silvicultural best practices to increase multi-taxa biodiversity in Natura 2000 priority habitats (9210* and 9220*) Apennine beech forests. Barbati, A. (*University of Tuscia, Italy; barbati.sisfor@unitus.it*), Burrascano, S., Sabatini, F. (*Sapienza University of Rome, Italy; sabinaburrascano@gmail.com; francescomaria.sabatini@gmail.com*), Corona, P. (*Forestry Research Centre (CRA-SEL), Italy; piermaria.corona@entecra.it*), Portoghesi, L. (*University of Tuscia, Italy; lporto@unitus.it*), Blasi, C. (*Sapienza University of Rome, Italy; carlo.blasi@uniroma1.it*).

Beech forests of the Appennines priority habitats 9210* and 9220* are remnants of more extensive forests where beech was mixed with European yew (*Taxus baccata*) and/or European holly (*Ilex aquifolium*) and silver fir (*Abies alba*). Nowadays, most of their natural range is represented by almost pure beech stands, with cascading effects on the diversity of plants and other taxonomic groups. The EU funded LIFE+ project FAGUS (Forests of the Apennines: Good practices to Conjugate Use and Sustainability) aimed at testing silvicultural treatments to increase the presence of target trees (yew, holly, and silver fir) in beech habitats and biological diversity of other focus taxa (vascular plants, epiphytic lichens, saproxylic fungi and beetles, birds) while sustaining forest use by local communities (e.g., fuelwood collection, grazing). Under the conceptual framework that looks at forests as complex adaptive systems, we applied an advanced methodological approach to support the design of silvicultural treatments based on: (i) multiscale integrated forest structure and multi-taxa survey to analyze relationships between forest habitat heterogeneity and multi-taxa species diversity; (ii) experimental stand manipulation treatments aimed at increasing forest structural heterogeneity, as a way to enhance diversity levels of other focus taxa; and (iii) BACI experimental approach to assess the responses to the tested treatments.

Evaluation of the climate influence in the forest fire occurrences in the Lichinga district, northern of Mozambique. Batista, A., Mbanze, A., Tetto, A., Koehler, H. (*University of Paraná, Brazil; batistaufpr@ufpr.br; aires.banze@gmail.com; tetto@ufpr.br; koehler@ufpr.br*), Manteiga, J. (*Niassa Forest, Mozambique; manteigax95@gmail.com).*

The aim of this study was to assess the influence of climatic variables (temperature, precipitation, and relative humidity) on the occurrence of fire in forest stands in Lichinga District (northern Mozambique) over a period of 3 years. We analyzed the fire occurrences records in three districts (Lichinga, Lago and Sanga). Data was provided by the Center for Monitoring and Control of Forestry Fires (CCMIF) of the company Chikweti Forest of Niassa, and daily weather data including temperature, rainfall, and relative humidity was recorded at 13 hours by the meteorological station of the Institute of Agronomic Research of Mozambique in Lichinga (IIAM-Lichinga). Meteorological data were tested using regression analysis and the Tukey test. A significant variation in temperature and humidity was observed in both tests. The overlapping of the occurrences of fires and climatic variables suggested a great influence of the climate variables in the occurrence of fires, mainly due to the very long dry periods. In 2010 there was a delay in the fire occurrences due to the rainy season which was slightly longer. September and October were the months that recorded the highest number of fire occurrences throughout the study period.

Variation of FMA fire danger index due to climate change in Paraná State, Brazil, in the period 2010 to 2100. Batista, A., Tetto, A. (*Federal Univeristy of Parana, Brazil; batistaufpr@ufpr.br; tetto@ufpr.br*), Deppe, F. (*Technological Institute SIMEPAR, Brazil; deppe@simepar.br*), Filho, J.D.F. (*State University of Ponta Grossa, Brazil; jvirgens@globo.com*), Grassi, J. (*Federal University of Parana, Brazil; jgrassi@simepar.br*), Grodzki, L. (*Agronomic Institute of Paraná (IAPAR), Brazil; leogrodzki@hotmail.com*).

This research aimed to evaluate the temporal behavior of forest fire danger for the state of Paraná, Brazil in the period from 2010 to 2100. Daily index values were calculated for Monte Alegre Formula (FMA) fire danger index, using the scenarios of the Intergovernmental Panel on Climate Change (IPCC), published in 2007. Two IPCCs scenarios were considered: increase of 1.8 ºC and increase of 4.0 in the average temperature of the Earth by 2100. The results of FMA fire danger index were classified into five danger classes. The simulations for the best scenario showed that there will be no major changes in terms of area for the higher danger classes of FMA. However, for the worst scenario, a significant spatial variation in the analyzed period was noted, and in the very high and extreme classes, values reached 96.89% of the area in 2100. The results allowed us to conclude that, if the predictions of the IPCC are confirmed, there will be an increase in the number of wildfires in the state of Paraná, which will require integrated actions to prevent and suppression forest fires to minimize possible environmental, social, and economic losses.

Island size, isolation, and forest ground beetle (Coleoptera: Carbidae) diversity on the fire-prone landscape of Lac La Ronge. Bell, A. (*University of Alberta, Canada; ajbell@ualberta.ca*), Phillips, I. (*Water Security Agency, Canada; iain.phillips@wsask.ca*), Waite, E. (*Saskatchewan Wildlife Federation, Canada; ed.waite@botany.otago.ac.nz*), Nielsen, S., Spence, J. (*University of Alberta, Canada; scottn@ualberta.ca*), (*Univeristy of Alberta, Canada; jspence@ualberta.ca*).

The theory of island biogeography holds that the number of species present on an island is influenced by its size and distance from mainland. Large islands are typically more diverse because they have more resources and niches, in addition to supporting larger populations with reduced risk of local extinction. Similarly, islands near the mainland are typically more diverse on account of increased probabilities of colonization. However, the role of natural disturbances, such as wildfire, on island biogeography is not fully understood. In the boreal forest, the probability of lightning strikes increases with island size, while the probability of embers from distant fires landing on an island decreases with isolation. The purpose of this study is to (1) investigate changes in carabid beetle diversity between mainland and islands; (2) determine if island size, distance from mainland, and fire history influence carabid diversity; and (3) contrast the proportion of flightless species on the mainland with islands to compare colonization strategies across island characteristics. To evaluate these questions, we used pitfall traps to sample five mainland sites and 30 islands across a size and isolation gradient.

Termite richness in *Pinus caribaea* Muell. plantations in the Colombian Orinoquia. Beltrán Díaz, M., Pinzón Florian, O. (*Universidad Distrital Francisco José de Caldas, Colombia; alrja.rg@gmail.com; opatriciap@udistrital.edu.co*).

Termites are one of the most abundant groups of invertebrates in tropical savanna soils, having important ecological roles in cellulose degradation as well as in the improvement of the physicochemical characteristics of the soils. In order to estimate and compare specific as well as functional termite richness, we sampled in stands of different ages of *Pinus caribaea* established in lands previously occupied by natural savannas and introduced pastures in the Casanare department in the Colombian Orinoco region. Termites were sampled using the standard transect protocol. In addition, environmental (soil type, pH, moisture) and dasometric (basal area, tree height) measures were recorded. Termites collected in soil samples, mounds, and pieces of wood were identified to genus and species level and then classified by trophic group. Thirteen genera grouped in xylophages, humívorous, and intermediates were found. Humivorous termites were found in all plantations disregarding age or thinning. The establishment of *P. caribaea* plantations favors the occurrence of genera of intermediates and xylophagous such us: *Microcerotermes*, *Nasutitermes*, *Neocapritermes*, *Termes*, and *Rhinotermes marginalis*, common in gallery forest of this geographical region.

Flowering and fruiting phenology and floral visitation of four native tree species in the remnant moist Afromontane forest of Wondo Genet, south central Ethiopia. Beshawored, M., Isotalo, J. (*University of Helsinki, Finland; mamokeb@gmail.com; jarko.isotalo@helsinki.fi*), Valtonen, A. (*University of Eastern Finland, Finland; annu.valtonen@uef.fi*).

The flowering and fruiting phenology of four native tree species and their floral visitation by insects was investigated to understand their phenological pattern and the species richness and pattern of visitation. In the natural forest of Wondo Genet, Ethiopia, 25 mature individuals of four indigenous species were selected and monitored over 2 years for their phenology. Flower visiting insects were trapped with sweep nets at an interval of every 2 hours between 8:00–18:00 for 20 days. Circular statistics were employed to test for seasonality in flowering and fruiting. The visitor community compositions of the four species were compared with permutational ANOVA. While the tree species expressed synchronous seasonal flowering that peaked during the dry period, fruiting was also seasonal. The mean monthly rainfall and temperature significantly correlated with the periods of the phenophases. Visitor communities of *M. ferruginea* differed significantly from visitor communities of *A. abyssinicus, P. fulva* and *S. guineense.*

Forests and the hydrological regime: what can we tell policy-makers about how changing tree cover influences runoff. Bishop, K. (*Swedish University of Agricultural Sciences (SLU), Sweden; Kevin.Bishop@slu.se*), Creed, I. (*University of Western Ontario, Canada; icreed@uwo.ca*).

The influence of forests on the hydrologic regime has been investigated and debated over the past century. But the question remains: Do we know enough about how the water regime reacts to changes in forest cover to make water-wise decisions? Afforestation, deforestation, harvest methods, species selection, drainage, and other silvicultural alternatives facing individuals, communities, and governments involve difficult tradeoffs where knowledge of the implications for water should be considered. The author of this abstract will be convening a 2013 AGU fall meeting session with the title of this abstract-Forests and the hydrological regime: after all these years what can we tell policy makers about how changing tree cover influences runoff. The intention of this presentation to IUFRO 2014 is to highlight the major findings, agreements, and conflicts raised by the 20 papers presented at the AGU session which address the complex nexus of interactions between forests and runoff. Particular focus will be placed on the role of spatial scale and the ecoregion in making sense of the often conflicting views on how forests influence hydrology.

Phenological evaluation of five commercial forest species of ecological importance in the forests of the Department of Tolima, Colombia. Bonilla Vargas, J., Lozano Botache, L. (*Universidad del Tolima, Colombia; forest.lorena@gmail.com; llozano@ut.edu.co*).

Based on the forest management principles applied in the Department of Tolima, Colombia, the regional environmental authority Cortolima and the University of Tolima, we present preliminary results of a study that is aimed at getting to know the phenological importance of the following five native forests species: *Quercus humboldtii*, *Tetrorchidium boyacanum*, *Alfaroa colombiana*, *Cedrela odorata,* and *Endlicheria sp*. These species show a certain degree of vulnerability and are on the list of species of high commercial value for the Department. Monthly records were collected using the methodology of Fournier (1974). Six phenological variables have been evaluated: flower bud, open flower, green fruit, ripe fruit, leaf shedding, and leaf sprouting. Each individual has been geo-referenced and encoded on the stem. This study shows preliminary results of a period of 5 years, starting in 2008, including dendrophenograms and phenological calendars for each species of interest. This information will be used for decision making with regard to the planning of forest operations on local and departmental levels. However, at least 10 years of monthly measurements are necessary in order to cover all phenological events during local climatic fluctuations.

Response of small individuals of hardwood species to surface fires in western Chaco region, Argentina. Bravo, S. (*Universidad Nacional de Santiago del Estero, Argentina; sandrabrav@gmail.com*), Kunst, C. (*Instituto Nacional de Tecnología Agropecuaria, Argentina; ckunst@santiago.inta.gov.ar*), Leiva, M. (*Universidad Nacional de Santiago del Estero, Argentina; martaleiva@gmail.com*), Ledesma, R. (*Instituto Nacional de Tecnología Agropecuaria, Argentina; rledesma@santiago.inta.gov.ar*).

The objective of this work was to assess the response to surface fires of juvenile individuals (DBH $\leq$ 15 cm) of three hardwood species from Argentine Chaco, *Aspidosperma quebracho-blanco*, *Schinopsis lorentzii* and *Ziziphus mistol.* We characterized thickness and density of bark of the three species, and we conducted field work in 2008 and 2009 with prescribed burns applied at different times throughout Chaco region's fire season. We determined charring height of bole, mortality, and post fire resprouting pattern. Species and the interaction year of burning* species* timing of burn had significant effects. *A. quebracho-blanco* showed a greater charring height of bole than *S. lorentzii* and *Z. mistol,* and it was the thickest and lowest density bark species. The other two species had lower bark thicknesses and higher densities of bark than *A. quebracho-blanco*. Four months after fires, the mortality was 5% for *A. quebracho-blanco*, 8% for *S. lorentzii,* and 10% for *Z. mistol,* and differences among species were significant. The type of sprouting varied significantly among species, with *A. quebracho-blanco* exclusively producing basal resprouts and the other species producing both epicormic and basal resprouts. The species showed a high tolerance to medium and high severity surface fires in the juvenile state.

Biomass and carbon sequestration of selected natural mangrove forests in the Philippines. Breva, L., Castillo, J. (*Ecosystems Research and Development Bureau (DENR, Philippines; alcala_breva99@yahoo.com; allan536@yahoo.com*).

This study was conducted to determine the biomass, carbon stored in the biomass and sediment, and carbon sequestration rate in selected natural mangrove forests in the country. Quadrat sampling technique and existing mangrove allometric biomass models were used. Results showed that in natural stands, the total biomass ranged from 61 to 478 ton/ha with a mean of 229 ton/ha. The carbon stock in the biomass ranged from 28.81 to as high as 224.66 t C/ha or 107.81 t C/ha on the average. The sediment carbon ranges from 133.8 to 191.27 t C/ha or 154.93 t C/ha, on the average. The total carbon stock in biomass and sediment combined was 262.66 t C/ha, on the average, and ranged from 178.41 to 369.70 t C/ha, which is equivalent to 963.95 ton/ha of carbon dioxide, on the average. The carbon sequestered during the 2-year duration of the study based on biomass accumulation in four natural mangrove stands studied is 3.83 t C/ha/year, on the average and ranged from 1.90 to 5 t C/ha/year. This amount was equivalent to an annual uptake of 14.05 tonnes of carbon dioxide per hectare from the atmosphere. The total carbon stored annually of the mangroves studied was a significant amount which must be managed well in order not to release carbon back to the atmosphere.

Wood anatomy and dendroclimatological potential of trees of the dry tropical forests of Colombia. Briceño, A. (*National University of Colombia, Colombia; bricenoan@gmail.com*), Bogino, S. (*State University of San Luis, Argentina; stellabogino@gmail.com*), Rangel-Ch, O. (*National University of Colombia, Colombia; jorangelc@gmail.com*).

Dry tropical forests of Colombia are of outstanding value due to their high support of the human population and their phytosociological diversity which is higher than that of wet forests. Dendrochronological studies have only more recently been done in tropical areas compared to temperate ones because of their high value and interest in understanding the growth-climate association under changing climate conditions. Mean annual rainfall is about 475.3 mm distributed in two periods throughout the year. Dry periods motivate dormancy in the cambium activity that results in tree-ring formation. Wood anatomy characteristics of tree rings of *Bursera simaruba* (L.) Sarg., *Prosopis juliflora* (L.), *Ruprechtia ramiflora* (Jacq.) CA Mey., *Cordia colloccoca* L., and *Aspidosperma polyneuron* Müll. Arg. growing in dry areas of the Colombian Caribbean are described. Standard methodology for wood anatomy studies was applied. Results showed that *Bursera simaruba, Ruprechtia ramiflora*, *and Aspidosperma polyneuron* tree rings were delimited by woody density variations; however, *Ruprechtia ramiflora* showed lenses or false tree rings. *Prosopis juliflora* and *Cordia colloccoca* tree rings were determined by banded marginal parenchyma. These results allowed us to conclude that *Bursera simaruba*, *Prosopis juliflora*, *Cordia colloccoca*, and *Aspidosperma polyneuron* have an accurate dendrochronological potential for dry tropical forest studies.

Studying deep root dynamics with disaggregation modelling using SIMILE: fine root dynamics for an east central Amazonian moist tropical forest. Briceño-Elizondo, E. (*Instituto Tecnologico de Costa Rica, Costa Rica; ebriceno@itcr.ac.cr*), Christoffersen, B. (*University of Arizona, USA; bradleychristo@gmail.com*), Espeleta, J. (*University of Washington, USA; jfespeleta@gmail.com*), Arias, D. (*Instituto Tecnologico de Costa Rica, Costa Rica; darias@itcr.ac.cr*).

The belowground carbon pool contributes largely to the carbon balance of forest ecosystems, being particularly dynamic in terms of decomposition rates and carbon recycling to the soil carbon, but this pool is often under studied. In many studies, root

sampling has only taken place to a depth of 1–2 m, excluding potential large quantities of carbon and its distribution. Process-based models of forest ecosystems synthesize a broad array of processes from tree physiology, nutrient recycling, soil physics, and chemistry. The modeling environment SIMILE uses disaggregation modelling in which the soil can be divided into a number of layers, aiding the understanding of the demography of root dynamics at different depths, and integrating minirhizotron data sampling information for each layer, using differential equations to define the rate of recycling of each root defined biomass pool. The present research work collected data from belowground measurements in two deep soil pits (10 meter depth), one in closed canopy forest and another in an adjacent natural tree-fall gap. Minirhizotron data aims to integrate object based modeling with state of the art soil profile information on root depth and dynamics to create an accurate model to aid in the soil carbon balance of tropical forest ecosystems.

The impact of a changing climate on net primary production of Mediterranean forests in southwest Western Australia. Brouwers, N. (*Murdoch University, Australia; n.brouwers@murdoch.edu.au*), Coops, N. (*University of British Columbia, Canada; nicholas.coops@ubc.ca*), Hardy, G. (*Murdoch University, Australia; g.hardy@murdoch.edu.au*), Matusick, G. (*The Nature Conservancy, USA; gmatusick@tnc.org*).

Climate conditions in Mediterranean ecosystems have been predicted to undergo significant changes in the future. The southwest of Western Australia (SWWA) is considered a global guinea-pig with regards to impacts of climate change on forest health and function. The SWWA has experienced an average decrease in rainfall since the 1970s along with temperature rises of 0.15 °C per decade over this period. As a result, a number of endemic forest tree species have been undergoing significant declines in health and mortality since the early 1990s. This work reports on a study that used a time-series analysis approach using Net Primary Production (NPP) as an indicator of forest health. MODIS satellite imagery from 2000–2011 was used to look at trends in NPP for the SWWA. Climate data was used to find potential relationships between trends in temperature and rainfall and the observed trends in NPP. This study revealed that between 2000–2011, NPP mainly declined in the transition zone between tree-dominated vegetation and shrublands. We further explore the potential relationships with the climatology and the implications for the future forests in the SWWA.

A sustainability assessment of wood-energy-supply-chains based on the method of a life-cycle-assessment. Brunsmeier, M., Becker, G., Schweier, J. (*University of Freiburg, Germany; martin.brunsmeier@fobawi.uni-freiburg.de; gero.becker@fobawi.uni-freiburg.de; janine.schweier@fobawi.uni-freiburg.de*).

This study concentrates on a sustainability assessment of wood-energy-supply chains with a focus on split logs, wood chips, and wood pellets. The research is based on the method of life-cycle-assessment and evaluates the environmental impacts as well as the economic and social benefits of the products and their use for energy purposes. The three wood-energy products and their energy potential are modeled on the basis of case studies in Germany. All processes within the wood-energy-supply chain, i.e., harvesting of logs, production of the named wood-energy products, transportation and their conversion to energy, are included in the assessment. The results are compared based on selected criteria which include energy efficiency, production costs, and effects on employment, as well as ecological effects like greenhouse gas emissions, acidification, and eutrophication. For the study, 1 kilowatt-hour of thermal energy produced by the wood energy products is defined as the functional unit. Sensitivity analyses reveal differences in the impacts on the environment and production costs as a consequence of alternative technical and organizational solutions of the investigated chains. The results allow a holistic comparison of the sustainability of different wood energy products.

Understory ferns and lianas as indicators of the conservation status in remnants of Brazilian Atlantic rain forest. Cardoso-Leite, E., Castello, A.D., Coelho, S. (*Federal University of San Carlos, Brazil; cardosoleite@yahoo.com.br; caroldcastello@gmail.com; samucabeca@hotmail.com*).

The creation of protected areas (PA) is the main strategy to conserve biological diversity. Government agencies need to monitor biodiversity, and indicators can be used as a tool for monitoring. Biodiversity is too complex to be measured and quantified, therefore the research of ecological indicators is required. Vegetation is considered an indicator for the state of conservation because it responds relatively quickly to environmental changes. Accordingly, our aim was to evaluate if the understory, lianas, and ferns can be used as indicators of the state of conservation in remnants of Atlantic Rain Forest. We analyze two areas, area 1 considered more conserved (within PA) and area 2 considered less conserved (outside PA). We allocated 14 plots of 20 m × 20 m to sample ferns and lianas, and transects of 2 m × 20 m in the center of the main plots were used to sample the understory. Most of the individuals of *Euterpe edulis* were sampled in area 1, i.e., old growth forest. *Hevea brasiliensis*, considered exotic in the Atlantic Rain Forest, was found in area 2, indicating the degradation of this remaining area. The ferns of greater height and lianas with larger diameter were found mostly in area 1, remnants in advanced successional stage, therefore, indicating well-preserved remnants.

Spatial and temporal change of litterfall in the Nanjenshan Lowland Rain Forest, Taiwan. Chen, J. (*National Pingtung University of Science and Technology, China-Taipei; zzz.john@msa.hinet.net*), Wu, S. (*Shih Chien University, China-Taipei; st.wu@msa.hinet.net*), Chen, C., Wei, C., Kuo, C. (*National Pingtung University of Science and Technology Pingtung, China-Taipei; cct@mail.npust.edu.tw; andy3520@gisfore.npust.edu.tw; kawakamii01@gmail.com*).

Lowland rainforests consist of abundant wildlife species and complex components. Litterfall is an important source of nutrition for the lowland rainforests without any artificial management. The litterfall has been an important parameter in ecological research for decades because it can help to understand the function and structure of an ecosystem, and to estimate forest productivity, regeneration, and biomass as well. To analyze the variation of litterfall based on the effects of seasons and weather disturbance, the data used in this study consisted of the measurements of the litterfall quantity and variety from 2004–2012. The results showed that the average quantity of litterfall was 4.91±1.86 t/ha/yr in the past 9 years. The seasonal pattern of litterfall could be divided into summer and winter peaks. Plant litter was mostly composed of leaves (65%), followed by twigs (22%), and flowers and fruits (13%). Different terrains in Nanjenshan area had different quantities and types of litterfall.

Environmental responses and biophysical controls over transpiration by stands/trees subject to urban, suburban, and semi-arid environmental conditions. Chen, L., Zhang, Z. (*Beijing Forestry University, China; myclover17@gmail.com; 122283586@qq.com*).

The objective of this study was to compare the transpiration (E_c) responses to environmental factors under urban and natural conditions. Therefore, our study adopted Granier-type probes to monitor stand/tree transpiration in urban, suburban, and semi-arid natural conditions. We found isohydraulic control over transpiration across species based on the fact that species observed the 0.6 ratio between the sensitivity of canopy conductance to *VPD* and reference G_c under all environmental settings. Therefore, E_c can be estimated reliably based on the accurate canopy conductance measurement under 1 kPa and concurrent meteorological data. But species differences can not be obscured. Trees under urban conditions tended to have stronger transpiration coupling with the atmosphere. Different from those growing in urban and suburban surroundings, trees in a semi-arid environment failed to maintain $E_{c\max}$ when stressed by high *VPD*. No significant decrease was observed for trees during the rainless intervals under all environment conditions. But unlike in semi-arid environment, transpiration of trees in urban and suburban surroundings grew with frequent large rainfall (>30 mm/event). Post-rainfall transpiration recovery results indicate that changes of the rainfall characteristics (scale and frequency) will lead to variation of vegetation cover under natural conditions.

The season, severity, and frequency of prescribed fire shaping the community dynamics of heathland shrub species. Chick, M., Cohn, J., Nitschke, C., York, A. (*University of Melbourne, Australia; mchick@student.unimelb.edu.au; janet.cohn@unimelb.edu.au; craign@unimelb.edu.au; alan.york@unimelb.edu.au*).

Throughout the fire prone regions of the world, the threat of wildfire is being met through increasing both the temporal and spatial components of prescribed burning, meaning the frequency is increasing and the seasonality and severity are altered. Within Victoria, Australia, fire management practices are such that fire prone communities, such as heathland, will experience prescribed burning across a larger range of age classes and at higher frequencies into the future. This research will be focusing on the ecological responses of shrubs in the heathland community to time since last fire (TSLF), the season (spring versus autumn) and severity of prescribed fire, and how these responses vary geographically across a precipitation gradient. This will occur retrospectively through the assessment of TSLF shrub species dynamics, presently through building predictions of community responses when prescribed fire is introduced into these different TSLF dynamics, and into the future through modeling community responses to alternate seasons of prescribed fires with the use of fire scenario modeling. To obtain these objectives, data collected will parameterize the landscape dynamics model LANDIS-ii. Through this research better understanding of the relationship between climate, fire regimes, and shrub dynamics in heathland will be developed.

Stand transpiration estimated by sap flow measurements in a mixed broadleaved forest, western Japan. Chiu, C. (*Kyushu University, Japan; ccwei97@gmail.com*), Komatsu, H. (*Kyoto University, Japan; kmthkr@gmail.com*), Kume, T. (*National Taiwan University, China-Taipei; kumett@ntu.edu.tw*), Otsuki, K. (*Kyushu University, Japan; otsuki@forest.kyushu-u.ac.jp*).

The amount of water used by trees has been widely researched for more than 100 years, and several studies have mentioned that forest types can affect the hydrological cycle of watersheds. Now more than 45% of the forest area in Japan is covered by natural broadleaved forests and most of them consist of mixed forests. However, rare studies have examined variations in sap flow among different types of forests which prevented researchers from estimating canopy transpiration on the basis of the sap-flow method. As a starting point to establishing a method to estimate canopy transpiration based on tree transpiration measurements on the basis of the sap-flux method, we evaluated stand transpiration of a temperate mixed broadleaved forest in Kyushu Island, western Japan. On the other hand, from the viewpoint of water resource management, it is commonly believed that conifer forests have relative higher annual evapotranspiration than broadleaved forests in Japan. To confirm this assumption, we will use data from previous studies which have estimated transpiration of a conifer forest near our study site to compare with our data.

Insect diversity and conservation of Nurod Urod Forest Reserve in Sabah, Malaysia. Chung, Y., Ibrahim, N., Richard, M., Yukang, J., Reuben, N. (*Sabah Forestry Department, Malaysia; arthur.chung@sabah.gov.my; nurulaqidah.ibrahim@sabah.gov.my; richard.majapun@sabah.gov.my; John.Lee@sabah.gov.my; reuben.nilus@sabah.gov.my*).

An insect diversity survey was carried out in June 2012 in Nurod Urod Forest Reserve. Located at the southern part of the Malaysian Sabah in Borneo, the upland mixed dipterocarp forest covers an area of 1 705 hectares. Nocturnal insect diversity was moderately high when compared to other forest reserves surveyed in the past. The Bornean endemics recorded during the survey were four moth species and two damselfly species, namely *Adites hosei, Amata egenaria, Auriculoceryx pterodactyliformis,* and *Lygniodes schoenbergi* (moths); *Rhinocypha aurofulgens* and *Rhinagrion elopurae* (damselflies). As no other insect survey has been conducted in this forest reserve in the past, this pioneer data serves as baseline information for future research work. The endemic, rare, and interesting insect species recorded during the survey provide salient information to enhance the conservation of this forest reserve as well as to provide input for the preparation of a forest management plan. Threats and recommendations to enhance the biodiversity are also discussed.

Climate signals derived from day-to-day analysis: climate sensitivity of *Picea abies* in Northern Italy (Trentino, Eastern Alps). Cocozza, C., Palombo, C (*University of Molise, Italy; claudia.cocozza@unimol.it; caterina.palombo@unimol.it*), Anichini, M. (*Trees and Timber Institute (IVALSA), Italy; anichini@ivalsa.cnr.it*), Tognetti, R. (*University of Molise, Italy; tognetti@unimol.it*), Giovannelli, A. (*Trees and Timber Institute (IVALSA), Italy; giovannelli@ivalsa.cnr.it*), La Porta, N., Emiliano, G.

The intra-annual dynamics of wood formation were used to describe seasonal changes in xylem differentiation phases and to calculate the timing of cell development in Norway spruce (*Picea abies* (L.) Karst.). Tree-ring dynamics of Norway spruce from two altitudinal limits were studied to detect climate signals in the day-to-day dynamics of wood formation. The investigation was conducted during the years 2011–2012 in Trentino-South Tyrol (eastern Italian Alps), in two sites, Savignano (650 m a.s.l.) and Lavazè (1800 m a.s.l.). The climate is subalpine-continental type with a solstitial pluvial curve (maximum values in summer and minimum values in winter). Dendroclimatological analysis was performed to examine the relationship between the tree rings formation of Norway spruce and climatic parameters in the study sites. Climate–growth relationships were analyzed using

correlation function (CF) analysis and moving CF (MCF), detecting correlations between wood formation and seasonal patterns of temperature and precipitation. During the monitored years, the effects of climatic variables on cell structure and stem diameter variation were examined daily. Cell structure was investigated through microscope analysis, and stem diameter variation was detected with microdendrometers. The results were interpreted according to dynamics of forest vegetation and synchronicity of cambial activity.

Saproxylic Diptera biodiversity and intensive biomass harvesting. What are the implications of a damaged deadwood profile? Deady, R., Work, T. (*Université de Québec à Montréal, Canada; mycetophilid@gmail.com; work.timothy@uqam.ca*), Venier, L. (*Canadian Forest Service, Canada; lisa.venier@nrcan-rncan.gc.ca*).

Residual forest biomass in the form of fine and coarse woody debris continues to be proposed as a sustainable source of energy that will reduce dependence on fossil fuels. Biomass harvesting drastically transforms the deadwood profile. Saproxylic Diptera (true flies) like the Sciaroidea is likely affected by changes in deadwood and fungal communities. We will compare saproxylic Diptera assemblages in coarse woody debris (CWD), fine woody debris (FWD), and stumps using emergence traps. We will use Dipteran assemblage differences to: (1) assess whether per unit volume FWD of Jack pine (*Pinus banksiana*) wood is more conducive to speciose and abundant communities than CWD; (2) test how intra-log CWD variation affects saproxylic Diptera assemblages; and (3) examine whether residual stumps act as persistent refuges for biodiversity after removal of biomass. Approx. 500 Sciaridae specimens have been identified to date of 40 species. Preliminary ordinations and GLMs show a slight though significant demarcation between advanced decay assemblages versus early decay assemblages, which may be more apparent with more sampling. Diameter appears to be an important variable despite using provisional data. We are using this information to quantify thresholds of deadwood retention under biomass harvesting and integrating Sciaroid biology into applied forest management.

Response of ground-beetle (Carabidae) assemblages to harvest and wildfire in lodgepole pine forests of western Alberta, Canada. Del Bel Belluz, V., Spence, J. (*University of Alberta, Canada; vbelluz@gmail.com; jspence@ualberta.ca*), Langor, D. (*Canadian Forest Service, Canada; david.langor@nrcan-rncan.gc.ca*).

Ground-beetle assemblages that occupy forests regenerating after harvest differ between stands of various age classes. Such differences have been attributed to differential habitat preferences, and species have been categorized as generalists and specialists in both open-habitat and mature forest. This study explores how assemblages have changed in lodgepole forests near Hinton, Alberta up to c. 60 years post-harvest, and explores potential differences between assemblages from forests regenerating, respectively, after fire and harvest disturbance. Results will increase the understanding of how effects of human harvest may change beetle assemblages in Albertan forests as compared to the natural disturbance of wildfire.

The influence of thinning on tree-water relations in an Aleppo pine forest in Valencia, Spain. Del Campo, A. (*Universidad Politécnica de Valencia, Spain; ancamga@upv.es*), Fernandes, T. (*Federal University of Acre, Brazil; tjgfernandes@yahoo.com.br*), Molina, A. (*Institute of Agrifood Research and Technology, Spain; amolihe@gmail.com*), Herrera, R. (*Venezuelan Institute for Scientific Research (IVIC), Spain; potoy@hotmail.com*).

Thinning of trees may be useful to improve growth rates and to change water fluxes, which are desirable outcomes when managing forests in semiarid water-limited environments. In these conditions, the need to implement proactive adaptive silviculture is widely recognized. The effect of thinning on tree-water relationships (transpiration and soil water content) and growth (basal area increment (BAI), determined through dendrochronological procedures) was investigated in 55-year-old Aleppo pine trees thinned at three different intensities plus a control. Tree growth was significantly enhanced after thinning, with an annual BAI four-fold that of the pre-thinning value and a lower dependence of growth on climate fluctuations (rainfall variability). The sap flow velocity (v_s) in thinned and control trees revealed different functionality of the sapwood. Higher values of v_s (3.59 cm/h) were observed in the thinned trees due to the improved soil water content, whereas it dropped off much more rapidly in the control trees due to lower functionality of sapwood (poorer site conditions). Tree transpiration in the study year reached 6 768 litres per tree in the heaviest intensity thinning. Combined dendrochronology and hydrology methods have proven to be useful in the study of the effects of hydrology-adaptive silviculture in semiarid Mediterranean forests.

Eddy-covariance-based estimates of carbon balance in two tropical seasonal forests in Thailand. Diloksumpun, S. (*Kasetsart University, Thailand; sapit.d@ku.ac.th*), Panuthai, S. (*Department of National Parks, Wildlife and Plant Conservation, Thailand; newsam@3bbmail.com*), Suansawan, C. (*Kasetsart University, Thailand; chatuphon_32@hotmail.com*).

The eddy covariance technique ascertains the exchange rate of CO_2 across the interface between the atmosphere and a plant canopy by measuring the covariance fluctuations between vertical wind velocity and CO_2 mixing ratio. Meteorological parameters were also measured for understanding the environmental conditions for ecosystem carbon cycle. To compare carbon balance of two contrasting tropical forests in Thailand, dry evergreen (DEF) and deciduous (DF) forests, net ecosystem exchange (NEE) was estimated and the choice of a friction velocity (u^*) correction for the estimation of flux on calm nights and other corrections were applied for data quality control. The change in NEE as a function of the u^* threshold was marked, and some of the measured nocturnal data were eliminated by using the 0.4 and 0.25 m/s u^* threshold for DEF and DF respectively. Data gaps were filled with linear interpolation, mean diurnal variation, and nonlinear correlation with temperature and photosynthetically flux density. The seasonal pattern of CO_2 exchange and effects of its factors was evident. The 2-year mean annual NEE from 2010 to 2011 was −2.68 and −3.62 Mg C/ha/yr respectively, reflecting differences in carbon gain in these two forests.

Mammal trade for zootherapeutic and mythic purposes in Benin (West Africa): capitalizing species involved, provision sources, and implications for conservation. Djagoun, C. (*Laboratory of Applied Ecology, Benin; sylvestrechabi@gmail.com*), Akpona, A. (*General Directorate of Forestry and Natural Resources, Benin; akpona@gmail.com*), Mensah, G. (*National Institute of Agricultural Research of Benin (INRAB), Benin; mensahga@gmail.com*), Nuttman, C. (*Topical Biology Association, United Kingdom; cvn22@cam.ac.uk*).

In Benin, in spite of the existence of intense commercial dealings with wildlife for medicinal purposes, no official statistics on the use of animals for medicinal and magic/religious purposes are available, and consequently are taken into consideration even less in laws, decision making processes, and conservation strategies. This study highlighted the global importance and the conservation implications of the use of mammal species in traditional folk medicines. Among the 194 mammal species traded on the traditional medicine market in Benin, 46 were most common. Different threat categories were represented including rare, vulnerable, and threatened species. Moreover, it was noticed that the provision source of animals was not limited to Benin area since some species not listed in Benin fauna are identified on the markets. This study suggested that the more rare the species, the more costly it is. This constitutes an economic motivation for sellers who develop strategies for the availability of threatened species on their displays. Urgent conservation actions are needed to reduce the pressure that this activity sector might cause to biodiversity lost. Moreover, an analytical and operational basis is necessary to guide the forestry and wildlife agencies to consider animal based medicine in the conservation strategies, politics, priorities, and laws.

Application of cost-benefit analysis to estimate the value of the protection function of forests against rockfall. Dupire, S. (*National Research Institute of Science and Technology for Environment and Agriculture, France; sylvain.dupire@irstea.fr*), Bruciamacchie, M. (*National School of Rural Engineering, Water Resources and Forestry (ENGREF) and National Institute for Agricultural Research (INRA), France; max.bruciamacchie@agroparistech.fr*), Berger, F. (*National Research Institute of Science and Technology for Environment and Agriculture, France; frederic.berger@irstea.fr*).

A complex methodology has been implemented to adapt cost-benefit analysis to the interaction between rockfall hazard and mountain forests. It has been tested on six pilot areas situated in the Alps in France, Italy, and Switzerland. Starting from a precise field data collection, it combines the use of GIS software, databases and a tool developed specially to assess the economical calculation. This work allows giving an economical value for the protection function offered by the presence and the management of forests according to two different economical approaches: the substitute cost method and the damage cost avoided method. Results confirm the utility of forests against rockfall and their specific management to face this hazard. This is particularly true when: (1) the length of forest on the slope is important, (2) rockfall threatens a linear issue (roads, railways, etc.), or (3) when issues are of low economic importance. This study also shows the complementarity relevance between forest and rockfall nets. In most cases, especially when threatened issues are homes and human lives, forests cannot ensure sufficient protection, and rockfall nets or embankments are needed. However, the presence of forests allows a reduction in their size so cost is reduced.

Fate and transport of mercury in watersheds: hot-spots and hot-moments in Pennsylvanian watersheds. Eklöf, K., Boyer, E., Drohan, P., Iavorivska, L., Chen, Y. (*Pennsylvania State University, USA; kje15@psu.edu; ewb100@psu.edu; pjd7@psu.edu; lui100@psu.edu; yongsheng@psu.edu*).

The increased input of anthropogenic mercury (Hg) in the environment has led to an accumulation of Hg in soils as well as in the aquatic food web. Much concern is focused on methylmercury (MeHg) as it is the most bioavailable species. In this study, we are identifying factors causing high Hg methylation (transformation of inorganic Hg to MeHg) and mobilization both in space (i.e., hot-spots) and time (i.e., hot-moments). The mercury methylation rate has been suggested to increase when oxidized soils or sediments become reduced. The restoration of Lake Perez in a forested region of central Pennsylvania could thereby act as a potential methylation hot-spot. Soil/sediment as well as water samples are being collected before and after the lake has been filled to evaluate if the restoration causes increased methylation. High flow episodes are usually identified as hot-moments for Hg in forested catchments. Further, we are sampling a forested stream nearby during stormflow events to consider hot-moments, as well as factors influencing the mobilization of Hg in catchments, such as how organic matter characteristics are influencing the mobilization of Hg.

Effects of forestry on mercury runoff in catchment-scale studies in Sweden. Eklöf, K. (*Pennsylvania State University, USA; kje15@psu.edu*), Schelker, J., Sørensen, R., Åkerblom, S. (*Swedish University of Agricultural Sciences, Sweden; jakob.schelker@slu.se; rasmusvis@gmail.com; staffan.akerblom@slu.se*), Weyhenmeyer, G. (*Uppsala University, Sweden; gesa.weyhenmeyer@ebc.uu.se*), Kraus, A., Brömssen, C., Laudon, H., Boyer, E., Meili, M, Bishop, K.*; Kevin.Bishop@slu.se*).

Forestry operations have been found to increase the export of total mercury (THg) and methyl mercury (MeHg) to surface waters. However, little is known about the relative contribution of different forestry operations. In catchment-scale studies in Sweden, the individual effects of different forestry operations were evaluated. Stump harvesting, done to increase the amount of biofuels supplied from the forest, was compared with traditional site preparation for replanting. The stump harvest did not increase THg and MeHg concentrations in runoff relative to site preparation. However, the runoff concentrations were higher in both the stump harvested and site prepared catchments relative to the references. The relative importance of the logging itself, compared to the subsequent site preparation was investigated in catchments in northern Sweden. A more pronounced effect on the mercury concentrations after site preparation compared to logging only could be related to the site preparation being conducted during summer, causing more soil disturbance than the logging which was done during winter, with snow covering the ground. The results suggest that when and how forestry operations are implemented might be more important than the kind of treatment. These studies also identify a great variation in sensitivity to forestry operations between catchments.

Evapotranspiration (ET) as an ecosystem service: why we should care about precipitation recycling. Ellison, D., Futter, M., Bishop, K., Laudon, H. (*Swedish University of Agricultural Sciences (SLU), Sweden; ellisondl@gmail.com; Martyn.Futter@slu.se; Kevin.Bishop@slu.se; Hjalmar.Laudon@slu.se*).

Forests provide a number of important water-related ecosystem services including water purification and flood mitigation. Here we show that the precipitation-recycling role of forests must also be recognized as an ecosystem service. The role of forests as controllers of the hydrological cycle is clearly recognized. Deforestation leads to more local runoff and reduced precipitation. However, the importance of afforestation in promoting precipitation recycling is not sufficiently appreciated. Much of the evapotranspiration from forests falls as precipitation in downwind continental locations. Using hypothetical examples, we demonstrate the possible consequences of changes in precipitation recycling for both continental and local precipitation. Using

real data from a series of Swedish and at least one U.S. catchment, we illustrate the potential consequences of changes in forest cover on local and regional scales. Changing forest cover to modify the balance between runoff and evapotranspiration has hitherto unrecognized policy consequences. Here, we argue these consequences are not adequately recognized either in current legislation such as the Water Framework Directive, nor in the current discussions about payment for ecosystem services.

Establishment of hydrometeorological stations in national power corporation-managed reservations. Exconde, A., Daño, A., Atega, P., Castillo, J., Garcia, D. (*Ecosystems Research and Development Bureau (DENR), Philippines; angelitoexconde@yahoo.com.ph; tonydanolb@yahoo.com; pcatega@yahoo.com; alan536@yahoo.com; digsgarcia@yahoo.com*).

This study endeavors to establish hydrometeorological stations in National Power Corporation (NPC)-managed reservations to acquire hydrologic measurements, specifically rainfall, wind, and temperature, for hydrometeorologic monitoring. Collected data are important for hydrologic research since the climate and weather of an area profoundly influences most hydrologic processes. The NPC, the Philippines' largest energy producer in Mindanao, is dependent on hydrologic processes to produce energy, and thus needs reliable hydrometeorologic data to effectively plan and implement the integrated conservation and management practices needed to achieve sustained forest and other natural and agricultural resources. Mini hydrometeorological stations containing complete sets of calibrated automatic weather monitoring instruments and other manual instruments like 8-inch standard rain gauge, evaporation pan, and anemometer have been fabricated and installed in 11 major watersheds around the Philippines to measure and collect hydrometeorological data. The instruments were tested, and collected data were tested for correctness and accuracy. Skills enhancement training workshops in proper handling, collection, recording, and analysis of data have been conducted to train the station staff. The data for rainfall, wind, and temperature are then stored in the NPC Database System. This study can serve as a model for future studies on hydrology.

How green are forest fragments inserted into tropical agricultural landscapes? implications for ecosystem services provisioning. Ferraz, S., Ferraz, K., Cassiano, C. (*University of São Paulo, Brazil; silvio.ferraz@usp.br; katia.ferraz@usp.br; carla_cassiano@hotmail.com*).

Tropical forests play an important role regarding ecosystem services related to biodiversity, water, and nutrient cycling in such dynamic landscapes. Historical processes of deforestation culminate on native forest at different landscape structure and quality. We assessed historical land-use changes (1962–2008) at southeast region of Brazil using aerial photographs. Digitizing and parameters calculation were performed in ecological units based on historical forest polygon map overlays. Using LUCAT (Land-Use Change Analysis Tools), Forest dynamics were assessed by forest change curvature profile (FCCP) and forest change rate (Q). Landscape structure was assessed by neighborhood, proximity, and contiguity indices. Results showed that natural forests have increased from 8% to 16%, but besides that, transition matrix showed that old forests are being reduced while new areas are being regenerated. Historical analysis showed that current forest remnants are a result of different processes of spatial and temporal dispersed deforestation and regeneration. Different forest ages, forest dynamic processes, and current landscape structure together reveal a mosaic of forest patches under different conditions, implying a potential gradient of performance on ecosystem services what could not be represented by a single color fragment on a map, since only 25% of patches were considered able to fully perform ecosystem services.

Study of the tropical Sudanian area's major agroforestry landscape patterns involvement in carbon sequestration balance in Togo. Folega, F., Zhang, C. (*Beijing Forestry University, China; ffolega@yahoo.fr; zcy_0520@163.com*), Wala, K., Batawila, K. (*University of Lomé, Togo; kpwala75@yahoo.fr; batawilakomlan@yahoo.com*), Zhao, X. (*Beijing Forestry University; bfuz@163.com*), Akpagana, K. (*University of Lomé, Togo; koffi2100@gmail.com*).

This research was aimed at estimating total carbon stock in the tropical Sudanian zone agroforestry system of Togo. Physical measurements of trees (*Adansonia digitata, Parkia biglobosa, Sterculia setigera, Vitellaria paradoxa,* and fallows) in major agrosylviculture parklands were achieved by random quadrat sampling based on Braun-Blanquet concept. The total carbon stock was computed as the arithmetic mean of the values derived from two allometric equations. Results revealed that the total carbon stock of the agroforestry parkland was 72.8 t/ha whereas *A. digitata, P.biglobosa, S. setigera,* and *V. paradoxa* trees species accumulate 31.41 t/ha, 20.44 t/ha, 8.48 t/ha, and 4.02 t/ha, respectively. The *A. digitata* parkland has shown the highest total carbon stock (15.91±12.9 t/ha), whereas the lows values occurred in fallows landscapes (0.24±0.06 t/ha). Among the five parklands of the study zone, high carbon stock accumulated in the DBH classes ranging from 0–10 and 30–40. The agroforestry system landscape in the study is a carbon pool, as it has a significant capacity to uptake and stock carbon. To realize the agroforestry and wooded vegetation sector's potential in Togo, the carbon mitigation should be integrated within the Clean Development Mechanism (CDM) carbon trading system of the Kyoto Protocol.

Fluvial water quality and forest cover in southern Brazil. Fritzsons, E., Parron, L. (*EMBRAPA, Brazil; elenice.fritzsons@embrapa.br; lucilia.parron@embrapa.br*), Mantovani, L. (*Federal University of Paraná, Brazil; lem@ufpr.br*), Wrege, M. (*EMBRAPA, Brazil; marcos.wrege@embrapa.br*).

In natural environments, water quality depends on physical and biological factors such as climatic, geologic, pedologic, and vegetation. In addition to natural factors, the various human activities affect the aquatic environment and modify the water composition parameters. The present study was carried out at the Fervida a Karst watershed, which covers an area of 13 km^2 and is located over the Southern Brazilian Plateau in the State of Paraná, Brazil, 900 to 1 200 m over sea level. The natural vegetation corresponds to the original area of subtropical Araucaria forest (*Araucaria angustifolia*). Agricultural activity consists of small-holder crops of vegetables, mainly of horticulture, maize, and beans. The regional climate is Cfb. The aim of this study is to analyze the impact caused by land use to the river water quality, especially considering the pollution by nitrates, and verify the protection provided by the riparian forest to the fluvial water. A land use study will be done through the interpretation of aerial photographs and satellite images. Forest fragments in the landscape will be evaluated. Meanwhile, water samples will be collected at five controls zones of the basin. Preliminary investigations show that forested areas have better water quality than those that drain from agricultural areas.

Soil carbon storage in different species dominating the Sarawak Mangrove Forest, Malaysia. Gandaseca, S., Imam Aritanto, C., Haruna Ahmed, O., Muhamad Majid, N. (*Universiti Putra Malaysia, Malaysia; seca@upm.edu.my; chan2_himura@yahoo.com; osumanu@upm.edu.my; nik@upm.edu.my*).

Carbon storage in forest ecosystems involves inordinate components including plant biomass carbon and soil carbon. Sequestration of carbon along with other aggressive conservation efforts helps to reduce the increasing negative impact of global warming on the environment and mangroves of the coastal forest. Sequestration also plays a substantial role in global carbon cycling because a large stock of carbon is stored as well as the potential carbon sinks and sources to the atmosphere. Soil of Awat-Awat Mangrove Forest (AAWF) were collected in nine different plots dominated with different species using a peat auger at a depth of 0 to 50 cm. A total of 32 samples were collected. Soil carbon content of AAWF varied in each plot. The different dominate species resulted in different carbon content. In AAWF, the highest soil carbon content (6.24%) was found in soil under *Rhizophora mucronata*, whereas the lowest carbon content (1.73%) was in soil under areas dominated by *Sonneratia alba*. In addition, the soil carbon content in areas dominated by different species in AAWF varied.

Conservation of wildlife outside protected areas in community forests in Nepal. Ghimire, M., Lamsal, R. (*Ministry of Forests and Soil Consertation, Nepal; ghimire.madhu@gmail.com; ramplamsal@gmail.com*).

Protected areas are an essential means for conserving biodiversity, however, biodiversity friendly forest management outside protected areas has been given high priority in recent years. Based on primary and secondary information from communities and forest offices, this study reviews the community-based wildlife conservation in Barandabhar forest corridor of Chitawan, Nepal; examines the management priorities of community forests (CFs) and their compatibility for wildlife management; and assesses the institutional and legal arrangements of CFs for wildlife conservation including the performance of community-based anti-poaching movement and management of human wildlife conflict. The results indicate: (a) habitat destruction mainly by invasive alien species has caused wildlife to move from the National Park to corridor CFs, where they are found with higher density and safer with reduced poaching incidents; (b) community forest operational plan provides the institutional and legal base to communities for forest and wildlife management including community-based anti-poaching efforts; and (c) attempts are made to minimize the human wildlife conflict, however, the increased magnitude may pose serious limitations on community-based conservation. Therefore, it is recommended for an alternate model of CF implementation in the corridor area.

Long- and short-term hydrogeomorphic processes alters the spatial variability of soil carbon and nutrient accumulations in headwater catchments of Japan. Gomi, T. Hiraoka, M., Quynh Anh, P. (*Tokyo University of Agriculture and Technology, Japan; gomit@cc.tuat.ac.jp; hiraokam@cc.tuat.ac.jp; quynhanh.vfu@gmail.com*).

We investigated the spatial distribution of understory vegetation ground covers in two headwater catchments of watershed 3 (7.0 ha) and watershed 4 (4.6 ha) of Japan. Deer over-grazing for the last three decades affected the species and distribution of understory vegetation in the watersheds. Hillslope with bare soil in watershed 3 was 1.3 ha, whereas one in the watershed 4 was 0.7 ha. Most of the hillslopes with bare surface and/or litters were located adjacent to stream channels with slopes gradient more than 40°. Canopy openness and hillslope gradient were critical factors for controlling vegetation ground cover. Dominant understory vegetation was non-preference and torrent species by deer over-grazing. Soil organic carbon (SOC) and soil organic nitrogen were positively correlated with understory vegetation biomass and soil bulk density. The amount of SOC tended to increase with increases in ^{137}Cs and $^{210}Pb_{ex}$ which indicate long-term soil erosional processes. Our findings suggest that vegetation types and the resultant long- and short-term soil erosion processes may feed back into both the production and accumulation of SOC, but forest cover did not always result in high soil fertility or low erosion.

Long-term variation of coefficients of peak discharge in a small watershed, in association with forest restoration and succession on denuded hills. Gomyo, M. (*Forestry and Forest Products Research Institute, Japan; gomyo@affrc.go.jp*), KURAJI, K. (University of Tokyo*, Japan; kuraji_koichiro@uf.a.u-tokyo.ac.jp*).

The objective of this study was to quantify the changes in the coefficients of peak discharge (fp) with reference to the long-term natural recovery of forests on denuded hills. The Ananomiya Experimental Watershed at the Ecohydrology Research Institute (the University of Tokyo Forests) was selected for this study. We compared the relationship between fp and discharge when the discharge trend changed from decreasing to increasing (Qi) and from the onset of precipitation to the time when peak precipitation (Pi) was attained. This was done in order to estimate peak discharge during an early 11-year period and a late 22-year period. Regardless of whether measurements were taken during early or late periods, the fp increased when the Pi increased. Conversely, the relationship between fp and Qi, an indicator of the wetness condition of the watershed, was not clear. The maximum fp values during the late period, when Pi was 0, 25, and 50, represented a decrease of 53, 45, and 42%, respectively, with respect to the corresponding figures from the early period. This study showed that fp of a heavy precipitation event referred to as the Tokai Heavy Rain event (total precipitation of 401.5 mm), was 0.58, far below 1.0.

Vegetation greenness and nebulosity in Central Africa. Gond, V. (*CIRAD, France; valery.gond@cirad.fr*), Philippon, N., Camberlin, P. (*CNRS/Université de Bourgogne, France; Nathalie.Philippon@u-bourgogne.fr; Pierre.Camberlin@u-bourgogne.fr*), Cornu, G., Gourlet-Fleury, S. (*CIRAD, France; Guillaume.cornu@cirad.fr; sylvie.gourlet-fleury@cirad.fr*), de Lapparent, B. (*CNRS/Université de Bourgogne, France; benjamin-de-lapparent@hotmail.fr*).

In the next decades, central African forests are predicted to experience profound climatic changes with increased temperature, alteration of rainfall patterns, and possibly longer dry seasons. In this context it is important to understand the climate variables and mechanisms driving the forest photosynthetic activity. Relationships between central African forests canopy photosynthetic activity and climatic parameters have not been documented enough. We propose here to analyze the mean (seasonal cycle) and inter-annual (year to year variations) temporal dynamic of EVI (enhanced vegetation index) for a region comprised between 0–5°N and 13–19°E with respect to climatic parameters potentially influencing the vegetation such as rainfall and nebulosity (through light intensity). We evidenced using coarse resolution cloud cover data that the forest photosynthetic activity mean

seasonal cycle matches seasonal changes in the cloud cover. These changes affect both the cloud cover fraction and the cloud types. This is currently explored using the more adequate MSG (Meteosat Second Generation) data. These results are of crucial importance to support the hypothesis of a strong dependence of central Africa forests cover with climatic seasonal to inter-annual variations.

Biotic homogenization and differentiation of the flora within man-made and near-natural habitats across urban green spaces in Shenzhen, China. Gong, C., Ning, Z. (*Southern University, USA; chongfeng.gong@gmail.com; Zhu_ning@subr.edu*).

Shenzhen, a new city existing for less than three decades, experienced dramatic biological invasions of alien plants resulting from the development of urban green spaces. In an investigation of plant species from 390 plots in 186 sites across five main types of green spaces (forests, public parks, vegetation corridors, residential, and industrial area), a total of 474 plant species, including 221 alien species (46.6%), were recorded. Our study witnessed the spread and establishment of alien species across all urban green spaces, with greater proportions of alien species in the man-made ones than in the natural ones. Furthermore, we found the positive relationship between native and alien species richness existed across all the green spaces, and it was particularly prevalent in the man-made ones. Additionally, successful establishment of alien species instigated by anthropogenic disturbances and most frequent species assemblages caused biotic homogenization in the man-made ones. In contrast, biotic differentiation in the near-natural habitats was still preserved due to a greater level of protection for native species, resulting in resistance against the establishment of alien species. Therefore, urbanization was proven to have distinct effects on the biota of human-modified and near-natural habitats coexisting in the new city.

Adaptive water-oriented forest management using BIOME-BGC in Mediterranean Aleppo pine plantations. Gonzalez-Sanchis, M., Campo, A. (*Universitat Politecnica de Valencia, Spain; macgonsa@gmail.com; ancamga@dihma.upv.es*), Molina, A. (*Institute of Agrifood Research and Technology, Spain; amolihe@gmail.com*), Fernandes, T. (*Federal University of Acre, Brazil; tjgfernandes@yahoo.com.br*), García Prats, A. (*Universidad Politécnica de Valencia, Spain; agprats@upvnet.upv.es*).

Water-oriented Forest Management (WOFM) aims to adapt the forest to water availability by means of affecting forest structure and density. Regions under water scarcity situations, such as the Mediterranean, might require WOFM to optimize the hydrological cycle under normal and future global change conditions. The present study uses the process based model BIOME-BGC to predict the effects of WOFM in a Mediterranean Aleppo pine plantation. At the same time, the present work pretends to make easier the model application to forest managers. To that end, the model is slightly modified where canopy average specific leaf area and canopy water interception coefficient are both introduced as a function of forest coverage. Then, the model is calibrated and validated using a year sapflow, soil moisture, and throughfall field data from three forest covers (85 to 26%). Calibration and validation show an acceptable accuracy, whose Nash–Sutcliffe ranges between 0.39–0.76 and 0.31–69, respectively. The model is finally applied to analyze and predict the need of forest management in a Mediterranean forest. The application shows an optimization of the hydrological cycle that establishes a new equilibrium between blue and green water. The new scenario significantly reduces water interception and transpiration and increases runoff and percolation.

Assessing the trail condition and environmental factors of the Kumano pilgrimage routes in the Kii Mountains, Japan. Gou, S. (*Kyoto University, Japan; shiwei.gou@gmail.com*).

Kumano Kodo (officially referred as Kumano Sankeimichi) are pilgrimage routes traversing diverse landscapes of Kii mountain range and were inscribed collectively with other cultural properties as the UNESCO World Cultural Heritage Site, Sacred Sites and Pilgrimage Routes in the Kii Mountain Range in 2004. Bearing distinctive religious and cultural meaning, these routes are also popular hiking trails for both domestic and international tourists. Historically maintained by surrounding residents for their daily life and silvicultural practices as well as religious practices for people coming from all over the country, Kumano Kodo are facing serious deterioration nowadays due to a complex combination of environmental, cultural, and social factors associated with intensive plantation and lack of proper management of the planted forest in the surrounding area. This research used systematic sampling methods of 100 m interval along the trail from Takiji Oji to Kumano Hongu Taisha Shrine (about 30 km), one of the most popular sections of Kumano Kodo, to investigate the current condition of the Kumano Kodo, and the influences of a wide range of use-related, environmental, and managerial factors on the condition of the trail in order to purpose possible solutions tailored to deterioration of the pilgrimage routes under different situations.

Coarse woody debris characteristics: a case study in a 9-ha old-growth cold-temperate coniferous forest plot from Great Hing'an Mountains, Northeastern China. Gu, H. (*Northeast Forestry University, China; ghuiyan@nefu.edu.cn*).

Coarse woody debris (CWD) volume is a vital attribute of forest ecosystems and plays a key role in global C cycle. However, despite their importance, there have been no reports of CWD volume in China boreal forests. We carried out this study in the old-growth cold-temperate coniferous forest located in the "Huzhong" National Natural Forest Reserve in Great Hing'an Mountains in Heilongjiang Province. The forest covers an area of 1.7×10^5 ha in the reserve owned by the local government. In 2011, a large-scale plot (9 ha) was selected for an intensive study of stand structure and the quantity and quality of CWD. Our result showed: (1) the growing volume of living trees was 142.3 m^3/ha with the species *Larix gmelinii* accounting for more than 90% of the total living volume; (2) The average volume of CWD was 87.4 m^3/ha, and among the CWD, the volume of primary decay and intermediate decay (more than 60%) was greater than the volume of advanced decay (less than 30%); and (3) Of the total volume of dead and living trees, CWD comprised 61.4%. Considering these results, we concluded that the amount of carbon stored in the boreal forest is underestimation, as CWD comprise a significant fraction of the total volume in boreal forest.

Life cycle evaluation of forest sector greenhouse gas emissions sensitivity to changes in forest management in Maine (USA). Gunn, J. (*Spatial Informatics Group – Natural Assets Laboratory, USA; jgunn@sig-nal.org*), Hennigar, C. (*FORUS Research, Canada; FORUS.Research@gmail.com*), Cameron, R. (*University of New Brunswick, Canada; cameron.ryan.e@gmail.com*), Buchholz, T. (*University of Vermont & Spatial Informatics Group LLC, USA; tbuchholz@sig-gis.com*).

We used a life cycle greenhouse gas accounting tool to test sensitivity of Maine (USA) statewide forest sector greenhouse gas (GHG) emissions to changes in forest management using forest cover data and growth and yield models for the state of Maine.

We summarized net GHG emissions over 100 and 300 year time horizons of different management strategies across a range of carbon pools and emission sources. Carbon pools include: (1) storage in aboveground and belowground live and dead biomass; (2) storage in forest products in use and in landfills; (3) harvest, transport, and manufacturing emissions; 4) avoided emissions (substitution; bioenergy); and (5) landfill methane fluxes. The current baseline forest sector is a net GHG sink throughout the 300 year modeling period. Greater use of even-aged management increases total emissions compared to the baseline. When forest product substitution for fossil-fuel intensive building materials is considered, increasing uneven-aged silvicultural systems reduces forest sector GHG emissions compared to the baseline. Scenarios that increase area of protected reserves compare favorably with baseline GHG emissions predicted for reduced harvesting intensity scenarios when product substitution is not considered.

Restoring ecological legacies in boreal Sweden: a saproxylic beetles perspective. Hägglund, R., Hjälten, J. (*Swedish University of Agricultural Sciences, Sweden; ruaridh.hagglund@slu.se; joakim.hjalten@slu.se*), Dynesius, M. (*Umeå University, Sweden; mats.dynesius@emg.umu.se*), Roberge, J., Johansson, T., Olsson, J (*Swedish University of Agricultural Sciences (SLU), Sweden; Jean-Michel.Roberge@slu.se; therese.johansson@slu.se; jorgen.m.olsson@slu.se*).

Forest practices in boreal Sweden have during the last two centuries led to simplified forest structure and more homogeneous tree species composition, resulting in declining biodiversity in order to reduce the rate of decline restoration of ecological legacies already plays, and in the future will play an even more important role. In order to carry out restorations in an efficient manor, knowledge on the efficacy of different restoration measures is essential. By using a replicated design we have compared species composition of saproxylic beetle communities after two active restoration methods and compared these with both temporal and spatial controls. The two treatments carried out were prescribed forest fire and artificial gap cuttings. Both treatments have increased structural complexity and added substantial amounts of dead wood to the treated forest stands. Intercept traps of the IBL-model were used in the collection of beetles. Preliminary results suggest that changes in the species composition of saproxylic beetle communities has occurred in the treated stands compared to the base line and spatial controls. Especially noteworthy is the increase in pyrophylic species in the burned sites.

The assessment techniques of desert ecosystem services in China. Hao, G., Shi, Z., Xianghui, C. (*Chinese Academy of Forestry, China; guohaomail@163.com; shijie1204@163.com; cxh_lion@126.com*).

Desert ecosystem services are gradually becoming appreciated by the public as a greater awareness and understanding of the function of desert ecosystem is acquired. Compared to other ecosystem, the desert ecosystem has unique structure and function, but the services are very poorly known. So how these can be evaluates and how scientific, reasonable and feasible assessment index systems can be established become urgent problems in the present time. Considering thoroughly desert ecosystem service mechanisms, adopting frequency analysis and experts consultation methods, and index system and methodology for desert ecosystem service assessment in China has been established, along with the development of world's first desert ecosystem service assessment criteria (Assessment criteria of desert ecosystem services in China), be promulgated on Feb 23, 2012 by the State Forestry Administration of the PRC. These efforts will greatly promote the research and work of desert ecosystem services assessment in the world.

Bioenergy production and soil sustainability in the Pacific Northwest USA. Harrison, R. (*University of Washington, USA; robh@uw.edu*), Knight, E. (*Shannon & Wilson, USA; erika.j.knight@gmail.com*), James, J., Menegale, M., Michelsen-Correa, S., Turnblom, E., Eastin, I. (*University of Washington, USA; jajames@uw.edu; marcism@uw.edu; smiccor@gmail.com; ect@u.washington.edu; eastin@uw.edu*).

Though it has often been expressed in other terms, the basis of sustainability of bioenergy production in the Pacific Northwest is primarily soil-centered, dependent on the extent and availability of soil nutrient pools. Some PNW forest soils are very low in total and available nutrients relative to the current pools and inputs and would be sensitive to normal harvesting, whereas many soils are very rich in nutrients relative to intensive removals and are very resilient to high rates of biomass removal. Research at Fall River, Matlock, and Molalla long-term soil productivity projects show high resilience based on soil nutrient levels in the PNW, though other work in 72 forest plantation sites from northern Vancouver Island, Canada to southern Oregon show a wide range of soil nutrient pools, and potentially sensitive sites. Additional work on 22 forest plantations shows that many sites have substantial amounts of nutrients in deep soils (up to 3–4 m), and trees seem to be utilizing this soil zone. Some fire-driven systems would benefit from removal of biomass for bioenergy by reducing susceptibility to catastrophic wildfire. In nearly all cases, loss of nutrients through high rates of biomass removal can be substituted by adding removed nutrients; however, environmental and social considerations are typically the driving forces that limit expansion of biomass-to-energy growth in the region.

Model-based assessment of land-use / land-cover change on water quality and economic outcomes in an agricultural watershed in north central Portugal. Hawtree, D., Feger, K. (*Dresden University of Technology, Germany; dhawtree@gmail.com; fegerkh@forst.tu-dresden.de*), Pettenella, D. (*University of Padova, Italy; davide.pettenella@unipd.it*), Nunes, J., Roebeling, P., Abrantes, N. (*University of Aveiro, Portugal; jpcn@ua.pt; peter.roebeling@ua.pt; njabrantes@ua.pt*).

Efforts to improve water quality through alterations in land-use and/or land-cover (LULC) must be considered within a broader economic context, so the potential financial impacts on local stakeholders can be better understood and quantified. The Cértima watershed, located in north-central Portugal, is heavily utilized for agriculture and has persistent concerns related to low water quality. This threatens downstream aquatic environments (including the natural lake Pateira de Fermentelos and the Ria de Aveiro lagoon), as well as local groundwater supplies. This study utilizes an eco-hydrologic model, the Soil and Water Assessment Tool, to examine the water quality impacts of potential LULC changes, such as the implementation of agricultural best management practices and/or land conversion (including afforestation options). This output is then used to generate economic assessments of the cost-benefit of these different alternatives to provide a baseline of different land-use options. These results are considered within the context of Portugal's obligations under the Water Framework Directive, and the financial impacts of noncompliance as compared to the cost of implementing steps necessary for water quality improvements.

Potassium availability in smectitic soils under *Gmelina arborea* and *Pachira quinata* plantations of tropical dry forest in north Colombia. Henao Toro, M. (*Universidad Nacional de Colombia, Colombia; mchenaoto@unal.edu.co*), Escobar Quemba, L., Cadena Romero, M. (*Universidad Distrital Francisco José de Caldas, Colombia; hojyann@yahoo.com; mecadenar@udistrital.edu.co*).

In the Colombian north region, *Gmelina arborea* plantations grow in soils with high saturations of calcium and magnesium, which could reduce potassium uptake. The objective of this research was to evaluate potassium availability for these plantations through measurement of K fractions (soil solution, exchangeable, non-exchangeable, and structural), K selectivity (Gapon coefficients, K_G), K quantity-intensity relationships (Q/I), and K release capacity. Soils in the study area are Vertisols and Inceptisols. DRX data indicated that smectite is the predominant mineral in the clay fraction of both soil orders, followed by micas. K fractions and K release capacity were similar in two soil types, although Inceptisols presented lesser content in soil solution (1.3 mg/kg), exchangeable (335.2 mg/kg), non-exchangeable (31.0 mg/kg), and structural (6258 mg/kg). Non-exchangeable potassium was much lower in Inceptisols than Vertisols, showing a more limited buffering capacity for K from non-exchange to exchange sites, which could be related with lower clay content in Inceptisols. Both soils showed a higher selectivity for calcium than potassium, with low potassium K_G and Q/I (2.7 to 3.5 $(mol/l)^{-1/2}$ and 15.4 to 21.1 $cmol_c/kg\ (mol/l)^{1/2}$, respectively), even if high amounts of exchangeable and reserve K were found.

Invasive North American beaver (Castor canadensis) habitat selection and impact in Tierra del Fuego, Argentina. Henn, J. (*Centro Austral de Investigaciones Cientificas, Argentina; henn.jonathan@gmail.com*), Martinez Pastur, G. (*Consejo Nacional de Investigaciones Científicas y Técnicas* (CONICET), *Argentina; cadicforestal@gmail.com*), Anderson, C. (*Centro Austral de Investigaciones Cientificas, Argentina; canderson@alumni.unc.edu*).

Since their introduction in 1946, North American beavers (*Castor canadensis*) have spread through all of Tierra del Fuego, flooding and felling trees in riparian zones. As beaver populations have grown and spread, the governments of Argentina and Chile decided to eradicate beavers and restore degraded areas. However, little work has been done to understand beaver habitat selection and the areas that beavers could potentially occupy in the near future. The goal of this study was to fill this gap by surveying satellite images for beaver impact through the whole Argentine side of Tierra del Fuego. To do this, a grid of 175 points of approximately 200 ha each were surveyed for number of beaver ponds and area affected by beaver. Overall, there was an average of 1.7 beaver dams per 100 ha, and beaver engineering affected an estimated 1.4% of the total land area. Beaver effects were present more often than expected in forested areas ($X2=42.35$, $df=5$, $p<0.001$), especially in mixed forests (*Nothofagus pumilio* and *N. betuloides*). These data were used to build a habitat suitability model using ecological niche factor analysis that should be useful as planning for restoration and eradication efforts move forward.

Fungal succession after fire in *Cistus ladanifer* L. ecosystems. Hernandez Rodriguez, M., Martín-Pinto, P., Oria-de-Rueda, J. (*University of Valladolid, Spain; mariahr@pvs.uva.es; pmpinto@pvs.uva.es; oria@agro.uva.es*).

Wildfires are the major disturbance in Mediterranean ecosystems. After fire, fungal communities follow succession patterns mainly driven by the dynamics of post-fire plant communities. The aim of this study is to analyze post-fire fungal succession in a Mediterranean ecosystem dominated by *Cistus ladanifer* in northwestern Spain. Sporocarps were collected and identified on a weekly basis during the autumn season from 2003 to 2006 in 100 m^2 plots located in recently burned plots (early stage) and mature stands (late stage). A total of 146 fungal taxa were found during the 4-year sampling. There was a shift in the taxa composition of the fungal community during *C. ladanifer* succession. *Cistus*-specific taxa were classified as multi-stage taxa as they were able to fruit in both early and late stages. Furthermore, several mycorrhizal taxa, usually associated with mature forest tree stands, were able to fruit much earlier in *C. ladanifer* scrublands. According to the results of this study, these ecosystems, traditionally considered ecologically and economically unproductive, seem to exhibit significant levels of fungal richness and can play an important role in diversity conservation as well as acting as a bridge for mycorrhizal inoculum in the recovery of forest stands after fire.

Fungal production after fire in *Pinus pinaster* stands using classificatory models. Hernandez Rodriguez, M., Martín-Pinto, P., Oria-de-Rueda, J., Vásquez Gassibe, P (*University of Valladolid, Spain; mariahr@pvs.uva.es; pmpinto@pvs.uva.es); oria@agro.uva.es; vasquez@ecmingenieriaambiental.com*).

This study was aimed at describing post-fire mushroom production in a Mediterranean ecosystem dominated by *Pinus pinaster* in the northwest of Spain and assessing the results by classificatory models. During the autumn periods 2003–2006, sporocarps from 115 fungal taxa were collected in burned and unburned areas and grouped into the following categories: saprotrophic/mycorrhizal and edible/non-edible. After wildfires, a significant reduction in the number of fungal species and fruit body biomass production was observed. Based on this relevant information, the first simple classificatory model was provided. Nine alternative models based on classifications according to combinations of edibility and functional groups were fitted, and four fruiting body biomass production classes were defined as possible responses. Time after fire and climatic variables were significantly related to fruit body production. The best predictive results were obtained for edible and edible-mycorrhizal models, with a correct classification rate of production classes of 92–85%. Moreover, obtained models were applied to analyze the effect of time after fire on fungal production. Mycorrhizal and edible fungal production after fire was classified into the lowest class, whereas saprotrophic and non-edible species followed a contrary trend. The classificatory models can be useful to optimize management and harvest of this appreciated forest resource.

Dendrometric indicators of understory vegetation along ecological gradients: do nonlinear models outperform linear ones? Herpigny, B., Gosselin, F., Vallet, P. (*National Research Institute of Science and Technology for Environment and Agriculture, France; basile.herpigny@irstea.fr; frederic.gosselin@irstea.fr; patrick.vallet@irstea.fr*).

Trees are among the main components of forest ecosystems. They affect understory vegetation composition and diversity through their influence on resources (light, water, nutrients). Therefore dendrometric indicators such as tree cover, species richness, or basal area are used as biodiversity indicators. Their effect varies along ecological gradients and among species. The relationship

between dendrometric indicators and understory plant diversity has already been modelled in some French plain forests. We extend the models to larger areas and take into account the variation of the relationship along ecological gradients. Those models are incorporated in the SIMMEM software, a forest simulator. We compare the efficiency of linear (general linear models) and nonlinear (such as models including asymptotes or threshold effect) forms when modelling the relationship between dendrometric indicators and understory plant species richness or abundance. We model this relationship at plot but also at landscape scale, including variables such as forest cover, hardwood or conifer percentage, and tree species abundance. Besides the sheer ecological interest, these models can also be included in the SIMMEM software, which can simulate the evolution of either forest plots or landscapes.

Biodiversity conservation on private lands: a comparative study of the USA and Europe. Hily, E., Stenger, A. (*National Institute for Agricultural Research* (*INRA), France; emeline.hily@gmail.com; anne.stenger@nancy.inra.fr*), Zhang, D. (*Auburn University, USA; ZHANGD1@auburn.edu*).

The objective of this paper is to review and compare the emergence and evolution of regulatory and market instruments for biodiversity conservation on private lands in the United States and Europe. We focus on the integration of these instruments (e.g., integration *via* environmental impact assessment, combination with economic instruments) and on the share of biodiversity conservation benefits and costs. Traditional conception of forestry has strongly influenced early definitions of regulatory tools for biodiversity conservation both in Europe and the United States. However, even though private forest owners in the United States nowadays have to comply with strong regulations such as the Endangered Species Act, new regulatory and market initiatives have provided them with added flexibility and incentives. Much of these new initiatives are developed in the U.S. because of this restrictive aspect of biodiversity conservation and strong reactions from private forest owners. On the one hand, a clear recognition of multifunctional forestry, the conception of private forest owners as biodiversity producers, and perhaps the lessons learned from the U.S. experience have oriented biodiversity conservation in Europe towards cooperation, voluntary approaches, and a hardly stringent regulation. We compare various regulations, incentive payments, and conservation market mechanisms and summarize their impacts in the United States and major countries in West Europe.

Mitigating effects on runoff chemistry after final felling using forest buffers. Högbom, L., Ring, E. (*Forestry Research Institute of Sweden, Sweden; lars.hogbom@skogforsk.se; eva.ring@skogforsk.se*), Löfgren, S. (*Swedish University of Agricultural Sciences, Sweden; stefan.lofgren@slu.se*).

Final felling typically affects water quality, in headwater streams in particular. In order to reduce negative effects, forest buffers left along the streams can be an efficient countermeasure. We have studied the effects of a narrow forest buffer along a small headwater stream in a paired-catchment study in Northern Sweden. The experimental site is situated in an area with low nitrogen deposition (2–3 kg N/ha/year). The study was initiated in 2004 and included in total six catchments; two catchments to be felled with or without leaving a forest buffer and two unfelled control catchments, and in addition, two larger catchments to investigate the effects on landscape scale. After two years of reference measurements two of the catchments were harvest, and in 2008 site preparation occurred. Water flow has been monitored using V-notch weirs. Runoff chemistry (c. 20 constituents) has been measured on a fortnight schedule for the last 8 years. In the stream surrounded by a forest buffer, the concentration of nitrate and ammonium in the runoff was substantially reduced as compared to the catchment without the buffer, while constituents like potassium, chloride, and total phosphorus increased regardless of the presence of a forest buffer.

Life cycle carbon and economic assessment of biochar-based bioenergy production in Ontario, Canada. Homagain, K., Shahi, C. (*Lakehead University NRM, Canada; khomagai@lakeheadu.ca; cshahi@lakeheadu.ca*).

Bioenergy is considered a carbon-neutral solution for the current environmental crisis. Biochar is a by-product of bioenergy which can sequester carbon for a longer time if applied in soil which is claimed to be carbon negative in the life-cycle. Fossil fuel related emissions are often blamed as one of the biggest contributors of current environmental greenhouse gas and subsequent global warming. Fossil fuels make up a significant proportion of the current power supply mix in Ontario. In order to reduce GHG emissions from coal fired power stations, the province of Ontario is phasing out coal firing plants and replacing with forest biomass plants by 2014. The use of biomass feedstock for power generation not only has the potential to address the environmental problems related to air pollution and climate change, but also ensures energy security for local communities. Production of biochar-based bioenergy by using woody biomass and replacing fossil fuel based power supply will have a very important impact in the environment. We conducted a thorough life cycle assessment using SimaPro® and EIO-LCA. Here we present a detailed life cycle carbon and economic assessment of biochar-based bioenergy production in Ontario, Canada with comparisons to conventional bioenergy production along with GHG and other environmental consequences.

Water erosion vulnerability of upland watersheds under different forest covers in the Chittagong Hill Tracts, Bangladesh. Hossain, M. (*University of Freiburg, Germany; mohitulh@yahoo.com*), Haque, S. (*University of Chittagong, Bangladesh; sms_haque@yahoo.com*), Olarieta, J. (*Universitat de Lleida, Spain; jramon.olarieta@macs.udl.cat*), Hossain, M. (*University of Chittagong, Bangladesh; noorhossain28@gmail.com*).

Water erosion is the most serious environmental problem in hilly watersheds of Bangladesh and is a major concern for forestry and agricultural productivity. It is, therefore, necessary to identify land use practices that will control this problem in order to establish sustainable watershed management strategies. In this context, the study was carried out in 21 different sites in the Chittagong Hill Tracts (CHTs) by conducting direct field assessments of soil loss under various land uses using erosion pins and pedestals measurement during the period 2009–2010. The results showed that average soil loss was highest (64 t/ha/yr) in deeply-tilled agricultural slopes, followed by *Tectona grandis* plantations (47 t/ha/yr), while the lowest soil losses (13 t /ha/yr) were recorded in bamboo plantations. Among the other forest plantations studied, soil loss rates were comparatively smaller under mixed-plantations (17 t/ha/yr) and *Gmelina arborea* plantations (30 t/ha/ya). Land use was the most significant factor explaining these erosion rates compared to slope and soil characteristics. This study can be useful to identify areas with high erosion risk and to develop adequate soil conservation measures in the hilly watershed of the CHTs.

Biomass and carbon stores estimated in 2011 and 1934 at Priest River Experimental Forest, northern Idaho, USA. Hudak, A., Sandquist, J., Jain, T., Byrne, J. (*U.S. Forest Service, USA; ahudak@fs.fed.us; jsandquist@fs.fed.us; tjain@fs.fed.us; jbyrne@fs.fed.us*), Fekety, P. (*University of Minnesota, USA; pafekety@gmail.com*), Falkowski, M, Wei, L., Marshall, J., Link, T., Kavanagh, K.

Environmental monitoring data have been collected at the ~3 000 ha Priest River Experimental Forest (PREF) in northern Idaho since 1911. Streamflow has doubled in the past 70 years while annual precipitation has remained unchanged. We hypothesize that these trends are due to forest succession. PREF was initially dominated by western white pine but today is dominated by western red-cedar; transpiration rates of western red-cedar are less than half those of western white pine. We estimated the effect of succession on forest biomass carbon by relating forest inventory data collected in 2011 to a 1934 stand map of timber type and age class. We impute 20 m × 20 m gridded maps of species-level forest biomass, measured in 2011 at 60 systematic forest inventory plots data, using as predictor variables canopy metrics derived from a 2011 airborne LiDAR collection. Mapped predictions are aggregated to the 1934 stand map polygons, and the timber type and age class attributes from the 1934 stand map are cross-walked to species-level biomass estimates using look-up tables with long-term data from permanent plots monitored at PREF since 1914. Results will inform landscape-level models of forest carbon and water budgets constrained by 1911–2011 climate records.

Debarking of trees by deer is affected by deer density, tree size, species palatability, and maximum snow depth. Iijima, H., Nagaike, T. (*Yamanashi Forest Research Institute, Japan; hayato.iijima@gmail.com; nagaike-zty@pref.yamanashi.lg.jp*).

The increase of deer density and the deer impacts on forest ecosystems are serious problems all over the world. Debarking, one of the impacts of deer, is frequently surveyed as the indicator of deer impacts, but the occurrence of debarking is known to fluctuate among studies. In this study, we examined factors for the variability of debarking in Yamanashi Prefecture, central Japan. Deer densities of spatially fine scale (ca. 5 × 5 km) were estimated with a Bayesian state-space model. We measured the presence of debarking of trees (> 3 cm in diameter at breast height) at 569 forests in Yamanashi Prefecture (n = 14 225). The occurrence of debarking was affected by deer density, tree size, species palatability, and maximum snow depth, but not the amount of understory vegetation.

Landscape of vulnerability: forest cover change and fragmentation in Istanbul, Turkey. İnan, M. (*Istanbul University, Turkey; inan@istanbul.edu.tr*), Inan, Z. (*Yeditepe University, Turkey; zerrinan@gmail.com*), Serengil, Y. (*Istanbul University, Turkey; serengil@istanbul.edu.tr*).

Because of its unique location between Asia and Europe, İstanbul is suffering from significantly increasing consumption rates and population growth that have caused great changes in land use, land cover, and new land use types which are not harmonious with the environment and forest areas of the city. The city scale landscape and forest areas are significantly impacted by human-environment interaction in Istanbul, and consequently, rapid change in forest habitats have occurred. In this study, a GIS based system is executed and presented to identify the land use changes and evaluate the forest change and forest cover fragmentation by using Landsat images between the years of 1987, 2006, and 2013. Changes in landscape patterns, habitat fragmentation, habitat quality, and forest corridor alternatives between these fragmented habitats are analyzed by the system. Based on these analyses, some recommendations are discussed for forest landscape planning and management for sustainability of forest habitats and wildlife.

Forest adaptation to climate change in Iran. Jafari, M. (*Research Institute of Forests and Rangelands, Iran; mostafajafari@libero.it*).

Mitigation and adaptation are two main strategies to address climate change (CC). Various stakeholders define and interpret adaptation quite differently. Multiple dimensions of the adaptation process, programs, policies, strategies, and actions have three steps: (1) assess risks, (2) implement adaptation, and (3) review effectiveness. The adaptation capacities that have the potential to reduce adverse impact of CC and should be considered include increasing the sink for emissions and reducing the source of gases. Increasing the capacities of sink potentials could be implemented in two ways and include an increase in area and increase of volume potential. Decreasing the emissions sources capacities could be accomplished by a decrease in areas and decrease of volume potential. Urban forestry might be considered as an opportunity responding to the CC. The CE of LFCCs situated in Tehran could be used as a tool for urban and pre-urban forestry at local, national, regional, and international levels. Hyrcanian and Zagrosian forest ecosystems have tolerated the CC in the past centuries based upon the ability of the species. Fragmented and degraded forests will be unable to adapt to rapidly changing conditions. An overview of the major categories of changes expected in forest ecosystems as a consequence of CC include disturbance, simplification, movement, age reduction, and extinction or extirpation.

Relationships between vegetation, tree canopy composition, and soil in canopy gaps in dry *Pinus sylvestris* stands. Jankovska, I., Brumelis, G., Straupmanis, G., Amatniece, V., Dauskane, I. (*University of Latvia, Latvia; ilze.jankovska@llu.lv; guntis.brumelis@lu.lv; gustavs.straupmanis@inbox.lv; vita-amatniece@inbox.lv; iluta.dauskane@lu.lv*).

The aim of this study was to determine the effects of changes in tree species composition and soils on vegetation in canopy gaps of dry *Pinus sylvestris* forest stands. The study was conducted in forest stands located in the outskirts of the City of Riga in Latvia. Recreation and pollution loads in the city are leading to conversion of nutrient poor coniferous tree ecosystems to deciduous tree cover. Conversion of the 15 canopy gaps of various sizes were measured. In the gaps, vegetation was described and tree saplings and shrubs were counted and measured. For data analysis, the vegetation was described using plant traits. Tree discs and cores were removed for estimation of sapling age. Soil samples were collected at three depths for determination of pH, organic content, and N, P, and base cation concentrations. Gradual invasion of deciduous tree species in canopy gaps was associated with soil changes and increased shade. Both of these factors are causing a loss of the typical moss-dominated plant communities and an increase in cover of graminoid and forb species.

Evaluating vegetation complexity at different site conditions of subtropical forest of Okinawa Island Japan. Jemali, N. (*Kagoshima University, Japan; idiana0303@yahoo.com*), Shiba, M. (*University of the Ryukyus, Japan; mshiba@agr.u-ryukyu.ac.jp*), Binti Ahmad Zawawi, A. (*Kagoshima University, Japan; azitazawawi@gmail.com*).

The purpose of this paper was to study vertical vegetation structure and spatial distribution of several subtropical broadleaved trees species in Okinawa Island, Japan. Data was collected from Okinawa prefectural forest in 2012 and 2013 with different site condition. Forest monitoring resource survey under National Forest Inventory System method was utilized to provide objective data for forestry planning as well as to understand the biodiversity and productivity of forest ecosystem and carbon cycle. Plots were established in a concentric fashion with three different circle sizes. The radii of small, medium, and large circles were 5.64 m, 11.28 m, and 17.84 m respectively. In each plot, investigation of general plot condition was recorded including aspect, slope, soil type, distance from road and villages, complete tree tally on DBH (>1 cm), tree height, species name, tree health condition, and number of adjacent seedlings. The analysis was carried out from statistical and spatial analysis including species richness, Shannon's and Simpson's diversity indexes, and degree of concentration on each species. Methods for evaluating forest structure in a complex topographical condition at the studied forest are also discussed in this paper.

Quantifying carbon reduction services by urban landscape trees in Korea. Jo, H., Kim, J., Park, H. (*Kangwon National University, Republic of Korea; jhk@kangwon.ac.kr; kjy84@kangwon.ac.kr; bhm63@kangwon.ac.kr*).

The purpose of this study was to quantify storage and annual uptake of atmospheric carbon by urban landscape trees through a direct harvesting method. The study selected eight tree species that are popular for urban landscape plantings in Korea: *Abies holophylla*, *Acer palmatum*, *Ginkgo biloba*, *Pinus densiflora*, *Pinus koraiensis*, *Prunus yedoensis*, *Taxus cuspidata*, and *Zelkova serrata*. Ten to eleven individuals of each species, for a total of 82 trees, were sampled reflecting various diameter sizes at a given interval. The study measured biomass for each part including the roots of sample trees to compute total carbon storage per tree. Annual carbon uptake per tree was also quantified by analyzing radial growth rates of stem samples at breast height or ground level. Carbon reduction services by an urban tree were greater than those by a forest tree for the same species and diameter sizes. The study has broken new ground to overcome limitations of carbon estimation for urban landscape trees associated with a difficulty in direct cutting and root digging. [This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korean Government (MOE) (2011-0009379)].

Epiphytes on *Pinus mugo* introduced around 1850 from the Alps to Danish coastal dune systems. Johnsen, I. (*University of Copenhagen, Denmark; ibj@bio.ku.dk*).

Pinus mugo (Mountain Pine) is native to the high alpine region of southern Europe. It was introduced to the west coast of Jutland, Denmark during the 1850s and was planted on the Skagen Spit to reduce sand drift. The study presented in this paper refers to Skagen Plantation, just south of the city of Skagen, the northernmost city of Jutland. These plantations are now mainly of historic value, as the sand drift is being controlled otherwise or accepted as a natural phenomenon. Similarities and differences between the epiphytic vegetation of lichens and bryophytes of the Danish *Pinus mugo* stands compared with alpine stands of the same species are being presented and discussed. The genus *Ochrolechia* is subject to particular scrutiny, as there apparently is only one common species (*Ochrolechia microstictoides)* among the epiphytes on *Pinus mugo* in the Alps and Denmark. It is also discussed whether the present day high Danish levels of atmospheric deposition of nitrogen and phosphorus compounds may be reflected in the epiphytic vegetation of *Pinus mugo*. Included in the paper is also a presentation of the ground vegetation below the *Pinus mugo* stands. The terrestrial vegetation of lichens and bryophytes within the *Pinus mugo* stands is briefly compared with the epigeic vegetation adjacent to the *Pinus mugo* plantations.

Spiders as indicators to evaluate the changes of a *Pinus taeda* plantation in grassland biodiversity in Uruguay. Jorge, C., Laborda, Á., Simó, M. (*Universidad de la Republica, Uruguay; carolina.jorge@cut.edu.uy; alaborda@fcien.edu.uy; simo@fcien.edu.uy*).

The objective of this study was to establish a suitable methodology for finding bioindicators of change that generate arthropod biodiversity in forest crops. Spiders are a megadiverse group and have proven to be good indicators of antropic ecosystem changes. Seasonal samples were taken from April 2011 to February 2012 in a *Pinus taeda* plantation in the northeast of Uruguay. For the relocation of the spiders we used two direct methods: nocturnal hand collection and a G-Vac. A total of 5 017 exemplars distributed in 21 families and 121 morphospecies were collected. Jacknife 1 estimator indicated that 70% of the araneofauna was sampled. Significant differences in the composition of species, families, guilds, and associations between both sites were recognized. The natural field was the site with the largest number of individuals, families, and species richness. Our results indicate that the culture of *P. taeda* generates changes in the composition and structure of the soil araneofauna regarding the natural field. The identification of indicator species for both study sites generates a knowledge framework for possible implementation in future monitoring in the context of sustainability and environmental certification in our country.

Flood generating areas: How much is land use/cover responsible? Kalin, L., Noori, N. (*Auburn University, USA; latif@auburn.edu; nzn0004@auburn.edu*).

This paper presents results from a study conducted in southeast coastal Alabama where we worked with two relatively small cities to identify critical areas within the 8-Mile Creek watershed that may have a higher contribution to downstream flooding, if developed. The watershed transitions from forested to urban land. It was shown that areas intuitively thought to have the highest impact on the increased high- or low-flows may not be critical at all. Highly impervious areas near the outlet of a watershed could contribute too quickly to the flow hydrograph such that their impact may only appear at the raising stage of the flow hydrograph. In other words, by the time peak flow is observed, flow generated from those areas might have already left the watershed. The interaction of different land use/cover at different parts of the watershed, flow travel times from those areas (mainly affected by topography and surface roughness), and soil types are important driving factors in the formation of the hydrographs. Results of this study led the two cities to work on modifications of their stream buffer ordinances. This study

showed that the inevitable population growth and economic development issues need to be holistically and sensibly addressed by government officials, planners, academia, developers, land owners, and others in ways that are environmentally protective and economically prudent.

Development of capacity building program in Thailand and Myanmar for combating desertification, land degradation, and drought. Kang, H. (*Seoul National University, Republic of Korea; silvi@chol.com*), Bang, M. (*University for Peace, Costa Rica; bangmiin@gmail.com*), Lee, P., Park, J. (*Seoul National University, Republic of Korea; shsnu337@gmail.com; parkjeongho82@gmail.com*), Kang, H. (*Dongguk University, Republic of Korea; hdk0225@dongguk.edu*).

Center for Combating Desertification in Arid and Semi-arid Areas (CCDASA, Korea Forest Service) is dealing with desertification, land degradation, and drought (DLDD) in Asia and Africa. The objective of our study is to develop a capacity building program for strengthening the capability of graduate students in conducting research on DLDD. In 2013, we organized two short-term training courses in Thailand and Myanmar. The course details include discussing DLDD issues in the workshop in Thailand, studying the current status of DLDD at the central dry zone of Myanmar, and exploring research topics on how to resolve DLDD in this region. Particularly, we developed these programs focusing on discussing DLDD with various stakeholders—international organizations, governmental agencies, research institutes, and local communities—in addition to field excursions. This provided the graduate students with the opportunity for learning how to consult local conditions most suitably to manage DLDD more effectively. We suggest further studies on sustainable land management at the central dry zone of Myanmar that could include improving soil quality, managing and developing water resources, and monitoring land use changes using geospatial techniques. (This study was carried out with the support of Forest Science & Technology Projects (Project No. S211212L030420) provided by Korea Forest Service.)

Collaborative research to combat desertification in arid and semi-arid areas. Kang, H. (*Dongguk University, Republic of Korea; hdk0225@dongguk.edu*), Woo, S. (*University of Seoul, Republic of Korea; wsy@uos.ac.kr*), Son, Y. (*Korea University, Republic of Korea; yson@korea.ac.kr*), Lee, S., Cho, W. (*Dongguk University, Republic of Korea; nash7700@hanmail.net; valkyre@naver.com*).

Some hybrids or clones grow well in desert areas because they have characteristics making them tolerant to drought, wind, sand, cold, heat, and salt. Improvement of popular species through the establishment of plantations is important to prevent desertification expansion in arid areas of Northeast Asia. We selected clones from the fast growing species that show strong tolerance traits to salt and cold, which have been developed through cross breeding and breeding by selection over the past ten decades from native and exotic local regions. The Center for Combating Desertification in Arid and Semi-arid Areas (CCDASA) was founded in 2012. It has been supported by the Korea Forest Service. The objectives of the center are to study scientific and technological desertification matters in arid and semi-arid areas, to make capacity building for graduate students in international society, and to learn relevant ways and means of how to combat desertification. The center also aims to establish networks in the country and to assist specialists in combating desertification through the country's training program and implementation based on UNCCD COP-10's follow-up action in Korea. The center is operating scientific and educational programs with the bilateral collaboration of other countries.

Tree census and diversity issues of urban forest of Chandigarh India: an update. Kohli, R. (*DAV University, India; rkkohli45@yahoo.com*), Jassal, J., Singh, N. (*Panjab University, India; jaswinder.j@hotmail.com; narayan.singh@gmail.com*).

For the present day environmental concerns and urban heat islands, trees are needed more in cities than anywhere else. The managers of urban communities find it really hard to grow and nurture the trees, especially in populated cities. Chandigarh in North India is one such city with population density exceeding 12 000 per square Km. In spite of several perceptible problems of spaces for trees and other related services, the city is wonderfully managing the urban forest character. With new inputs and ground truthing data on census and various related ecological indices, the objective of this presentation is to share the problems and the solutions thereof for a better upkeep of urban forests in crowded communities.

Sustainable wetlands adaptation and mitigation program (SWAMP). Kolka, R., Mackie, C. (*U.S. Forest Service, USA; rkolka@fs.fed.us; cmackie@fs.fed.us*), Murdiyarso, D. (*Center for International Forestry Research, Indonesia; d.murdiyarso@cgiar.org*), Kauffman, B. (*Oregon State University, USA; Boone.Kauffman@oregonstate.edu*), Anderson, C. (*U.S. Forest Service, USA; christamanderson@fs.fed.us*).

Carbon-rich tropical wetlands (mangroves and peatlands) are important in climate change adaptation and mitigation strategies and provide numerous ecosystem services such as storm protection, nursery areas for fish, habitat for rare species, long-term storage of carbon, and food, fiber, and fuel for humans. Because of their importance we developed the Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) to assist countries with their accounting and conservation of tropical wetlands. SWAMP is a collaborative effort between the Center for International Forestry Research, U.S. Forest Service, and Oregon State University through support from the U.S. Agency for International Development. The goal of SWAMP is to provide policy makers and natural resource professionals with credible information and training to make sound decisions regarding the role of tropical wetlands in climate change adaptation and mitigation. The SWAMP objectives are to: (1) quantify greenhouse gas emissions from intact and disturbed wetlands; (2) quantify carbon stocks of representative tropical wetlands; (3) develop carbon modeling tools and scaling approaches using remote sensing; (4) define roles for tropical wetlands in climate change adaptation strategies; and (5) promote capacity building and outreach as integral parts of all activities. Here we discuss the accomplishments of SWAMP, current activities, and the future.

Adapting forest ecosystems in Kailash Sacred Landscape of Hindu Kush Himalayas for sustained flow of ecosystem services. Kotru, R. (*International Centre for Integrated Mountain Development (ICIMOD), Nepal; rkotru@icimod.org*).

The Kailash Sacred Landscape is a transboundary region consisting portion of the Tibetan Autonomous Region of China, and adjacent areas of India and Nepal, spread over 31 000 km^2. With a forest area of 36% this landscape is unique for being

culturally rich and ecologically diverse. Forest cover and its interface with other ecosystems provide inestimable transboundary ecosystem goods and services vitally important for lives and livelihoods of millions of people. Assessment of existing forest management systems show that burgeoning basic human needs of food, water and energy are not matched by sustainable forest management practices. Forests have been degraded as a result of over-harvesting, forest fires, heavy ungulate browsing or livestock grazing. Regional climate models combined with community science findings show that forests will be affected by climate change in future. The reactive and exclusionary forest protection policies, and enormous deficits in relevant information, innovative practices, stewardship and funding essential for judicious management to secure and sustain the host of environmental services whilst forest ecosystems adapt to climate change are a major constraint. The research suggests proactive forest management as the key to transform current stagnant forest sector to more adaptive and vibrant one for positive conservation and development outcomes.

Site conditions of Grey mangrove (Avicennia Marina) at Nayband National Marine Park. Kouhgardi, E., Akbarzadeh, M. (*Islamic Azad University, Iran; kouhgardi@yahoo.com; mehrdad.ak@gmail.com*).

In order to determine the relation among physiochemical parameters of water and soil as well as heavy metals of sediments and vegetative characteristics, samples of water and sediments were collected at the fifteen stations, with three repetitions in Nayband Mangrove Forest south of Iran. The results revealed that vegetation in most zones enjoys desirable conditions in view of qualitative parameters, and physiological weakness has only been observed at stations 6 and 7. Relying on results obtained, positive correlations only existed between average diameter and pH of water. Also, there was a negative significant correlation between pH of water and qualitative characteristics of trees ($P<0.05$). There was no significant correlation between amount of mercury and chrome and stand quality. Amount of nickel had a negative significant correlation with average height and average diameter of trees as well as vanadium and lead with all characteristics of Grey Mangrove ($p<0.05$). On a whole, quantity of lime on sediments, pH of water, completeness of tide, and quantity of vanadium and lead has an effective role on growth and quality of the stand that is a unique habitat for aquatic animals and landscape planning as well as coastal protection.

The species diversity of the steppes and the Sahara desert: central and southern Tunisia. Kwak, M., Woo, S. (*University of Seoul, Republic of Korea; 016na8349@hanmail.net; wsy@uos.ac.kr*), Khaldi, A., El Khorchani, A., Stiti, B. (*National Research Institute Of Rural Engineering, Water And Forests* (INRGREF), *Tunisia; khalditn@yahoo.fr; ali_el_khorchani@yahoo.fr; stiti_b@yahoo.fr*), Je, S., Lee, E., Yu, H., Jin, H., Kwon, Y.

One of the major environmental problems throughout Northern Africa is desertification of arid lands, specifically in Southern Tunisia (i.e., the semi-desert region of the northern Sahel Zone and the desertification of the northern margin of the Sahara Desert, in which desertification has occurred during the past few decades). Tunisia represents three different climatic zones forming a broad zone composed of a mixture of varied topography. Around 40% of the country is composed of the Sahara desert. Because of the geographic location, the northern part of Tunisia is influenced by the Mediterranean Sea climate. Sahara in southern Tunisia is desert due to the limited rainfall. Interestingly, central Tunisia is influenced by the combination of both. The vegetation of the steppes of central Tunisia and the Sahara desert of southern Tunisia is strongly dominated by chamaephytes (dwarf-shrubs) and therophytes (annual plants) such as *Acacia tortilis*, *Stipa tenacissima, Zygophyllum album, Artemisia campestris*, *Plantago albicans*, *Lygeum spartum*, *Artemisia herba-alba*, *Polygonum equisetiforme*, *Ruta chalepensis*, *Thymelaea hirsuta*, *Retama retam*, *Deverra scoparia*, *Scilla villosa*, *Anacyclus monanthos*, *Echium pycnanthum*, *Oudneya africana*, *Paronychia arabica*, *Euphorbia guyoniana*, *Astragalus armatus*, *Astragalus gombo*, *Aristida pungens*, *Lygeum spartum*, and *Rhus tripartita.*

Influence of forest management strategies and environmental conditions on epigeic arthropod biodiversity. La Rocca, C., Spence, J., He, F. (*University of Alberta, Canada; larocca@ualberta.ca; jspence@ualberta.ca; fhe@ualberta.ca*).

The relationship between biodiversity and ecosystem productivity is of great interest to foresters. Previous studies demonstrated a positive correlation between the increase of overall stored carbon in the system and biodiversity, a fundamental component for the assessment of better forest management strategies. However, evidence shows that this relationship is strongly influenced by environmental characteristics (temperature, moisture, ground cover,) more than from single Carbon indicators (DBH, coarse wood material). To test this hypothesis, we will use pitfall traps to collect epigeic arthropods (ground and rove beetles, spiders) and a series of environmental variables (DBH, coarse woody debris volume, ground cover, temperature, canopy cover, time since last disturbance) from sites in the boreal transition zone of central Alberta (Canada), selected on the basis of their age (time after harvesting) and retention strategies applied (percentage of trees retained during harvesting).Using ordination analyses and geo-statistical approaches, the goal of this study is to determine which factor has greater influence on species richness and relative abundance of litter and soil arthropods, to assess which forest management strategy (i.e., different retention level or time after the harvesting) is preferred.

Forest succession stagnation in southern Brazil forests – the role of bamboos. Lacerda, A., (EMBRAPA*, Brazil; andre.biscaia@embrapa.br),* Kellermann, B. (*Brazilian National Council for Scientific and Technological Development (CNPq), Brazil; kdbetina@hotmail.com*).

In this paper, we explore the relationship between bamboos and forest stagnation. After the 30-year die-off cycle of bamboo, other species begin to establish but are quickly overcome by bamboos as they recreate pure stands. In this context, long-term forest monitoring allows us to explore the role of bamboo in forest dynamics. As such, we monitored in EMBRAPA's Caçador Research Station (Santa Catarina, Brazil) 2 208 trees in 20 plots (15 m × 15 m) from two forest subtypes in 2007, 2010, and 2012: *Pristine* (few bamboos) and *bamboo* (dense bamboo populations, mainly *Merostachys skvortzovii*). The diversity of pristine forests fluctuates at around 60 species, whereas bamboo forests show three times fewer species and fewer individuals, with a slight declining trend. On the other hand, dominance (m^3/ha) in Pristine forests is increasing (82 to 87) but has stagnated at much lower levels (16) in bamboo forests. The results confirm that after bamboo die-off, a large number of individuals of many species regenerate, but only a few succeed and grow into adults because of quick bamboo re-establishment. This stagnates succession in (species-poor) early succession forests. Because of its widespread distribution in southern Brazil, bamboo management should be integrated into forest conservation practices.

Climate change impacts on forests and biodiversity in Western Himalaya of Nepal. Lamichhane, D. (*Ministry of Forest and Soil Conservation, Nepal; dlamichhane@gmail.com*), Silwal, A. (*HELVETAS, Nepal; anjali.silwal@helvetas.org.np*).

Forest resources and biodiversity in the Himalayan region of Nepal are considered as more fragile mainly due to climate change and other anthropogenic causes. The research was conducted in the remote mountainous region of western Nepal to analyze the climate change impacts on forests and biodiversity. Socioeconomic data were collected using semi-structured questionnaires, focus group discussions, and checklists, while forest and biodiversity-related data were collected through direct field observation, plots establishment and measurement, and field experiments. Results indicated that the rising temperatures, glacial retreat and the changes in the availability of water resources affected a considerable number of globally important plant and wildlife species in the region. Other impacts, such as a high rate of snow melting, caused the tree line to shift up, the biodiversity to narrow down, and downstream flooding. Forest degradation and biodiversity loss had largely affected agricultural crops production, livestock farming with low availability of grazing area and forage, and livelihood assets in the Himalayan region. The adaptive strategies by local people included activities like altering the timing of planting of crops, changing crop types, controlling insect outbreaks, and breeding new agricultural and forest species that would be better suited to the changing climatic conditions.

Performance and potential of landscape level biodiversity conservation for climate change adaptation and mitigation in Nepal. Lamsal, R. (*Ministry of Forests and Soil Conservation, Nepal; ramplamsal@gmail.com*), Khanal, S. (*Kathmandu University, Nepal; sanjay@ku.edu.np*).

Landscape approach in conservation has gained prominence to reconcile conservation and development tradeoffs and tends to generate impacts not only on conservation of biodiversity and ecosystem services, improvement of livelihoods, but also on climate change. This study, which focuses on the Terai Arc Landscape (TAL) area of Nepal, addressed the following: (a) discusses linkages between biodiversity and climate change adaptation and mitigation; (b) reviews observed and perceived impacts of climate change; (c) offers some community-based mitigation and adaptation techniques; and (d) discusses issues on identification and assessment of impacts. The study is based on literature review, field visits, case studies, and relevant participatory tools and techniques. This study illustrates the practice, outcomes, and future potential of landscape level conservation in Nepal as an approach to achieving conservation and livelihood goals and supporting climate change adaptation and mitigation. It presents cases where communities are using various strategies to improve biodiversity conservation and natural resources management to minimize the negative impacts; reveals potentiality of mitigation through biodiversity conservation and sustainable forest management; and finally presents a community-based assessment framework, methodology, and tools dealing with vulnerability and climate change.

The carbon footprint of forestry in east Norway: a life cycle analysis. Lange, H., Timmermann, V., Dibdiakova, J., Gobakken, L. (*Norwegian Forest and Landscape Institute, Norway; holger.lange@skogoglandskap.no; tiv@skogoglandskap.no; JAD@skogoglandskap.no; gol@skogoglandskap.no*).

A wide range of forest products and industries have been examined in life cycle analyses (LCA). Life cycle data are essential for identifying forestry operations that contribute most to carbon emissions. Forestry can affect net CO_2 emissions by changing carbon stocks in biomass, soil, and products, by supplying biofuels to replace fossil fuels as well as by establishing new forests. The transport of forest products is crucial to greenhouse gas (GHG) emissions. We conceptualize the chain from seed production, silviculture, harvesting, and timber transport to the industry as a system. Inputs to the system are energy and fuel, the output represents GHG emissions. The reference functional unit used for the inventory analysis and impact assessment is one cubic meter of harvested timber under bark. GHG emissions from forestry in East Norway were calculated for the production of one such unit delivered to the industry gate in 2010 (cradle-to-gate inventory), showing that timber transport from the forest to the final consumer contributed with more than 50% to the total GHG emissions. To assess uncertainty of model approaches, the LCA was conducted with two different models, SimaPro and GaBi, both using the Ecoinvent database with data adapted to European conditions.

Estimating and extracting the optimal parameters of random walk model for debris flow hazard mapping. Lee, C. (*Korea Research Institute, Republic of Korea; leecw@forest.go.kr*).

Random walk model can predict the sediment areas of debris flow, but three fitted topographical environment parameters must be extracted. This study developed the method to extract the optimal values of three parameters, once flowing volume, stopping slope, and gravity weight, for the random walk model. Extracted parameters were validated by aerial photographs of the debris flowed area. Extraction of the optimal parameters was randomly performed, limiting the range values of three parameters and developing an accuracy decision method that is called the rate of concordance. In order to apply to other sites, we need to development estimation methods by pseudo sample neural network (PSNN). PSNN is a variant of traditional neural network using pseudo samples based on existing training samples to mitigate the local-optima-convergence problem when the size of training samples is small. PSNN can take advantage of the smoothed solution space through the use of pseudo samples. PSNN focuses on the quantity problem in training, whereas, methods stressing the quality of training samples is presented in this paper to improve further the performance of PSNN.

Effects of plug cell trays, soil components, and shading rates for seed germination and growth of *Hippophae rhamnoides*. Lee, S., Kang, H., Cho, W. (*Dongguk University, Republic of Korea; i871214@hanmail.net; hdk0225@dongguk.edu; valkyre@naver.com*).

Hippophae rhamnoides, a member of Elaeagnaceae, is gaining popularity at home and abroad ever since its beneficial effects were introduced. Seabuckthorn doesn't grow well in Korea and problems are being encountered in raising seedlings due to indiscriminate introduction of high value species and lack of skills and knowledge. Therefore, this study was conducted in field conditions in order to disseminate the cultivation method amongst tree growers. Chinese seeds had a relatively high germination rate in 128 cell traya and grew well in 50 cell trays, whereas the Russian seed had relatively high germination rate and growth

rate in 50 cell trays. In terms of soil type, both the Chinese and the Russian seeds showed less than 20% germination rate in weathered granite soil and the growth rate was also the lowest. Chinese seeds had high germination rates in TKS-2 and the Russian seeds in horticultural substrate, respectively. The growth rates of Chinese and Russian seedlings were high in TKS. Chinese seed had the highest germination rate in controls and shoots grew well at 70% shading, whereas the roots grew well in full sunlight. Russian seed had about 50% germination rate at 30% and 70% shading. Support of Forest Service and Technology Projects (Project No. S120911L120110 and S211213L030110) provided by Korea Forest Service.

Dieback of evergreen coniferous forests due to climate change in Korea and their management options for adaptation. Lim, J. (*Korea Forest Research Institute, Republic of Korea; limstree@hanmail.net*), Lee, D. (*Seoul National University, Republic of Korea; leedk@snu.ac.kr*), Suh, S. (*Chubgbuk National University, Republic of Korea; suhs77@hanmail.net*).

Climatic warming, especially warmer and drier winters, exacerbate decline of evergreen coniferous forests in Korea, in addition to pressures of insects and successional trends. Following mass mortality of pines in 1998, 2002, and 2007, more than 1 million trees were dead in 2009 due to drought and warm winter climate especially in southern areas of its distribution range. While deciduous *Larix leptolepis* and broadleaved trees survived, mass mortality occurred on dense unmanaged *Pinus koraiensis* plantations and on dense natural *Pinus densiflora* stands on southern slopes. Drought and warm winter temperatures promoted the pathogenicity of *Cenangium ferruginosum.* According to the projected changes of seasonal climate by IPCC-SRES models, air temperature will increase more rapidly in winter than summer, while precipitation is variable and uncertain. In the future, diebacks of evergreen conifers due to drought stress in winter are anticipated to occur more frequently in Korea. Thus, evergreen coniferous forests in Korea are potentially more vulnerable to future climate change impacts, primarily due to increasing winter temperatures. Significance and silvicultural options, including thinning and planting species selected for the adaptation of conifer forests to climate change, is discussed.

The Mica Creek project: a comprehensive assessment of environmental effects of contemporary harvest practices in the interior Pacific Northwest, USA. Link, T. (*University of Idaho, USA; tlink@uidaho.edu*), Gravelle, J. (*PineOrchard, Inc., USA; jag@pineorchard.com*), Hubbart, J. (*University of Missouri, USA; HubbartJ@missouri.edu*), Karwan, D. (*University of Minnesota, USA; dlkarwan@umn.edu*), Du, E. (*Lawrence Berkeley National Laboratory, USA; edu@lbl.gov*).

The Mica Creek Project in northern Idaho is a comprehensive monitoring program to fill the critical knowledge gap concerning the environmental effects of contemporary forest harvest practices. The experiment employed paired and nested watersheds at multiple scales in a before-after, control-impact (BACI) study design. The experimental period consisted of pre-treatment calibration, post-road construction, and post-harvest phases. Specific results of the study indicated that stream flows increased significantly by ~30% in the harvested areas following timber harvest. Hydrologic modeling indicated that annual yields and flow regimes were relatively insensitive to harvest patterns, relative to total area harvested. Stream temperatures increased by several degrees in some harvested headwater reaches but were unchanged in others and downstream of harvested areas. Riparian shade in many reaches recovered rapidly as a result of low-growing herbaceous vegetation. Suspended sediment loads increased following harvest but returned to background levels within a year. Nitrate concentrations in stream water were very low but increased by roughly an order of magnitude following post-harvest burning. There was generally no change in the macroinvertebrate community structure resulting from timber harvest. Fish occurrences increased slightly and were found to expand upwards in the stream network following harvest, possibly as a result of increased flows and/or food abundance.

Density and regeneration of *Carapa guianensis* Aublet. in floodplain forests of the Amazon estuary in Amapá State, Brazil. Lira-Guedes, A., Guedes, M.C. (*EMBRAPA, Brazil; ana.lira@embrapa.br; marcelino.guedes@embrapa.br*), Pinto, E. R. (*Federal University of Amapá, Brazil; pemanuelle@yahoo.com.br*).

Carapa guianensis Aublet. is an important species of multiple use in Amazon. Besides the timber, considered noble, its seeds provide oil with high medicinal and cosmetic value. In the Amazon estuary floodplains, the crabwoods were intensively exploited. We compared the density (DBH≥10 cm) and regeneration (5–10 cm) of crabwoods in estuarine floodplain forests along the Amazon River (Amapá State). We conducted 100% inventory (DBH≥10 cm) in Mazagão Novo (56 ha) and the Fazendinha Protected Area (136.6 ha). We inventoried (DBH≥5 cm) 80 plots of 10 m × 25 m at each site in Mazagão Velho, Maraca, and Ajuruxi. Densities in Mazagão Novo, Fazendinha, Mazagão Velho, Maraca, and Ajuruxi were 3, 6, 6, 8, and 18 trees/ha, respectively. The lowest densities can be attributed to locations closer to urban perimeters and timber marketing centers. The sampling may overestimate the crabwood population due to its clumped distribution. The percentage of juveniles (DBH 5–10 cm) in Mazagão Velho, Maraca, and Ajuruxi were 32%, 27%, and 41%, respectively, indicating a good regeneration capacity. The Ajuruxi region, which is more isolated and located within a conservation unit (Resex Cajari), had the highest density and regeneration, demonstrating that the protected area may also have contributed to the abundance of crabwoods.

Climatic Effects on Teak Growth in Northern Thailand. Lumyai, P., Duangsathaporn, K. (*Kasetsart University, Thailand; fforpcl@ku.ac.th; fforkcd@ku.ac.th*).

The purpose of this research was to investigate the relationship between teak growth and climate data in local, regional, and global scales. The standard techniques of dendrochronological study were used to analyze 36 sample cores from Thampathai National Park. The crossdated ring width data could be extended back to 125 years (1888–2012). In Umphang Wildlife Sanctuary, a total of 35 cores from 20 trees were successfully crossdated. The crossdated ring width data could be extended back to 124 years from 1889–2012. The relationship between ring-width index and climatic data indicated the positive correlation of teak growth in Thampathai National Park with rainfall in April–May and indicated the positive correlation of teak growth in Umphang Wildlife Sanctuary with rainfall in June. Results revealed the beginning period of the rainy season which had effects on teak growth in northern Thailand. In the case of tree growth regional and global climatic relationship, the southern oscillation index (SOI) and sea surface temperature (SST) were significantly correlated with teak growth in Umphang Wildlife Sanctuary. Therefore, teak is a reliable recorder of rainfall during the beginning of the rain season and can be applied to investigate the droughts and periods of great diminution in the past.

The chain of climate change, forest fires, runoff and erosion: key processes, mitigation prospects, and information needs. MacDonald, L. (*Colorado State University, USA; lee.macdonald@colostate.edu*).

Climate change is projected to increase the number, size, and severity of wildfires. High severity fires are already a major concern in many forested areas because they can increase peak flows and erosion rates by several orders of magnitude, with resulting adverse effects on water quality and other aquatic resources. The objectives of this paper are to: (1) provide a process-based understanding of the observed increases; (2) use this understanding to help predict post-fire erosion risks, recovery rates, and the effectiveness of various post-fire mitigation treatments; and (3) identify key information needs from both a research and a management perspective. Recent studies have identified the loss of surface cover and changes in soil erodibility as the key controlling factors rather than canopy loss or post-fire increases in soil water repellency. The critical role of ground cover is supported by studies showing that mulching is the most effective treatment for reducing post-fire erosion. Rainfall intensity is the other key control, necessitating a stochastic rather than deterministic modeling approach. The most urgent research and management need is to determine how hillslope-scale changes can be aggregated and routed to the watershed outlet, as this is the key scale for resource managers.

Interaction on land use changes to hydrological characteristics of Mae Klong Head watershed, western Thailand. Marod, D., Kamyo, T. (*Kasetsart University, Thailand; dokrak.m@ku.ac.th; torlarp66@yahoo.com*), Yarnuvdhi, A. (*Center for Advanced Studies in Tropical Natural Resources, National Research University, Thailand; psdaryv@ku.ac.th*), Panuthai, S. (*Department of National Parks, Wildlife and Plant Conservation, Thailand; newsam@3bbmail.com*), Hiroshi, T. (*Forestry and Forest Products Research Institute, Japan; hirop@affrc.go.jp*).

The interaction on land use changes and hydrological characteristics was conducted at LinThin watershed, Kanchanaburi Province. Changes in forest area cover was monitored by satellite images of LANDSAT TM from three phases (1992, 2000, and 2008). The meteorological and hydrological data from 1994 to 2011 were analyzed. The hydrological data was divided into three phases based on their cyclical period, 1994–1999, 2000–2005, and 2006–2011, for detecting the response on land use changes. The results showed average annual rainfall was 1 662.6 mm, and it provided stream flow of 552 513 m^3/km^2. Potential stream flow of the watershed was 33.2% of total amount rainfall. The stream flow was a higher percentage in wet the period than dry period at 73.5% and 26.5%, respectively. The highest forest covered area found in 1992 to 2000 was about 74.2%, whereas from 2000 to 2008 it was10.6%. The annual stream flow and flow during the wet period tended to decrease from first to third phase when the forest areas increased. In contrast, flow tended to increase during the dry period, indicating that increasing forest area covered led to decrements in 5% and 1% intervals of the stream flow. It regulated flooded and water shortage during wet and dry periods.

The role of poplar plantations on biodiversity in riparian landscapes. Martín-García, J. (*University of Valladolid, Spain; jorgemg@pvs.uva.es*), Jactel, H. (*National Institute for Agricultural Research, France; herve.jactel@pierroton.inra.fr*), Diez-Casero, J. (University of Valladolid*, Spain; jdcasero@pvs.uva.es*).

In Mediterranean areas, riparian zones are particularly important for maintaining biodiversity. Nevertheless, the native vegetation in these zones has been modified or lost at an alarming rate during the last decades. The main objective of this study was to investigate the influence of poplar plantations on biodiversity in riparian zones in order to estimate the ecological implications of a substantial expansion of poplar plantations. The studies were carried out in three different taxonomic groups, including macroscopic life forms (birds and vascular plants) and microbial diversity (endophyte fungi). Towards this purpose, a wide variety of both poplar plantations and the remnant patches of natural riparian forests were surveyed. Breeding birds and vascular plants were sampled by the point-count and quadrant methods, respectively. Endophytes were identified according to sequences of the ITS region of their rDNA. These studies showed marked differences on species, structural, and functional diversity between poplar plantations and native forests. This suggests that poplar plantations should not be used as surrogates for native forests. Nevertheless, poplar plantations can still accommodate rich biodiversity, providing that suitable management is applied at local (minimizing the use of harrowing) and landscape levels (increasing the percentage of poplar plantations in relation to other crops).

Frost pocket effect results in severe canopy damage in a Mediterranean-type forest in southwestern Australia. Matusick III, G., Ruthrof, K., Brouwers, N., Hardy, G. (*Murdoch University, Australia; G.Matusick@murdoch.edu.au; K.Ruthrof@murdoch.edu.au; n.brouwers@murdoch.edu.au; g.hardy@murdoch.edu.au*).

Alterations to the frequency and intensity of extreme temperature events, predicted with climate change, pose a threat to the health forest trees in many areas of the world. Although global climate models predict Mediterranean climate regions are expected to get warmer with climate change, recent evidence suggests southwestern Australia may experience more frequent extreme cold events due to regional climate drivers. To determine the impact of extreme cold temperatures on forest vegetation in southwestern Australia, a study was initiated following the onset of frost damage in 2012. From an aerial survey, frost affected sites were found more frequently in valleys and lower to mid-slope positions compared to unaffected sites. Results from transect sampling along elevational gradients confirmed increasing tree crown damage with decreasing elevation and air temperature. Results from regression analysis suggest air temperatures reached a minimum of –2.7 °C in the zone of affected forest when the damage occurred. Dominant canopy species *Eucalyptus marginata* and *Corymbia calophylla* were both severely affected, though differences in symptomology were observed. This research confirms forest trees in Mediterranean climate regions are susceptible to severe damage from extreme cold temperatures, which could significantly impact forest health if climate change increases the frequency of cold temperature events.

Fine woody debris (FWD) and biodiversity in managed forests: effects of the spatial distribution of FWD on invertebrates, small vertebrates, fungi, and plants. McCavour, M. (*Concordia University/Université de Québec à Montréal, Canada; mccavour@gmail.com*), Messier, C. (Université du Québec en Outaouais, *Canada; ch.messier@gmail.com*).

We evaluate the role of fine woody debris (FWD) in the maintenance of biodiversity in managed high-latitude forests, with an emphasis on the effect of the spatial distribution of slash. Further, we contrast the degree of FWD aggregation in intensive management vs. varied types of natural disturbance, distinguishing between FWD used as shelter, substrate, nutrition, or (indirectly) as an enhanced source of light. Taxa examined include cryptogams, invertebrates, vertebrates, and plants. We find that, overall, the taxa most sensitive to FWD removal are fungi and plants. Aggregated FWD especially benefits shade-intolerant plants, small vertebrates, and some cryptogams, though all taxa had examples with a positive response to more evenly-dispersed slash. We propose that aggregated slash mimics the role of small canopy gaps by increasing deadwood input and soil nutrition and maintaining high light levels for extended periods. Further, this delayed canopy closure means that piles and windrows, like gaps, enhance flower and fruit production, and thus serve as crucial foraging sites for pollinators and frugivores. Concluding that FWD retention is an important element in biodiversity maintenance in industrial forests, we discuss the potential for using local natural disturbance regimes as a template for decisions on slash retention and spatial distribution.

Interspecific tree competition and functionality in tropical dry forest environments in the Alto Magdalena region, Colombia, South America. Melo Cruz, O., Rodríguez Santos, N., Fernandez Mendez, F. (*University of Tolima, Colombia; omelo@ut.edu.co; natha8902@hotmail.com; fmendez@ut.edu.co*).

This study presents findings about environmental conditions for growth and interspecific tree competition in three types of tropical dry forests in the region of Alto Magdalena (Colombia). The sample areas were located in sections of natural vegetation of forests on hillocks (bosque de Lomerío – BL), hills (bosque de colinas – BC) and riversides (bosque rivereño – BR). In each area, four monitoring plots of 0.25 ha were established. Competition was evaluated by means of crown indices and illumination by canopy openings for individuals with a DBH (diameter at breast height) of more than 5 cm. The values obtained were related to the surrounding canopy. Canopy openings were determined by means of hemispherical images and related to the values of photosynthetically active radiation recorded with a quantum radiometer (LI-191). The densest canopy was found on the BC plots with 1 134 trees/ha, whereas the BR and BL plots had 365 and 794 individuals, respectively. Vertical and lateral illumination was recorded in 55% of the individuals of the BL canopy, as compared to 39% of the BR and 70% of the BC canopies. In conclusion, it was found that the BC plots showed higher interspecific competition values than the BR and BL plots, which suggests differential management and conservation strategies for these forest covers.

Assessment of management effectiveness of six national forests in Brazil. Mendonça, S.D., Junior, L.D.C., Tetto, A., Batista, A. (*Federal University of Paraná, Brazil; dmsabina@hotmail.com; ldonizeti2@gmail.com; tetto@ufpr.br; batistaufpr@ufpr.br*).

The establishment of National Forests in the south of Brazil aimed to develop sustainable use of forest resources along with protection of Atlantic Forest remnants. Assessing the management effectiveness of these areas is as important to nature conservation as the creation of new ones. In this study, six national forests in the south of Brazil had their management efficiency assessed through WWF's Rapid Assessment and Prioritization of Protected Areas Management (RAPPAM) methodology. The most recurrent pressures and threats were invasion of alien species, hunting, and waste disposal (pollution). Weaknesses observed were low financial resources and flaws in the national protected area system, including lack of commitment and financial resources, low communication among institutions, and no national policies promoting widespread environmental education at all levels. Other weaknesses in the system were: lack of revision of the system (probably due to its incipiency) and no assessment of the historical range of variability of ecosystem types in the region. According to RAPPAM parameters, the national forests assessed displayed high efficiency (64%). Despite the good overall results shown by the areas, the assessment brings to light the challenges that should be faced by the present political system in order to achieve better conservation standards.

Knowing the past to anticipate the future: soil charcoal as a proxy to model the evolution of tropical forests. Morin-Rivat, J., Biwolé, A., Bourland, N., Dainou, K., Fayolle, A. (*University of Liège – Gembloux Agro-Bio Tech, Belgium; jmorin@doct.ulg.ac.be; achille.biwole@doct.ulg.ac.be; nils.bourland@aigx.be; kdainou@ulg.ac.be; adeline.fayolle@ulg.ac.be*), Gillet, J., Gorel, A., Hardy, O, Vleminckx, J., Doucet, J., Beeckman, H.

Tropical forests of Central Africa constitute the second most important block of moist forest of the world. However little is known about their past evolution. Indeed, determining the past specific composition of these forests could allow modeling their evolution over time and providing data about their resilience capacity facing global change. To do this, we performed a pedoanthracological analysis in the semi-deciduous forests of southeastern Cameroon. We excavated test pits in 53 plots of botanical inventory along a gradient of vegetation, quantified wood charcoals by layers of 10 cm, identified the species present in charcoals, dated the charcoals by the radiocarbon method, then built up sequences including present forest composition. Results show that repeated fire events occurred across the study area during the last 2 500 years. These disturbances are likely human-induced regarding evidence of anthropogenic activities (e.g., potsherds). Nonetheless, the past specific composition does not strongly differ from the current one except for the oldest layers related to the major dry climatic event of 2500 BP. We conclude that moist forests have a good resilience capacity regarding moderate disturbances but were and will be deeply impacted by climate change.

Water volume and sediment impacts of forest-based biomass site preparation and planting. Nettles, J. (*Weyerhaeuser Company, USA; jami.nettles@weyerhaeuser.com*), Chescheir, G. (*North Carolina State University, USA; cheschei@ncsu.edu*), Amatya, D. (*U.S. Forest Service, USA; damatya@fs.fed.us*).

To quantify the potential environmental impacts of forest-based biofuel systems, Catchlight Energy LLC, a Chevron|Weyerhaeuser joint venture, established a study of the sustainability of biomass cultivation in managed forests, with soil productivity, carbon life cycle, biodiversity, and water resource components. The water resource component is being conducted primarily on three sets of forested watersheds in North Carolina, Mississippi, and Alabama. Each sub-watershed (10–30 ha) is instrumented to provide data on precipitation, stream discharge, weather, groundwater table, and water quality. In addition to these long-term watershed studies, smaller scale plots are installed in Lenoir County, NC. Biomass treatments were applied to the large watershed studies in 2012–2013. These treatments represent a range of operational intensities, from traditional pine plantation management, to intercropping,

to switchgrass only plantings. The sites also span a range of operability, from coastal North Carolina to the higher slopes and more erodible soils of Northern Mississippi. With data from one year post-site prep and planting at most large watershed sites, preliminary comparisons can be made between treatments and sites. This presentation is an overview of the results, focusing on hydrology and sediment impacts.

Maintenance of urban forest biodiversity of Boa Vista, North Amazon, Brazil. Neto, E.L., Pinheiro, F., Reisq, F. (*State University of Roraima, Brazil; everaldo.limaneto@gmail.com; flavia_abreu@hotmail.com; flr_77@hotmail.com*), Batista, D.B. (*Federal University of Paraná, Brazil; dbiondi@ufpr.br*).

The indiscriminate use of alien species in urban forestry can generate impacts on regional biodiversity and cultural aspects involved with species native to your area. The aim of this study was to analyze the floristic composition of the city of Boa Vista to suggest the inclusion of native species and regular local biodiversity. Census conducted inventory of trees on the sidewalks of the city of Boa Vista found the presence of 91 tree species distributed in 69 gender and 30 botanical families. Of these, nine species represent 85% of the individuals used in forestry, of which 53.5% are exotic species and 46.5% are native to Brazil. Although the number of exotic species is slightly larger than the native, one can consider that the urban trees of Boa Vista still prioritize native species. Considering that in Brazilian cities it is common for more than 70% of afforestation to be composed of exotic species, it is concluded that the results obtained in this study are very positive. Therefore, it is recommended that those responsible for planning the urban trees of Boa Vista should be encouraged to maintain or enhance the rate of species native to the city.

The role of landscape connectivity on terrestrial mammal conservation in a fragmented tropical rainforest. Nicasio, S., Benítez-Malvido, J. (*National Autonomous University of Mexico, Mexico; snicasio@cieco.unam.mx; jbenitez@cieco.unam.mx*).

The biodiversity conservation into fragmented tropical rainforests relies on multi-scale factors which affects their survival. The presence of terrestrial frugivorous mammals is key for plant diversity conservation due to their ecological functions as seed dispersers and seed predators. Landscape connectivity is pivotal for alleviating the effects of fragmentation on these mammals, whose movements between fragments are restrained by the landscape matrix. Despite its importance, the connectivity assessments have not been addressed in tropical areas. In this study, we used satellite imagery and network metrics to assess the landscape's connectivity in a frugivorous mammal community ($\geq$ 1 Kg) into a fragmented rainforest at southern Mexico. The matrix resistances were estimated through different vegetation indexes (ARVI, EVI, MI, NDVI) and the connectors strength between fragments were quantified by the methods of least-cost path and circuit theory. These connectivity models were tested with field data of the community composition. Our results showed that the patches of semiaquatic vegetation and secondary forests are key to maintaining the landscape connectivity for this mammal community. Some management guidelines for connectivity conservation within these fragmented rainforests are suggested.

Removing forest harvesting residuals: effects on biodiversity and species composition in Norwegian forests. Økland, T., Nordbakken, J., Lange, H., Røsberg, I., Kjønaas, O. (*Norwegian Forest and Landscape Institute, Norway; tonje.okland@skogoglandskap.no; jfn@skogoglandskap.no; holger.lange@skogoglandskap.no; roi@skogoglandskap.no; kjo@skogoglandskap.no*), Clarke, N., Hanssen, K.

Harvesting of forest residues (branches and tops) for bioenergy use may lead to biodiversity loss and changes in species composition in forest ground vegetation, which in turn also will affect soil properties. Short-term effects have been analyzed at two boreal sites dominated by *Picea abies* in Norway (one site in SW and one in SE). Whole tree (WTH) and stem-only (SOH) harvesting have been performed recently here. Long-term effects have been analyzed at two other experimental sites, where whole-tree thinning and stem-only thinning were performed 30–40 years ago. In each of the vegetation plots established at these sites, percentage cover of each species as well as environmental variables (topographical, soil physical, soil chemical, and tree variables) were recorded. Effects of different harvesting methods on plant biodiversity for several species groups were analyzed, as well as effects on species composition. Short-term effects seem to be considerably related to remnant residuals and to the more uneven distribution of residuals at WTH plots (due to piles of residuals left on the sites). Long-term effects of whole-tree thinning on vegetation will also be presented.

Validation of a landscape-scale habitat suitability model and map for the Oregon slender salamander. Olson, D. (*U.S. Forest Service, USA; dede.olson@oregonstate.edu*), Suzuki, N. (*University of Northern British Columbia, Canada; nobi.suzuki@gmail.com*).

Retention of forest-dependent species with small ranges and low dispersal, such as the Oregon slender salamander (*Batrachoseps wrighti*), is a challenge in a multi-use landscape inclusive of timber harvest. To aid development of species-conservation priorities for Oregon slender salamanders on the west slope of the Oregon Cascade Range on federal lands, we developed a landscape-scale habitat suitability model and projected four habitat suitability classes (low, moderately low, moderate, and high) onto a map. We field-validated the model by surveying randomly selected sites within each of the four habitat classes. We detected Oregon slender salamanders at a large proportion (76%) of sites within either the high or moderate habitat suitability class. Zero-inflated negative binomial regression analyses and 95% confidence intervals verified that significantly high nondetection rates were associated with the low habitat suitability class, whereas significantly high detection rates were associated with the moderate and high habitat suitability classes. The model correctly classified 67% of field-validation data. Our model and map are useful to define geographic areas for further development of combined conservation and timber harvest priorities.

Spatial characteristics of physicochemical parameters of a reservoir adjoined by degraded watershed forest. Oyebola, O., Akinyele, A. (*University of Ibadan, Nigeria; olusegun.oyebola@yahoo.com; akinyelejo@yahoo.co.uk*).

Asejire reservoir in southwestern Nigeria was adjoined by a degraded watershed. Spatial characteristics of its physicochemical parameters were investigated through a 2 year bi-monthly water sampling of 38 sites for mean values, variability, and limiting spatial values (LSV) of temperature, dissolved oxygen (DO), pH, alkalinity, and hardness. Percentage of sites showing LSV was

documented per parameter for seasons. The LSV sites were related with degraded watershed using Geographic information Systems technique. Range of wet and dry season values of temperature, DO, pH, Alkalinity and hardness were: 27.50±2.50-29.67±1.89 and 27.4±1.78- 30.13±2.37 °C; 4.63±0.64-7.60±0.36 and 4.23±0.61-7.97±1.84 mg/l; 7.10±0.17-7.53±0.31 and 7.10±0.61-7.88±0.24; 55.33±37.65-74.67±21.94 and 80.67±47.93-123.33±47.39 mg/l; 44.00±5.29-60.00±24.33 and 39.33±5.03-64.00±6.00 mg/l respectively. Range of percentage variability in wet and dry seasons values of temperature, DO, pH, alkalinity and hardness were: 6.37-9.09 and 6.5-7.87; 4.74-13.82 and 14.42-23.09; 2.39-4.12 and 3.05-8.59; 29.38-68.04 and 38.43-58.41; 12.02-40.55 and 9.38-12.79 respectively. LSV did not occur in pH but was observed in 52.63% sites in dry season temperature values, in wet and dry seasons DO, hardness and alkalinity with percentage sites: 7.89 and 18.42; 100 and 84.21; 13.16 and 2.63 respectively. The study implied that variation and LSV of water quality parameters characterized aquatic environment adjoining degraded watershed.

Effect of woody and shrub plants with different patch size on selected soil chemical properties in semi-arid lands. Özçelik, M., Şengönül, K., Gökbulak, F., Uygur, B. (*Istanbul University, Turkey; msaid.ozcelik@istanbul.edu.tr; sengonul@istanbul.edu.tr; fgokbulak@istanbul.edu.tr; uygurb@istanbul.edu.tr*).

The purpose of this study was to examine effects of woody and shrub plant populations with different patch sizes on soil chemistry in a semi-arid region. Study site was located in the semiarid mid-northern part of Turkey (40° 33′-40° 51′ N and 33° 17′-33°46′E). Effect of two types of plant groups woody and shrub species) with three different patch sizes (radius <4 m, 4–8 m, >8 m) were studied. Woody plant populations were mainly composed of Caucasian oak (*Quercus macranthera* Fish et Mey. *subsp. syspirensis* (C.Coch.) Menitsky.) whereas shrubs consisted of Blackthorn *(Paliurus spina-christi* Miller). In order to investigate patch size impacts, soil samples were collected from topsoils under the plant canopies and surrounding areas adjacent to plant canopies. Soil samples were analyzed for pH, electrical conductivity, organic matter, N, P, K, Mg, and Ca. Results showed that woody and shrubs populations with different patch sizes did not differ significantly in terms of their impacts on soil chemistry under the canopies and surrounding areas. Based on results of this study, these plant populations with current patch sizes can be cleared in the site preparation in land rehabilitation works if necessary due to insignificant influence on soil fertility.

Small scale distribution in ground-dwelling arthropods reveals big picture patterns. Pinzon Cortes, J., Spence, J. (*University of Alberta, Canada; jpinzon@ualberta.ca; john.spence@ualberta.ca*), Bourassa, S. (*Canadian Forest Service, Canada; sb22@ualberta.ca*), He, F. (*University of Alberta, Canada; fangliang.he@ualberta.ca*).

Spatial distribution of species over large areas is of great interest for forest managers and conservationists. Consequently, increasing research efforts have been applied to understand factors that determine and influence large-scale patterns. Patterns at the small scale are less studied, but we hold that they are equally important to conservation of biodiversity. We address this issue by studying relationships between local distributions of ground-dwelling arthropods and those of understory and overstory layers of the forest within a 1-ha permanent plot of never-cut forest in central Alberta (Canada). All stems (alive and dead) greater than 5 cm in diameter at breast height were mapped within the plot using a total station, and species identities were recorded. Percent cover by species of understory vegetation were also recorded, and epigaeic arthropod samples were collected from the ground using evenly spaced pitfall traps. Results show that microhabitat variation at a small spatial scale has an important influence in determining the distribution of highly mobile organisms such as spiders and carabid beetles, and through other work, we know that such variation is homogenized with prevailing forest practices. Biodiversity depends on such variation, and only through understanding it will we be able to conserve it.

Structure and floristic composition of the cloud forest on Cocos Island National Park. Porras Jiménez, M., Acosta Vargas, L., Castillo Ugalde, M., Quesada Monge, R. (*Costa Rica Institute of Technology (ITCR), Costa Rica; mapjcr82@gmail.com; lacosta@itcr.ac.cr; mcastillo@itcr.ac.cr; rquesada@itcr.ac.cr*).

During 2012, in Cocos Island National Park, six permanent sample plots of 2 500 m^2 were established near the hills of Yglesias and Pelón (630 and 560 musl) where humidity and cloudiness favor a type of plant association considered the cloud forest, and at lower altitudes between 300 and 630 musl. Total height, position, cup-shaped of lianas were measured for all individuals with a diameter greater than 5 cm at 1.3 m above ground. Sixteen plant species were found of which five were endemic. Species diversity relative to the vertical structure decreased from 14 in the lower canopy to 5 in the canopy. *Sacoglottis holdridgei* is the only species with continuous horizontal and vertical distribution. The abundance was 1653 ± 80 tree/ha. *Cyathea alfonsiana* was densest (1202 tree/ha) in the first diameter class. The basal area was 21.53 ± 0.74 m^2/ha, with 23% corresponding to C. *alfonsiana* and 62.5% corresponding to *S. holdridgei*. Both importance value indices of some species, such as the diversity indices showed significant differences compared to the altitude. The behavior of the species, altitude, and climatic conditions of the site allow estimation of the structural dynamics and composition of these populations as an indicator of climate change effects.

Does biodiversity make a difference? evolutionary diversity indicators of forest ecosystem function across broad regions. Potter, K. (*North Carolina State University, USA; kpotter@ncsu.edu*), Woodall, C. (*U.S. Forest Service, USA; cwoodall@fs.fed.us*).

Biodiversity conveys numerous functional benefits to forested ecosystems, including community stability and resilience. Biodiversity metrics that account for evolutionary relationships among species may be better surrogates for functional diversity than traditional measures such as species richness. We conducted two broad-scale studies that applied measures of evolutionary diversity to assess forest function. In one, we assessed trends in live aboveground tree biomass (LAGB) in relation to tree biodiversity calculated on 79 000 Forest Inventory and Analysis plots across the United States, controlling for site productivity and live tree stocking. We found that biodiversity was more closely associated with greater LAGB on low-productivity sites with low tree stocking. This is consistent with the expectation that the coexistence of functionally different species increases forest productivity in less productive and more stressful environments, while dominant and highly productive species are able

to competitively dominate in more productive habitats. In a second study, we tracked regional changes in forest community biodiversity separately for trees and seedlings on FIA plots across broad regions of the eastern United States. We detected broad-scale patterns of forest evolutionary diversity change that are consistent with expected early effects of climate change. Such changes could alter the ecological functions of forest communities.

Ecological role of forests fragments in Antananarivo urban area. Rabenilalana, F., Rakoto Ratsimba, H., Ratovoson, A., Rakoto Ratsimba, P. (*University of Antananarivo, Madagascar; rmihajamanana@yahoo.fr; rrharifidy@moov.mg; rainanavale@yahoo.fr; percyyvon@gmail.com*), Bogaert, J. (*University of Liège/Gembloux Agro-Bio Tech, Belgium; j.bogaert@ulg.ac.be*).

Most of natural evergreen type vegetation in the central plateau has been cleared and modified by anthropogenic activities. Some large blocks still persist and the most important are located at Ambohitantely and Mandraka areas. These forests are the remnants of the center Ecoregion forest ecosystem, and they still have a wide range of biodiversity which plays a crucial role for urban areas. The setting up of a protected areas system does not prevent some types of threats and pressures on these ecosystems. This research analyzes the temporal and spatial variability of fragments in these blocks of forests and their impacts on biodiversity. LANDSAT satellite images have been used to study the evolution and the intensity of the fragmentation during the last thirty years. Biological data on the fauna and flora have also been assessed. The results show that the process of fragmentation is increasing and is linked to anthropogenic pressures growing in the study area. These spatial data will serve as the basis for decision makers and to the local communities in order to implement new initiatives of forest restoration for biodiversity conservation.

Can capturing global ecosystem service values reduce poverty? Ramamonjisoa, B. (*University of Antananarivo, Madagascar; bruno.ramamonjisoa@gmail.com*), Gordon Jones, J. (*Bangor University, United Kingdom; julia.jones@bangor.ac.uk*), Schreckenberg, K. (*University of Southampton, United Kingdom; k.schreckenberg@soton.ac.uk*), Ranjatson, J. (*University of Antananarivo, Madagascar; pranjatson@yahoo.fr*).

There has been a recent explosion of interest in market mechanisms to capture global ecosystem service values. An argument in their favor is that they can, in principle, benefit the poor by increasing the value of their resources. However, the effect on poverty is not easily predicted and depends on the structure and distribution of payments and how land-use changes driven by the payments influence the supply of locally important ecosystem services and livelihood options to poor people. How can international ecosystem service payment schemes (specifically for carbon sequestration/storage and biodiversity conservation) most effectively reduce poverty in low income countries, given biophysical, economic, and political realities? There have been few, if any, detailed multi-dimensional assessments of either existing programs or the conditions needed for optimal program design. We focus on a single ecosystem (tropical forest) in a single low income country (Madagascar) to achieve a uniquely complete analysis. Links to global structures involved in developing international payment for ecosystem services schemes (PES) ensure the results will be influential over a wider scale. Welfare impacts on the poor will be different under the major land-use changes which international payments are incentivizing. They also vary in their potential for producing global benefits.

Building resilience from the bottom up: the soil's role in regulating forest health in British Columbia, Canada. Reid, A. (*University of British Columbia, Canada; anyamartinareid@gmail.com*).

In British Columbia and the United States, forest pests kill approximately 25% of the annual allowable cut. Soil microbial and physiochemical properties can regulate damaging insects and pathogens. For example, soil acidification creates conditions more favorable for *Phytophthora ramorum,* the fungal pathogen that causes sudden oak death, and saprotrophic fungi can directly compete with the pathogenic root disease *Armillaria*. This common agricultural concept is gaining recognition in forest health research. The objective of this study was to determine soil properties that influence patterns of forest health in six long-term soil productivity (LTSP) sites established 15 to 20 years ago. Forest health was quantified by visual ground surveys, near infrared aerial imagery, and hemi-view photos. Pyrosequencing of the soil microbial community and standard physiochemical measurements also took place. Conventional and whole tree harvesting increased the abundance of soil pathogenic fungi by 45% and 47%, respectively. Whole tree harvesting created a 7% increase in poor or moribund trees compared to conventional harvesting. The abundance of soil pathogenic fungi is positively correlated to the number of poor or moribund trees (r=0.62). Further results linking forest health and soil properties pertinent to forest management policy and practices will be presented and discussed.

Insect plant relationships and the role of insects in mangrove conservation. Remadevi, O.K., Chatterjee, D., Mangala, N. (*Institute of Wood Science And Technology, India; okremadevi@gmail.com; yuv.jyoti@gmail.com; mangala_n2000@rediffmail.com*).

Mangroves in the west coast of India are fast being deleting due to manifold reasons, both natural and anthropogenic. Studies were conducted to investigate the insect-plant relationships and the role played by them in mangrove health and conservation. The interactions of insects with the mangroves as defoliators, woodborers, fruit feeders, parasites, predators, and pollinators were studied. A total of 625 species of insects belonging to 252 families of 15 orders were documented, and 282 insects could be identified up to genus/species level. Coleoptera, Diptera, Hemiptera, Hymenoptera, and Lepidoptera constituted the major groups in the collection. A total of 141 species of herbivorous insects were documented from the study. The leaf damage inflicted by different folivorous insects in three major mangrove species, namely *Avicennia officinalis, Rhizophora mucronata* and *Sonneratia alba,* was assessed using digital leaf area analysis, and it was found to vary from 0.5% to 16.11%. Diversity of flower-visiting insects and their visitation dynamics in six mangrove species, *Rhizophora mucronata, Avicennia officinalis, A.marina, A.alba, Sonneratia caseolaris* and *S. alba*, were studied in detail for documentation of major pollinators and their role in fruit setting. This study highlighted some of the most fascinating relationships of insects and plants in the mangrove ecosystem.

Relevance of LIDAR canopy and relief indicators in the assessment of spatial distributions of soil water resources under forest stands. Ridremont, F. (*University of Liège Gembloux-Agro-Bio Tech Belgium; francois.ridremont@ulg.ac.be*).

Water resources constitute one of the most decisive factors of the adaptation of forest ecosystems facing climate changes. The assessment of soil water resources should then lead to better determine forest sites vulnerability to water stress and to provide appropriate management recommendations. This study aimed to evaluate the relevance of canopy and relief indicators in the assessment of spatial distributions of soil water resources under forest stands (Belgium Ardenne Ecoregion, Houille watershed). The estimation of spatial and profile distributions of water resources were based on multi-year monitoring of real time soil moisture content (subsurface (15 cm) and profile (≤ 70 cm)) using TDR technology on 32 local sites. Additional laboratory analyses were conducted to determine soil properties influencing soil water content. The identification of canopy and terrain attributes able to explain the spatial distribution of soil moisture was derived from a LIDAR dataset and forest inventory. It is expected that the results could lead to the development of operational tools to ensure the forest site has tree species adequate to increasing the resilience of the forest ecosystems to ecological drifts.

Relevance of pedotopographical indicators in the assessment of spatial distributions of soil depth and soil water resources under forest stands. Ridremont, F. (*University of Liège Gembloux-Agro-Bio Tech, Belgium; francois.ridremont@ulg.ac.be*).

Water resources constitute one of the most decisive factors of the adaptation of forest ecosystems facing climate change. The assessment of soil water resources should then lead to better determining the vulnerability of forest sites to water stress and to provide appropriate management recommendations. This study aimed to evaluate the relevance of pedotopographical indicators in the assessment of spatial distributions of soil depth and soil water-holding capacity under forest stands (Belgium Ardenne ecoregion). Two factors that directly impact soil water content, soil depth and stoniness, were investigated in contrasting topographic conditions by: *(i)* two traditional and destructive methods (32 soil pits and 160 holes with auger soil); and *(ii)* an electromagnetic and non-intrusive method (5 120 m of ground penetrating radar traces with 200 and 500 MHz antennas). Additional laboratory analyses were conducted to determine soil properties influencing soil water content. The identification of terrain attributes able to explain the distribution of soil depth, and therefore of soil water-holding capacity, was derived from Digital Elevation Model from LIDAR. It is expected that the results could lead to the development of operational tools to ensure there are adequate tree species for the forest site in order to increase resilience of forest ecosystems to ecological drifts.

Influences of meteorological variables on the diametric growth of *Araucaria angustifolia* (Bertol.) O. Kuntze in Southern Brazilian Highlands. Rodrigues, A.L., Sanquetta, C., Corte, A.D., Mognon, F., Barreto, T., Behling, A. (*Federal University of Paraná, Brazil; alourencorodrigues@gmail.com; carlos_sanquetta@hotmail.com; anapaulacorte@gmail.com; mognonf@gmail.com; tauanebiologia@gmail.com; alexandre.behling@yahoo.com.br*).

Araucaria angustifolia (Bertol.) O. Kuntze (Araucariaceae), popularly known as *Araucaria*, is a neotropical gymnosperm widely distributed in the Southern Brazilian highlands. This research evaluated the diametric growth of *Araucaria* based on observations from eight permanent sample plots inventoried during 14 years (2000–2013) and its relation to meteorological data. Results indicated that growth is favored by elevated temperatures in April and May, possibly due to the extension of the growth season. Relative humidity in August was positively correlated with growth as well, and may be attributed to the growth restart and demands for water availability. On the other hand, positive anomalies in January temperatures had an adverse effect on *Araucaria* diametric growth, indicating stress development in abnormally hot temperatures, since this month has been found to be the hottest in the year in accordance with the historical series. Based on the meteorological annual averages, it was noticed that the number of rainy days in the year has a positive effect on tree growth. Such results reinforce the dependence of *Araucaria angustifolia* on a humid (ombrophilous) climate with mild temperatures, raising concerns on the species behavior under global warming scenarios.

Ecophysiology of seedling banks of tree species in contrasting environments of tropical rainforests in the Columbian Chocó Bioregion. Rodríguez Santos, N., Melo Cruz, O., Villanueva, B. (*University of Tolima, Colombia; natha8902@hotmail.com; omelo@ut.edu.co; bsvillanuevat@ut.edu.co*).

This paper studies environmental characteristics of seedling banks of the species *Roucheria monsalveae*, *Vochysia ferruginea,* and *Cespedesia macrophylla* in contrasting light regimes in tropical rainforests of the Bajo Calima region in the Columbian Chocó Bioregion. Precipitation in this region exceeds 7 000 mm/year, which makes it one of the rainiest regions on earth and one of the richest in biodiversity. The trees are commercially used by the local community of African descent, which has affected natural tree populations and threatened the sustainability of the resource. The first species generates seedling banks in environments with a photosynthetically active radiation (PAR) of 20%, the second one grows under a canopy of a PAR of nearly 12%, and the third one regenerates in forest clearings with a radiation higher than 65%. The density of seedling banks amounted to 135, 28, and 253 seedlings/m^2, respectively. *R. monsalveae* establishes its seedling bank under the canopy of the seed tree. *V. ferruginea* establishes its seedling bank in an area around the seed tree that is 3.5 times larger than the canopy area. *C. macrophylla* establishes its seed bank in forest clearings independent of the distance to the seed tree. These results facilitate the development of strategies for the management of natural regeneration of the species with a view to resource recovery.

Forest vs. oil palm: the differences in plant water use. Röll, A., Hardanto, A., Furong, N., Hoelscher, D., Hanf, A. (*Tropical Silviculture and Forest Ecology, Germany; aroell@gwdg.de; ahardan@gwdg.de; nfurong@gwdg.de; dhoelsc@gwdg.de; ahanf@gwdg.de*), Junedi, H, Yanto, H.

Tropical rain forests are being converted to oil palm plantations at large scales. We asked how forests and oil palm plantations differ in water use for transpiration. We studied eight remnant forest plots, eight oil palm plantations (8–12 years old), and an age sequence of oil palm plantations ranging from 2 to 22 years in lowland Sumatra, Indonesia. In the forest, we used thermal dissipation probes (TDP) in the stems of 8 to10 trees per plot and also analyzed vertical profiles of sap flux density. In oil palm, TDP sensors were installed in the leaf petioles, typically on four petioles per palm and four palms per plot. A specific calibration for oil palm leaf petioles was established. The derived daily transpiration rates showed higher maxima and higher temporal

variability in rainforest than in oil palm. Oil palm transpiration increased 15-fold between 1 and 16 years of age and then leveled off in older plantations (up to 22 years). Thus, landscape-level variability in transpiration is introduced by the age-class structure of oil palm plantations.

Historic forest fires as influenced by climate, vegetation, and man in boreal Scandinavia. Rolstad, J., Storaunet, K., Blanck, Y. (*Norwegian Forest and Landscape Institute, Norway; jorund.rolstad@skogoglandskap.no; stk@skogoglandskap.no; ylb@skogoglandskap.no*).

Knowing the variability in historic fire regimes is pivotal to succeed in predicting what may happen in the future. By cross-dating 745 fire-scars in 378 remnant Scots pines, we delineated the spatial and temporal pattern of 253 forest fires during the past 700 years in a 74 km^2 section of Trillemarka Nature Reserve in south central Norway. Their size, numbers, and frequency were compared with historic climate proxies, vegetation maps, and written sources. We found a strong anthropogenic signal from 1625 onwards, revealed by a sudden increase in early-season fires and a shift towards more frequent and smaller fires. Summer temperature was a prime driver of the occurrence and size of late-season fires, but not early-season fires, which presumably were man-made. Pre-1625 fire rotation averaged 236 years, presumably reflecting a natural regime. Spruce forests burned less often (rotation 250–1000 years) than pine forests (150–300 years). Anthropogenic use of fire peaked during 1600–1700s (rotation 50 years) but ceased after 1800. The last 200 years have been almost fire free, mostly due to increased fire control, but possibly also due to an increasing dominance of spruce and an efficient removal of coarse woody debris. Possible future scenarios will be discussed.

Effectiveness of compensation for habitat loss at intensified forestry by creation of dead wood. Rudolphi, J., Ranius, T., Caruso, A., Mats, J. (*Swedish University of Agricultural Sciences, Sweden; jorgen.rudolphi@slu.se; thomas.ranius@slu.se; alexandro.caruso@slu.se; mats.jonsell@slu.se*), Artti, J. (*Finnish Forest Research Institute, Finland; artti.juutinen@metla.fi*), Thor, G. (*Swedish University of Agricultural Sciences, Sweden; goran.thor@slu.se*).

Negative consequences of human activities for biodiversity may be mitigated by compensation measures. The interest in applying compensation measures is generally increasing, although rarely applied in forestry. Many boreal forests are managed by clear felling for timber and pulp production. There is an increasing interest in intensifying forestry by also harvesting slash and stumps for biofuel. We evaluated the efficiency of combining intensified forestry production with compensation measures, by estimating the net revenue from slash and stump harvest, the cost of high stump creation, and simulating habitat availability for 680 bark- and wood-living species under different scenarios of biofuel harvest and compensation. We show that harvest of slash and stumps has a clear negative effect on the habitat amount available for many species, especially fungi and beetles. Combining slash harvesting with creation of high stumps results in an economic surplus and provides significantly more habitat in comparison with no slash harvesting and no high stump creation. When undertaking stump harvesting it is currently impossible to achieve such positive effects. Our analyses show that compensation can be a useful tool when both economic and biodiversity goals must be achieved in forestry, but under certain circumstances it is a better alternative to avoid the activity that causes the negative effects.

Drought-induced canopy collapse triggers increased fuel loadings: implications for fire behaviour in a Mediterranean-type eucalyptus forest. Ruthrof, K., Fontaine, J., Hardy, G (*Murdoch University, Australia; K.Ruthrof@murdoch.edu.au; J.Fontaine@murdoch.edu.au; g.hardy@murdoch.edu.au*), Matusick, G. (*The Nature Conservancy, USA; gmatusick@tnc.org*).

Drought and heat-induced forest dieback have recently been reported from a wide range of forest types globally. Flow-on effects of such dieback events and their interaction with subsequent processes is receiving increasing interest. One key impact may be elevated fine fuel loads, which drive increased intensity and severity of fire. In order to determine changes in the fuel complexes following a widespread, drought-induced canopy dieback event in the Northern Jarrah Forest (NJF), southwestern Australia, we quantified surface fine fuel loading in severely-affected and minimally-affected forest areas. Sixteen months following the dieback event, severely affected plots had significantly higher fuel loadings (1hr fuels) than areas minimally affected by the dieback event. Total fuels were greater in severely affected areas. These are expected to increase as trees fall. This study has added to the work describing the impact of drought-induced canopy dieback events by reporting changes in fuel complexes. With climate projections for many regions of the world, such as those for southwestern Australia, suggestive of increasing aridity and temperatures, it is critical that we increase our understanding of the effects of, and responses to, drought-induced canopy dieback events in forest ecosystems.

Distribution of woodland key habitats in Norwegian landscapes. Sætersdal, M., Gjerde, I., Heegard, E., Nilsen, J., Schei, F. (*Norwegian Forest and Landscape Institute, Norway; sem@skogoglandskap.no; gji@skogoglandskap.no; ehe@skogoglandskap.no; jan-erik.nilsen@skogoglandskap.no; hof@skogoglandskap.no*).

The purpose of this study was to investigate the spatial distribution of woodland key habitats in Norway. Woodland key habitats are small stands or parts of stands that contain important habitats for biodiversity. They are mapped in connection with forest planning procedures. By utilizing such maps from 10 municipalities in Norway, we asked the question as to whether there are parts of the forest landscapes that have consistently low/high densities of woodland key habitats compared to the surveyed landscape as a whole, and therefore are well suited/unsuited for timber harvesting. The analyses included kernel density estimation of three variables: altitude, distance to road, and slope. We found that woodland key habitats are (1) highly overrepresented at lower altitude; (2) slightly overrepresented at long distances from road; and (3) highly overrepresented in steep terrain. We argue that the distribution of woodland key habitats at landscape scales in Norway reflects patterns of productivity combined with patterns of historical logging. Furthermore we argue that harvesting in steep terrain, especially at low altitudes, may come at a high price, not only economically but also for biodiversity.

The influence of forest tree mixture on the potential of carbon storage in Hyrcanian forest. Salehi, M., Zahedi Amiri, G. (*University of Tehran, Iran; m.salehi89@ut.ac.ir; ghavamza@ut.ac.ir*).

Climate change is the most important environmental challenge in 21th century. Regarding the potential of carbon sequestration in soil and tree biomass, forest stands provide the main sink for atmospheric carbon dioxide. On the basis of forest potential for storing atmospheric carbon, we attempted to investigate the potential for carbon storage at the Hyrcanian Forests in Iran. The study was carried out in the Golband and Kheyroud forest districts north of Iran. The characters determined for each district were growing stock and percentage of species composition. Evaluations for average weight per ton of carbon per hectare were calculated for each tree in different forest stands. Then, based on results of the research in Iran as well as global investigation, the relationship between specific gravity and volume of each tree was studied to estimate tree biomass to calculate the carbon storage. Namkhaneh districts in the Kheyroud Forest showed the highest carbon storage (117 ton/ha) and biomass (240 ton/ha). The lowest tree biomass and carbon storage (105.5 ton/ha) were indicated in Lalis district in Golband Forest. This research showed that tree mixture and species diversity are the most important factors to be evaluated for carbon storage potential.

Dynamic forest of tree species in a fragment of Mata Atlantica rainforest. Sampaio, R., Martins, L., Engel, V.L., Nehemy, M., Rodrigues, J. (*São Paulo State University, Brazil; ritacamilasampaio@gmail.com; leonardoamartins@gmail.com; veralex@fca.unesp.br; mfnehemy@hotmail.com; rodriguesflorestal@gmail.com*).

Understanding forest fragment's demeanor, behavior, and variation is a challenge to management. The aim of this research was to investigate the dynamics of a tree community of a rainforest remnant and comprehend the trajectory of fragments in a eucalyptus landscape. The survey of woody trees was conducted in 2007 and 2013 in a fragment in areas that are flooded and not flooded in plots of 10 m x10 m, totaling 1 hectare. All trees with a diameter greater than or equal to 5 cm at breast height quantified. The samples that did not fit the inclusion criterion and were not previously identified in 2007, were evaluated and marked in 2013. The result showed that a high species richness exists. Moreover, it is believed that by increasing the sampling area, the richness will grow to complete stabilization. The survey conducted in two periods showed no difference in the richness and diversity of species. The recruitment of new individuals resulted in increased basal area. Overall, there was higher recruitment than mortality. This result demonstrated that there is a positive balance in the forest, even though at the landscape, the impact is not large enough to cause transformation in the species composition.

Weather radar: an efficient tool for forest fire detection. Saraiva, E., Batista, A., Soares, R., Tetto, A. (*Federal University of Paraná, Brazil; ernandessaraiva@gmail.com; batistaufpr@gmail.com; rvsoares@ufpr.br; tetto@ufpr.br*), Gomes, A. (*São Paulo State University, Brazil; ana@ipmet.unesp.br*).

The efficiency on forest fire control is directly related to the quickness on the event detection and localization, which significantly can minimize the potential of damages. The current technology used in weather radars has opened new venues for research, making it possible to detect small signals. The objective of this research was to use the capacity of weather radar, configured to execute tasks of high sensitivity, to monitor and detect the smoke produced by sugar cane burnings and, by similarity, forest fires. An experimental model was developed and applied to the S-band weather radar operated by the Meteorological Research Institute–UNESP, located in State of São Paulo, Brazil. All the monitored burnings were efficiently detected at time intervals varying from 2 to 9 minutes, with an average of 4.67 minutes, significantly reducing the response time of 15 minutes considered optimal for conventional detection systems. The methodology used in this study can add significant value to the information in the forest fire suppression decision-making. The results showed the efficiency of weather radar to detect smoke. Therefore, weather radars systems could be used during the dry periods when they are mostly idle, for monitoring agriculture burnings and to detect forest fires.

Characterization of fine fuels in grass-woody steppe in Paraná State, Brazil. Seger, C.D., Batista, A., Tetto, A., Soares, R., Batista, D.B. (*Federal University of Paraná, Brazil; celsoseger@terra.com.br; batistaufpr@ufpr.br; tetto@ufpr.br; rvsoares@ufpr.br; dbiondi@ufpr.br*).

The Grassland Woody Steppe is one of the phytogeographic regions of Paraná State, covering an area of approximately 20 000 km^2. Comprised mainly of fine material, it presents a high fire danger potential, especially during the winter and early spring when the vegetation is killed by frost incidence, favoring the occurrence and spread of wildland fires. Data used in the research were collected from 35 sampling plots systematically distributed over an area of 25 hectares. Fine fuels were collected in the fall, winter, spring, and summer seasons over a period of 1 year. The average fine fuel load observed was 10 985 ton/ha, a value that is within the range reported in the literature for grassland vegetation. Three classes of fuels were considered in the analysis: live, dead, and miscellaneous. Along the four seasons of the year, the percentage of dead fuels remained stable while the living fuels and miscellaneous differed significantly. The moisture content in the three fuel classes showed little variation for the live fuels, while for the other classes, statistical variations were detected. These research results will contribute to the knowledge of fuels characteristics in the Steppe region on Paraná State and could contribute to fire control actions in that vegetation type.

Evaluation of soil anti-erodibility *Eucaltptus grandis* forest land. Sheng, K., Li, Z., Zhang, W., Niu, D., Guo, X., Liu, S. (*Jiangxi Agricultural University, China; skyjxau@163.com; lizhi876@163.com; zwyjxau@163.com; ndk2157@163.com; gxmjxau@163.com; liushun89@163.com*).

Soil anti-erodibility is one of the important parameters for evaluating the ability of soil resistance to soil erosion, and based on the comprehensive investigation on soil physical and chemical properties to incorporate them into a bioindicator. By using principal component analysis, all the 16 anti-erodibility indices could be optimized to seven indices which were water-stable aggregates at size >0.5 mm and >0.25 mm, destructive rate of aggregates at size >0.25 mm, coefficient of dispersion, degree of aggregation, viscous grain powder at size 0.05 mm, and viscous grain at size <0.001 mm. Changing laws of soil anti-erodibility of different ages of *Eucalyptus grandis* are discussed and the result showed that soil anti-erodibility indexes were: annual>2-years-old>Bud annual of 4-year-old >bare land. Using soil erodibility index as the dependent variable, soil erodibility model equation in the rare earth mining area are: $y=0.309x^1 + 0.038x^2 – 0.161x^3 – 0.643x^4 + 0.491x^5 – 0.0328x^6 + 0.129x^7 + 41.637$. The equation derived factors significantly related and the model fits well. The results can provide theory basis for improving the index system of soil.

Carbon and nitrogen storage in monoculture and mixed plantation stands of nitrogen-fixing tree species in subtropical China. Shi, Z., Luo, D., Cheng, R. (*Chinese Academy of Forestry, China; shizm@caf.ac.cn; luoda2010@163.com; chengrm@caf.ac.cn*).

Three young plantation stands (a monoculture *Erythrophleum fordii*, a monoculture *Pinus massoniana*, and a mixed stand of the two species) in subtropical China were selected to assess the potential of carbon and nitrogen sequestration. The results showed that the total carbon storage of the mixed plantation stand was 137.75 Mg/ha, higher than that of monoculture stands of *E. fordii* (134.07 Mg/ha) and *P. massoniana* (131.10 Mg/ha). Nitrogen storage ranked in order of *E. fordii* (10.19 Mg/ha), the mixed plantation (8.68 Mg/ha), and *P. massoniana* stands (7.01 Mg/ha). The spatial distribution of carbon and nitrogen were identical across the plantation stands, with the majority found in the 0~100 cm soil (occupied 81.49% and 96.91% of the total, respectively), followed by aboveground biomass represented by the trees (17.52% and 2.69%, respectively), and then understory and litterfall (all less than 0.5%). The above/underground ratios of carbon and nitrogen suggested that these three plantation stands have a tremendous potential for carbon and nitrogen sequestration. The results also indicated that mixed plantation stands with a nitrogen-fixing species could provide a better silvicultural model for carbon and nitrogen sequestration in comparison to monoculture stands in this area.

Potential vegetation dynamics under climate change in a semi-arid ecosystem in the Western United States. Shrestha, R., Glenn, N., Flores, A. (*Boise State University, USA; rupeshshrestha@boisestate.edu; nancyglenn@boisestate.edu; lejoflores@boisestate.edu*).

Modeling the future composition of terrestrial ecosystems in response to coupled dynamics of climate change and disturbances such as fire relies heavily on model parameterization. Fine-scale field-based measurements can provide the necessary parameters for constraining models at a larger scale. But the time- and labor-intensive nature of field-based data collection leads to sparse sampling and significant spatial uncertainties in retrieved parameters. In this study we quantify fine-scale vegetation dynamics in the Reynolds Creek Experimental Watershed in southern Idaho, United States. We used locally downscaled climate projections to run a dynamic global vegetation model, the output of which was used to inform a state-and-transition model to assess the fine-scale vegetation dynamics under climate change scenarios. We also leverage field-measured vegetation data along with airborne LiDAR to initialize a process-based fire model to examine vegetation dynamics in response to stochastic fire events. The results will improve our understanding of fine-scale vegetation dynamics in a semi-arid ecosystem and will provide a basis for generating ensembles of spatially-explicit alternative scenarios to guide future land management decisions in this and similar regions.

Which factors can explain changes in the distribution range of *Mimusops andongensis* Hiern in Benin? Sinasson Sanni, K. (*University of Abomey-Calavi, Benin; sinasson.gisele@gmail.com*), Shackleton, C. (*Rhodes University, South Africa; c.shackleton@ru.ac.za*), Sinsin, B. (*University of Abomey-Calavi, Benin; bsinsin@gmail.com*).

Mimusops andongensis is a multipurpose species with the wood used for construction, to produce charcoal, and as firewood. Its bark, roots, and leaves are used for local healthcare needs, and fruits and bark for alimentary uses. It can be found in many African countries on different habitat types: gallery and riparian forests, forest-savannah transition zones, dense humid and semi-deciduous forests, savannah and fallows in last stages of succession. In Benin, the species can hardly be found in other natural habitats except semi-deciduous forest. Also, changes are occurring in climate and environment and may impact its distribution range. This research aims to understand specific factors which explain *M. andongensis* current distribution range and highlight factors which may impact the species ecological niche under shifts in environment. Data on the presence, morphology, and phenology of the species will be collected through forest inventory. Climatic data will be obtained from WorldClim database and soil data will be analyzed to describe the ecological characteristics of forests to be sampled. Data collection began in August 2012 and will be finalized in May 2014. Potential changes in the distribution range of *M. andongensis* will be discussed using scenarios under future climatic conditions.

Hydro-climatic variation and its interactions with landscape units in the Brazilian Pantanal, South America. Soares, M.T.S., Soriano, B.M.A., Crispim, S.A., Santos, S.A., Fernandes, F.A. (*EMBRAPA, Brazil; marcia.toffani@embrapa.br; balbina.soriano@embrapa.br; sandra.crispim@embrapa.br; sandra.santos@embrapa.br; fernando.fernandes@embrapa.br*), Wrege, M., Salis, S.M.

In the Brazilian Pantanal, one of the largest wetlands of the planet, the delicate relationship between the dynamics of water, vegetation cover, and antropic disturbance in livestock activity remains unclear. The present study aims to monitor climatic parameters and fluctuation of the water table in different landscape units, relating them with the biomass productivity of areas used for beef cattle management activity. The study is being conducted in the Nhecolândia sub-region, Pantanal, western Brazil. From March 2009 to July 2010, we monitored rainfall (mm) and the fluctuation of the water table in 10 monitoring wells distributed in the savannah woodland and open grasslands with predominance of native grasses and *Urochloa* pastures, established in place of the native forest. Productivity parameters in open grassland with predominance of *Mesosetum chaseae* were also evaluated. The natural vegetation cover interfered distinctly with the behavior of subsurface waters, whereas under forestry cover, the periods of groundwater responses to rainfall were higher. In native pasture, cumulative rainfall and groundwater level were related to increased soil cover by grasses. It is expected that the long-term monitoring of hydro and ecological relationships can generate key information to support programs for sustainable management of the cattle ranches in Pantanal wetlands.

Simulating the dependence of aspen net primary productivity on redistributed snow. Soderquist, B., Kavanagh, K. (*University of Idaho, USA; sode5734@vandals.uidaho.edu; katyk@uidaho.edu*), Seyfried, M., Winstral, A (*Agriculture Research Services, USA; mark.seyfried@ars.usda.gov; adam.winstral@ars.usda.gov*), Link, T. (*University of Idaho, USA; tlink@uidaho.edu*).

In the semi-arid mountainous regions across the western United States, the distribution of aspen (*Populus tremuloides*) is often directly related to heterogeneous soil moisture subsidies resulting from redistributed snow. With increasing temperatures, the amount and timing of snowmelt subsidies are changing, therefore future trends in aspen net primary productivity (NPP) remain

uncertain. With decades of climate and precipitation data across elevational and precipitation gradients, the Reynolds Creek Experimental Watershed (RCEW) in southwest Idaho provides a unique opportunity to study the relationship between aspen NPP and redistributed snow. NPP of three aspen stands was simulated at sites spanning elevational and precipitation gradients using a biogeochemical process model (Biome BGC) and precipitation data adjusted to account for drifting snow. Simulations coupled with soil moisture data, diurnal branch water potential, and stomatal conductance observations detail drought onset and the use of soil moisture in the rooting zone. Simulations in drought years forced by adjusted precipitation data resulted in NPP values approximately 30% higher than simulations assuming a uniform precipitation layer. These results emphasize the importance of redistributed snow in heterogeneous landscapes along with the need to account for temporal shifts in water resource availability when assessing ecosystem vulnerability to climate change.

Estimation of uncertainty for carbon emission factors by major species in Korea. Son, Y., Kim, R., Pyo, J., Kim, S., Bae, J. (*Korea Forest Research Institute, Republic of Korea; treelove@forest.go.kr; rhkim@forest.go.kr; resilviculture@forest.go.kr; cfcc@forest.go.kr; forestory@forest.go.kr*).

Carbon emissions are an important factor in inventory systems relevant to carbon in forestry, yet relatively little is known about carbon emission and removal by species. Therefore, this study was conducted to estimate the carbon emission factors in Korea and to determine uncertainty. In this study, the major species included were three species of softwoods and two species of hardwoods. To evaluate differences of the emission factor among the species, analysis of variance and duncan's multiple range test were used. Results showed that basic wood density ranged from 0.408 to 0.721, and the average of basic wood density was 0.532 g/cm^3 (the average uncertainty of 5.6%) Biomass expansion factors range from 1.335 to 1.742 and the average was 1.522 (the average uncertainty of 21.5%). Root-to-shoot ratio range from 0.258 to 0.387 and the average of root-to-shoot ratio was 0.305 (the average uncertainty of 31.2%). The results of this study on the emission factor and uncertainty of the different major species are very significant in providing accurate information for estimating the inventory system of most forests in the Republic of Korea.

Adaptive forest management: The key for forest adaptation to climate change? Spathelf, P. (*Eberswalde University for Sustainable Dvelopment (HNEE), Germany; Peter.Spathelf@hnee.de*), Bolte, H. (*Thünen Institute of Forest Ecosystems, Germany; andreas.bolte@ti.bund.de*).

Climate change is likely to increase the vulnerability of forests in Central Europe. Adaptive forest management can help forest ecosystems to adapt to these new conditions in order to achieve management goals, maintain desired forest ecosystem services, and reduce the risks of forest degradation. Forest adaptation may occur at the population level via long-term evolutionary processes or by short-term phenotypic response of individual trees. An integrative adaptive management concept is proposed that combines (i) active adaptation measures such as forest conversion with (ii) elements of forest succession (passive adaptation). A strategic co-operation of relevant institutions at the international to local level is indispensable to implement scientifically sound adaptation concepts at the stand level. Constraints are first seen in the desire to use only locally adapted tree populations by natural regeneration, which is hampering the implementation of adapted rear-edge populations via planting. Secondly, late-successional species are favored in predominating close-to-nature silviculture systems in Central Europe, which limits the possibility for early-successional drought-stress tolerant tree species to develop more resilient forests.

The spatial extent of peatland as a response to climatic and topographic factors. Stokland, J. (*The Norwegian Forest and Landscape Institute, Norway; jogeir.stokland@skogoglandskap.no*).

Open and forested peatlands are key landscape elements in boreal and mountain regions where they have accumulated peat and acted as carbon sinks for millennia. Peatlands have expanded laterally, and their total area has grown since the last glaciation. This study modeled and cross-validated the spatial extent of peatland (minimum 40 cm peat depth) based on 15 000 National Forest Inventory plots in Norway. This is a mountainous country spanning from the temperate zone in the south, through the boreal zone, to arctic-alpine zones in the north and at high altitudes. The area proportion of peatland increased from below 5% in the temperate zone to above 20% in the north boreal zone and dropped again in the alpine zone. Summer temperature was most important for peat formation followed by terrain slope, whereas precipitation was significant but less important. Highest peatland frequency (ca. 60%) occurred in flat terrain from the mid boreal to the low alpine zone. The combination of summer temperature and topography facilitated peatland occurrence in increasingly steeper terrain in cooler climates. The study will discuss expected changes in peatland distribution and carbon accumulation rates under climate change scenarios based on the quantitative relationships in the model.

Temperature and UV-B radiation affect bud phenology in *Populus tremula*. Strømme, C., Nybakken, L. (*Norwegian University of Life Sciences, Norway; christian.stromme@umb.no; line.nybakken@umb.no*).

At high latitudes, tree species commonly synchronize phenological shifts to change of seasons. Even though appropriate timing is dependent on environmental cues such as temperature and light regimes, little is known of possible climate change effects on tree performance and survival. We have investigated multifactor climate change effects on males and females of the dioecious Eurasian aspen (*Populus tremula*) through outdoor experiments in eastern Finland (established 2012) and central Norway (established 2013). Autumnal bud set and spring bud burst was be recorded in both studies. In Finland, these phenological shifts were followed in response to combinations of simulated temperature (infra-red heaters) and UV-B enhancement (UV-B tubes). In Norway, we established plots along an altitudinal gradient in a valley side. In both studies we found that increased temperature (simulated or natural along gradient) extends the growing season, resulting in delayed bud formation. Males were more responsive to temperature. In Finland, UV-B radiation was found to have an opposite effect, which was stronger in male plants. In the same study, temperature had a positive effect on bud burst in spring, while UV-B had an additional positive effect on males. Further results from autumn 2013 and spring 2014 will be included.

Floral biodiversity with special emphasis on forest dieback in Dotolugala, Knuckles Forest Range, Sri Lanka.
Suduhakuruge, B., Karunaratne, N. (*Forest Deparment, Sri Lanka; bandumala03@yahoo.com; ntpkarunaratne@gmail.com*).

The present study describes the comparative accounts of diversity, dominance of tree species, and forest dieback with altitudinal variation and climatic condition of the forest. In this study, a stratified random sampling method was used for field sampling to analyze the importance value index, alpha, beta, gamma diversity indices, and to identify the status of dieback. Collectively, 75 plant species belonging to 49 genera and 30 families were recorded. They represented 42.6% (32 species) of endemism. In dry submontane forest, the highest IVI index was recorded for *Syzygium spathulatum* Thw. While in dry montane forest, the highest IVI index was recorded for *Calophyllum cuneifolium* Thw. Four species, *Semicarpus nigro-viridis, Symplocos cochinchinensis*, *Symplocos moore,* and *psychotria* spp., were represented in all the vegetation types. In general, observations of forest dieback were mainly concentrated on the wet face of the submontane forest. Clear observations were made on the invasion of dieback areas by *Srobilanthus* sp. which hindered the natural regeneration of local species. Closely related alpha and beta diversity indices in different ecosystems revealed the equal importance of the conservation application.

Responses of vegetation activity and water balance to changing climates in a sub-alpine large-scale watershed of southeast Tibetan plateau.
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The subalpine natural and regenerated forests in West Sichuan Province of China became susceptive to climate change because warming resulted in earlier snow melting, thus accelerating the water loss in spring and decreasing growing season water availability. Based on trend analysis of normalized difference vegetation index (NDVI), we found the increased vegetation activity was due mainly to a warming trend in the subalpine region. In this study, the coupled water-carbon modeling (WASSSI-C) that has been used for ecohydrology process simulation, takes into account not only hydrological processes but also vegetation dynamics, thus examining the vegetation and water relationship in the large scale watershed. In general, the results indicated that low soil water availability in spring time has become the main constrain of subalpine forest green up and has resulted in a browning trend in most forests. However, the alpine meadow and shrub land showed greening trends that were attributed to the increasing temperature. It was concluded that warming itself and warming-resulted improvement of vegetation activity reduced annul catchment water yield. Compared with that of the regenerated forests, the natural forest-dominated watershed showed a higher runoff rate. In general, our study illuminated how the forest restoration practice affects catchment water balance under a context of changing climate.

Spatial distribution and demographic structure of the critically endangered Dipterocarpaceae in fragmented habitat in Malaysia.
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Endangered tree species are often characterized by small population sizes, limited geographic distribution, and specific habitat requirements. Many of them suffered reductions in their population sizes due to fragmentation which results in loss in genetic variation within populations. Five tree species from Dipterocarpaceae, i.e., *Dipterocarpus semivestitus*, *Vatica flavida*, *Hopea apiculata*, *Shorea hemsleyana* and *Shorea macrantha*, have been reported to have restricted distribution in the freshwater swamp forest in Perak, Malaysia. Much of the area has been developed into urban settlements leaving small fragments of isolated forests in the area. The objectives of this study are to evaluate the spatial distribution of the species and to describe how the demographic structure of the species differs between populations. All trees within the study site were mapped using a Geographic Information System (GIS). The diameter at breast height (DBH) and tree classes of all trees were recorded. The number of trees ranged from 11 to 28 individuals per species. All trees were categorized under critically endangered based on IUCN. There is a significant difference in the means of DBH among all species ($P \leq 0.05$). The findings from this study may contribute to identifying species of special concerns and determining their susceptibility to future habitat fragmentation.

Estimating uncertainty for measurements of long-term climate impacts on forested ecosystems across the Continent.
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The National Ecological Observatory Network is responsible for making automated terrestrial observations at 60 different sites across the continent for the next 30 years. Data will highlight key physical, chemical, and climate forcing, as well as associated biotic responses (e.g., CO_2, H_2O, and energy exchanges). This will help inform how biodiversity and biogeochemistry in forested ecosystems are being driven by climate change. The sheer volume of data that will be generated far exceeds that of any other observatory network or agency (> 45 Tb/year from tens of thousands of remotely deployed sensors). We address the question of how to develop and implement an ecological observatory that can accommodate such a large volume of data while maintaining high quality. Here, we describe our approach to uncertainty for large scale measurements with specific examples that focus on quality control while leveraging cyber infrastructure tools. Novel approaches to uncertainty are utilized to advance the techniques that have been historically employed in other networks (DOE-ARM, AmeriFlux, USDA ARS, OK Mesonet) to new state-of-the-art functionality. Ultimately, NEON will build upon existing frameworks of standardized uncertainty characterization to define its own operational standards for continental scale data products.

A comparative study on evapotranspiration of the same trees in urban forests and individual tree using lysimeter method.
Teshirogi, J. (*Organization for Landscape and Urban Green Infrastructure, Japan; teshirogi@urbangreen.or.jp*).

Urban forestry plays a major role in the mitigation of hot urban environments. It is essential to accurately measure the amount of evapotranspiration and the source of its effect. However, because related measurements of the change in overall weight of a standard-sized planting using a weight scale involve a total weight of 1 ton or more, with the amount of change only fluctuating on the order of several hundred grams, such measurements are extremely difficult. The author has developed a new type of weight scale able to measure the amount of evapotranspiration from a large, full-sized tree (maximum weighing capacity 3 t)

and is using the large-sized scale to carry out long-term measurements comparing the evapotranspiration of individual trees and those located in forests. For this, three test pieces were prepared, two of which used *Zelkova serrata* with heights of 7 m, DBH of 50 cm, and weights of 1.8 t. One of these was planted as an individual tree specimen and the other within a forest, while the third test piece was intended only for measurement of evaporation from the soil. Measurements of the individual tree specimen in a temperate region of Japan during the summer season showed a maximum evapotranspiration of 44.6 kg within a 12-hour daytime period.

Forest planners' perception of future landscape trajectories: case study in a French forested mountainous region. Thierion, V., Luque, S., Parmentier, C., Marechal, D., Cordonnier, T. (*National Research Institute of Science and Technology for Environment and Agriculture, France; vincent.thierion@irstea.fr; sandra.luque@irstea.fr; clement.parmentier@irstea.fr; denis.marechal@irstea.fr; thomas.cordonnier@irstea.fr*).

Land use change has been one of the major influences on the French forests and wooded landscapes over the last 50 years, with the future likely to be affected through changes in climate and social and economic pressures. This poses forest planners and policy makers with a difficult task: how to make decisions that affect the future delivery of ecosystem services when faced by rapid land covers changes issues? One approach is to consider how a range of futures may unfold and stimulate interdisciplinary debate about land cover changes scenarios. This work, funded by EU FP7 OpenNess and ANR Systerra FORGECO project, experiments with this strategy in the Quatre Montagnes massif (French Alps) considered as a forested hot spo" of biodiversity for Europe and also part of a LTER (Long Term Ecological Research Network) worldwide network. This research employed Dinamica EGO software, a spatial-explicit simulation model, parameterized with knowledge on past landscape trajectories (work presented at IUFRO Landscape Ecology Conference in 2012), biophysical variables, and socio-economic conditions. Landscape trajectories revealed by this model confirm past trends including closure of pasture and farmland areas and increasing artificial areas in the valley. How will planners react to those incoming issues, especially for biodiversity conservation?

Impact of whole-tree harvesting on water quality and quantity from drained peatland forests in Finland. Ukonmaanaho, L. (*Finnish Forest Research Institute, Finland; liisa.ukonmaanaho@metla.fi*), Starr, M. (*University of Helsinki, Finland; mike.starr@helsinki.fi*), Kantola, M., Nieminen, M., Piispanen, J. (*Finnish Forest Research Institute Finland; marjatta.kantola@metla.fi; mika.nieminen@metla.fi; juha.piispanen@metla.fi*), Ari, L., Heikkinen, J., Pietilä, H., Perämäki, P., Loukola-Ruskeeniemi, K., Nieminen, T.

Increasing demand for production of bioenergy has led to an interest on the forest harvesting method which also removes logging residues (whole tree harvesting, WTH) in addition to stemwood. It is known that all forest management measures increase leaching of elements to the water courses, on the other hand. It is hypothesized that WTH might reduce nutrient leaching to waters because the amount of decomposable litter at the site essentially decreases. Our aim was to study the potential risk of harvesting drained peatland forests, both stem only (SOH) and WTH, on the mobilizing and leaching of elements to surface waters. The study has been carried out on eight drained peatland dominated catchments in Finland. Four of the catchments are underlined by felsic bedrock, four by black shale. In 2007 study plots were established. In 2009, two of the catchments were clear-cut using SOH and four using WTH including stump removal. The remaining two catchments were left unharvested. Ditch water samples have been collected since 2008 during the nonfrost season. Results showed there are differences in drainage water quality and quantity after the harvesting (both WTH and SOH) as well as between the bedrock types. The changes were strongest the first 2 years after harvesting.

Arthropods and flooding affect microbial communities in dead wood. Ulyshen, M. (*U.S. Forest Service, USA; mulyshen@hotmail.com*), Diehl, S. (*Mississippi State University, USA; sdiehl@cfr.msstate.edu*).

It is well established that the abundance, richness, composition, and arrival sequence of microbes in dead wood have important implications for decay rates, nitrogen fixation, and other key processes. How these organisms are influenced by arthropod activity remains largely unknown despite a great deal of interest in both communities. We, therefore, sought to determine how excluding termites (*Reticulitermes* spp.) and other arthropods from decaying logs would affect bacterial and fungal communities after 2 years in both seasonally flooded and unflooded forests in the southeastern United States. Culturing methods and terminal restriction fragment length polymorphism (T-RFLP) were used to compare the abundance, richness, and composition of bacterial and fungal communities between logs protected or unprotected from arthropods in both forest types. For both bacteria and fungi, community composition differed significantly between protected and unprotected logs and also between forest types. In addition, arthropods appeared to significantly increase the abundance and richness of bacteria. These findings indicate that arthropods strongly affect microbial communities in decaying wood and may, as a result, alter some of the key processes mentioned above.

Species and ecosystem diversity at Sacred Mountain National Park for habitat conservation in Marawi City, Philippines. Umali, A., Pampolina, N. (*University of the Philippines Los Baños, Philippines; arthurglennumali@yahoo.com; nelsonmanguiatpampolina@yahoo.com*).

Species and ecosystem diversity at Sacred Mountain National Park in Marawi Philippines was investigated in 2011 for its conservation and sustainable development. Vascular plants, vertebrate fauna, and macro fungi were systematically sampled along elevation gradients using quadrat sampling and trapping techniques. Soil, physiography, and microclimate were analyzed, and key informants interviewed. Ecological parameters were measured and statistically assessed to determine variations among ecotypes. The sacred mountain is a secondary growth forest with varying ecotypes along elevation gradients inhabiting some 167 plant species (25 endemic; 18 threatened); 69 faunal species (34 endemic; 6 threatened; 10 rare); and 24 fungal species. Standing volume (366 m^3/ha), tree density (DBH > 10 cm = 844 trees/ha), and total biomass (312.94 Mg/ha) were comparable to tropical logged forests. Biodiversity was high ($p < 0.05$) at middle elevations but lower in all other gradients and was correlated ($p < 0.05$) to environmental conditions, where sacredness of the mountain was outweighed by local socio-economic needs. Overall, participatory biodiversity conservation programs incorporating Islamic view are proposed to sustain habitat in SMNP.

Quantification of water related ecosystem services in watershed planning. Uygur, B., Serengil, Y. (*Istanbul University, Turkey; uygurb@istanbul.edu.tr; serengil@istanbul.edu.tr*).

Watershed systems are complex units (forests, urban, agriculture, rangeland) that provide many ecosystem services that can be classified into four groups: provisioning, regulating, cultural, and supporting such as biodiversity, water supplying, water protection, soil conservation, carbon sequestration, flood mitigation, and recreation. Besides this, throughout the years many factors like climate change and land use change have affected the ecosystem services. Land use change has especially been a threat for the ecosystem services. In other words, urbanization is a stressor in watersheds if the functionality of ecosystem services are disregarded during the landscape planning. So it's clear that ecosystem services should be in the plans for more flexibilit in urban landscapes. Defining the ecosystem services and quantifying them are the major steps to integrate these functions to the landscape plans. In this study, we aimed to define some ecosystem services in the West Mediterranean Basin and to quantify these by mapping to explain the differences between the years 1990–2000 and 2006 by using GIS. Based on these data, some implications are discussed for integrating the ecosystem services into the landscape plans.

Examining drivers of long-term trends in evapotranspiration in forested small catchments in the northeastern USA. Vadeboncoeur, M., Asbjornsen, H. (*University of New Hampshire, USA; matt.vad@unh.edu; heidi.asbjornsen@unh.edu*), Campbell, J. (*U.S. Forest Service, USA; jlcampbell@fs.fed.us*), Green, M. (*Plymouth State University, USA; mbgreen@plymouth.edu*).

A better understanding of the relationships between long-term trends in water balance and plant physiological responses to environmental drivers is necessary to better model future water stress in forests of temperate humid regions, which may be more vulnerable to drought than previously thought. Climate change scenarios project more frequent water limitation of forest productivity, in spite of modest increases in precipitation, due to less reliable precipitation timing and greater evaporative demand. We examined long-term trends and interannual variability hydrologic records 17–62 years in length from seven intensively studied, forested small watersheds from West Virginia to Maine and collected increment cores from each study site. The two longest records show significant declines of ~10% in ET over 50+ years, while shorter records show both positive and negative trends. Combining the meterological and hydrological records with annual-resolution chronologies of wood growth and C and O stable isotope ratios for the dominant tree species at each site will allow us to begin to distinguish among the various potential physical and biological drivers for these changes, which range from changes in growing season water availability, solar radiation, vapor pressure deficit, production, canopy structure, water use efficiency, atmospheric CO_2 concentration, among others.

Rainbow water and influence of terrestrial evapotranspiration on downwind rainfall patterns: emerging scientific evidence and complex geopolitics. van Noordwijk, M. (*World Agroforestry Centre (ICRAF), Indonesia; m.vannoordwijk@cgiar.org*), Gebrekirstos, A. (*ICRAF and University of Erlangen, Germany; a.gebrekirstos@cgiar.org*), Namirembe, S. (*ICRAF, Kenya; S.Namirembe@cgiar.org*), Minang, P. (*ICRAF and ASB Partnership for the Tropical Forest Margins, Kenya; a.minang@cgiar.org*), Mbow, C. (*ICRAF, Kenya; C.Mbow@cgiar.org*).

Rainbow water, atmospheric moisture derived from oceanic or terrestrial evaporation and/or transpiration, is becoming a tractable part of the hydrological cycle, preceding the rainfall, with green, blue, and grey water stages that have a longer history of quantification and policy development. While forest-climate discourse has become overly focused on carbon emissions and its macroclimatic impact, the mesoscale of hydroclimatic relations has received new impetus with availability of atmospheric moisture transport data and models. We will report on new efforts to derive isotope signals from tree rings in the Sahel that may indicate temporal shifts in oceanic versus terrestrial origins of the rainfall that was used in tree growth over the past 100 years. The geopolitical dimensions of the likely relations between East African land cover and West African rainfall are substantially different from current climate policies and discussions in the public arena.

Comparative analysis of different dead woods from old growth and managed Scots pine forests. Venugopal, P., Julkunen-Tiitto, R. (*University of Eastern Finland, Finland; venugopa@student.uef.fi; riitta.julkunen-tiitto@uef.fi*), Junninen, K. (*Metsähallitu, Natural Heritage Services, Finland; kaisa.junninen@uef.fi*), Kouki, J. (*University of Eastern Finland, Finland; jari.kouki@uef.fi*).

Boreal forests, particularly the natural old forests, are one of the most important global carbon stores. Dead wood biomass forms one of its main aboveground components. Decomposers play an important role in carbon dynamics in boreal forest. In addition to the amount of dead wood in the forest ecosystem, wood quality may be equally important to determine the success of any decomposer species. The study aims to evaluate the chemical and physical composition of different kinds of deadwoods obtained from old growth forest, including *Kelo* (very old standing dead pine) and managed Scots pine trees. The analysis was carried out using chromatography and scanning electron microscopy. The initial results indicate that the heartwood components differ considerably between the different types of deadwoods; particularly in the case of Kelo. The results show that qualitative variation in deadwood components warrants further study. It is hypothesized that substrate quality required for many highly specialized fungi living in the old growth forest may be related to the chemical and physical condition of the substrate. Such information is crucial for improving the restoration policies that are currently widely planned all over Europe.

Diversity, composition and distribution: how fire influences the shrubby understory both now and in the future. Vickers, H., Kasel, S., Duff, T., Nitschke, C. (*University of Melbourne, Australia; h.vickers2@student.unimelb.edu.au; skasel@unimelb.edu.au; tjduff@unimelb.edu.au; craign@unimelb.edu.au*).

This study examines the potential impact of past fire regimes and future climate change on the diversity, composition and distribution of woody understory species in Eucalypt dominated forests of south-eastern Australia. As a result of the 2009 Black Saturday Fires in Victoria, Australia, current policy recommends that 5% of public land be burnt each year in an effort to reduce fire hazard. An increase in fire occurrence is also predicted for this region under climate change. Consequently, the understories of forests in this region will experience changes in fire frequency and severity as a result of increased planned burns and wildfire. We hypothesized that such an alteration in fire regime will change the composition of shrubs at the stand level and their abundance and distribution at the landscape scale. Data on species composition and structure were collected from three ecosystems

(dry, damp, and wet eucalypt forests) that had experienced fire ranging from 5 to 74+ years ago. In addition, we sampled stands from the 2009 wildfire that had experienced different fire severities. This dataset was used to parameterize the LANDIS-II landscape disturbance and succession simulation model to investigate the response of understory species to climate driven changes in wildfire and planned burning regimes.

A matter of scale? predicting the distribution of shrub species at the local or landscape level using a national dataset. Vickers, H., Kasel, S., Duff, T., Nitschke, C. (*University of Melbourne, Australia; h.vickers2@student.unimelb.edu.au; skasel@unimelb.edu.au; tjduff@unimelb.edu.au; craign@unimelb.edu.au*).

As for many species the current climatic, edaphic, or structural requirements of a large number of temperate Australian shrub species is unknown. This lack of knowledge on the biophysical variables that characterize the current ranges of these species highlights an important gap that requires investigation if we are to understand the potential impacts of climate variability and change on their distribution. A national Australian dataset compiled from state herbarium and government records for 200 temperate shrub species was collated with species distributions maps and analyzed against bioclimatic variables. Field observations on stand structure, species abundance, site topography, and edaphic conditions collected from over 60 sites were combined with available broader soil, climatic, and topographic data to determine the local impacts of edaphic variables on a subset of the 200 species. This two-stage analysis was then used to model species distribution at local and landscape scales and against predicted changes in climate for the region. The study highlights the importance of considering edaphic, structural, and climatic conditions when modelling the distribution of understory species to climate variability and change.

Dynamics of physicochemical parameters during secondary succession of forest in the Cataniapo river basin, Amazonas State, Venezuela. Villa, P., Infante, J. (*Instituto Nacional de Investigaciones Agrícolas (INIA), Venezuela; villautana@gmail.com; jdinfanted@gmail.com*), Montilla, M. (*Ministry of Environment, Venezuela; mmontilla@gmail.com*).

The dynamics of secondary succession forest in Amazonas State is highly variable and depends largely on the types of disturbances. The aim of this research was to evaluate changes in the physicochemical parameters in different stages of succession. Soil samples were collected from 40 sites with different ages of succession and in primary forest at different depths: 0–10, 10–25, 25–45, 45–80, 80–100 cm. The evaluation was conducted in five successional stages: 3–4 years, 7–8 years, 11–12 years, 15–16 years, 19 to 20 years, and primary forest. Significant differences were observed in soil parameters between levels of depth and successional stages. The soil organic matter increases by forest succession, showing significant differences between the early stages in the first layer of soil (0–10 cm) which ranged from approximately 2.3% which was lower in contrast to advanced stages values of 3.09%, and 3.70% in primary forest. It is assumed that changes in the physicochemical parameters have a marked effect on plant succession.

Effects of wildfire on storm hydrographs. Wagenbrenner, J. (*Michigan Technological University, USA; jwwagenb@mtu.edu*), Robichaud, P. (*U.S. Forest Service, USA; probichaud@fs.fed.us*).

Wildfires can convert forests from areas of water storage and filtration to areas with nearly impervious bare slopes that funnel rainfall and sediment into overloaded channel networks. Some extreme changes in runoff rates have been documented, and increases in peak runoff rates of 2–3 orders of magnitude are not uncommon in the western United States. We compared hydrograph statistics for three catchments (117–227 ha) in eastern Arizona for the first three summers after a wildfire (2011–2013) to the responses from the same catchments in the unburned condition (1963–1983). In one catchment, the average post-fire time to peak runoff and storm duration was only 2% and 5% of the pre-fire values, respectively, while the peak flow rates increased by a factor of 16 after the fire. This resulted in increases in the slopes of the rising and receding limbs of the hydrographs, which were 170 and 440 times greater than the pre-fire slopes, respectively. Modeling post-fire runoff responses is challenging, and our analysis can be used for predicting post-fire responses in small catchments. These results can also be used to plan for post-fire flooding, including for emergency responses, protection of water quality, and assessment of potential ecosystem impacts.

Effects of tree species and mixture on soil C sequestration and greenhouse gases emissions in subtropical plantations. Wang, H., Liu, S. (*Chinese Academy of Forestry, China; whui1919@gmail.com; liusr@caf.ac.cn*).

Afforestation and reforestation are taking place at a large scale in southern China. There is a desperate need to carry out intensive research to build up a solid scientific knowledge for developing an updated management regime for multi-purpose plantation forestry. Indigenous broadleaf plantations are increasingly being developed as a prospective silvicultural approach for substituting coniferous plantations in subtropical China due to potential site degradation and the vulnerability of pest and disease damage. However, little knowledge is known about the effects of tree species conversion on stock and stability of soil organic carbon (SOC), and on soil-atmosphere greenhouse gases (GHGs) emissions. The relationships between biotic and abiotic factors and SOC processes were analyzed to assess the contribution of plant or soil microbes to SOC sequestration and GHGs emissions. The study revealed: (1) mixture is a better module to substitute conifer plantation, with higher SOC stock and lower GHGs emission than broadleaf monoculture; (2) future strategy needs to consider effects of tree species on chemical composition in addition to quantity of SOC; and (3) microbial-derived C compounds, rather than litter quality or a direct flux of C from recalcitrant litter materials to stable SOC pools.

Larch forest in northeastern China: carbon sink capacity and soil importance. Wang, W. (*Chinese Academy of Science, China; wangwenjie@iga.ac.cn*), Zu, Y. (*Northeast Forestry University, China; wwj225@nefu.edu.cn*), He, X. (*Chinese Academy of Sciences, China; hexingyuan@neigae.ac.cn*).

Larch is broadly distributed in the northern hemisphere, and it is the main afforestation species in NE China. Both biomass and eddy-covariance method manifested a strong C sink. The former showed 102~363 g/m^2/yr with an average 224 g/m^2/yr, while the latter showed 176~367 g/m^2/yr with an average 248 g/m^2/yr. A total of 159 chronosequence replicating sites manifested C

sequestration in surface soil (0–20 cm), but depletion was in subsoil (60–80 cm). Soil C sequestration could take 39% of total forest C sink. Larch forest C sequestration was at an expense of nutrient depletion, especially in subsoil. Linear regression analysis showed that N depletion was about 6 mg/kg/yr, and P depletion was about 3.5 mg/kg/yr. Multivariate analysis of variance showed that N and P was the most likely affected by larch growth, while K was seldom affected. Of the data, 53% showed marked changes in subsoil (40–60 cm), while this percentage decreased to 40% in all other layers. The most likely age-group for significant temporal changes was between 20–40 year and > 40 year age groups (35%), while this percentage decreased to 4% between 0–20 year and 20–40 year age groups. The long-term data in this study is important for carbon sink evaluation and highlighting the importance of soil for C capture and nutrient supply.

The reconstruction of the fire behaviors and its effects in the Melaleuca peat forest wildfire, Nakorn Sri Thamarat, Thailand. Wanthongchai, K., Kooha, P., Chairak, S. (*Kasetsart University, Thailand; fforksw@ku.ac.th; pkpforester74@gmail.com; popforest74@gmail.com*), Meesook, K. (*Department of National Park, Wildlife and Plant Conservation, Thailand; fforksw@hotmail.com*).

During the 2012 exceptional drought period in Southern Thailand (March to September), forest fires destroyed ca. 2100 ha of the Kuan Kreng peat forest, which consisted of pure stands of *Melaleuca cajuputi*. Unfortunately, fire behaviors and its effects on this forest type have never been investigated. In October 2012, therefore, five 10 m × 100 m burned plots and an adjacent five 10 m × 50 m unburned plots were set up to reconstruct fire behaviors using the fire forensic evident (i.e., fire scar, crown scorch height, and the fuels remained on site), and fire effects on *Melaleuca* mortality and growth rate of the survival trees were investigated. The result showed that fire consumed 75% of pre-burned fuel loads (54.9 t, ha). The reconstructed of the rate of fire spread, flame length, and fireline intensity were 12.5 m/min, 4.3 m, and 6 257.7 kW/m, respectively. The tree mortality was 18%, while sapling mortality reached about 74%. The correlation between mortality and fire behaviors descriptors were highly significant. The growth rate of trees that survived from burning was significantly lower (0.44 cm/yr) compared to the tree in the unburned site (0.68 cm/yr), reflecting the influence of burning on future forest structure and composition and hence the need for restoration.

Spatio-temporal distribution of rainfall at NTU Experimental Forest for climate change in central Taiwan. Wei, C. (*National Taiwan University Experimental Forest, China-Taipei; d87622005@ntu.edu.tw*).

Recent research suggests that hydro-climatic variables should be performed at the local scale rather than the global scale because they may exhibit different trends between different locations. This research aims to look at the spatio-temporal variation of rainfall at NTUEF area in central Taiwan for climate change. Eleven meteorological stations with more than 50 total years were analyzed with the intensity-duration-frequency (IDF) curve and 48 rainfall contours with different combinations of eight duration and six return periods. The result shows that: (1) Stations in higher elevation may satisfy the extreme value type 1 (EV1) distribution while those in lower elevation satisfy Log-Person Type III (LPT3) distribution. (2) The rainfall contours show that a clear rainfall center exists near Ali-Shan mountain area with longer duration and return period design storm. (3) The recent extreme rainfall events show similar rainfall patterns with 24 hr-200 yr design storm contours with the amount of rainfall increasing from north to south and east to west. (4) Annual rainfall of three stations show a slight increase while another three stations show significant decreases with 5% confidence. The results conclude that a difference exists for hydro-climatic variables for climate change at local scale, especially in mountainous forest area.

Long-term changes in climate, forest vegetation, and streamflow in the Priest River Experimental Forest, northern Idaho. Wei, L. (*University of Idaho, USA; liangwei@vandals.uidaho.edu*), Hudak, A. (*U.S. Forest Service, USA; ahudak@fs.fed.us*), Marshall, J., Link, T., Kavanagh, K. (*University of Idaho, USA; jdm@uidaho.edu; tlink@uidaho.edu; katyk@uidaho.edu*).

Changes in climate, forest vegetation, and streamflow were continuously monitored in the Priest River Experimental Forest (PREF) in northern Idaho. Streamflow was simulated using a process based hydrology model to interpret the causes for the historical increase of streamflow. PREF was established in 1911, and meteorology data has been recorded since 1911 and streamflow since 1939. Annual mean minimum daily temperature increased since the 1950s, and annual mean maximum daily temperature remained unchanged. Streamflow increased in the recorded period while annual precipitation remained unchanged. Forest inventories and remote sensing data (aero images, LiDAR, and satellite images) recorded the changes in the forest vegetation at PREF. We integrated the observations and modeling to find the causes of changes in the streamflow. The simultaneous heat and water (SHAW) model was run on the PREF. We parameterize the model with field measurements, especially the key physiology parameters for canopy conductance and forest transpiration. The model was validated with the observed streamflow and soil moisture.

Structural and compositional patterns in forest communities in the Intermountain West. Windmuller-Campione, M., Long, J. (*Utah State University, USA; marcella.campione@aggiemail.usu.edu; james.long@usu.edu*).

The interactions of changing disturbance regimes and climate change are predicted to influence forest structure, composition, and diversity, possibly creating novel forest ecosystems. The Intermountain West, USA is characterized by numerous mountain ranges, creating high mountain peaks and low intermountain basins. Multiple transects from low elevation woodlands to high elevation treelines were sampled. Sampling followed the guidelines of the U.S. Forest Service Forest Inventory and Analysis (FIA) program. Patterns of forest structure and diversity are associated with major environmental drivers. For example, as elevation increases there is a gradual increase in basal area of live and dead standing trees which peaks at approximately 2 900 m and rapidly declines. There is, also, an increase in live overstory species richness as slope increases from 15% to 25% with a decrease at greater slopes. A non-metric multidimensional scaling (NMS) ordination explains approximately 75% of variation in the data; elevation and understory vegetation cover were the two most strongly correlated variables. Increased understanding of current patterns of structure and diversity may aid in predicting future composition of novel forest communities of the Intermountain West.

Carbon flux of down woody materials in forests of the Eastern United States. Woodall, C. (*USDA Forest Service, USA; cwoodall@fs.fed.us*).

Across large-scales, the carbon (C) flux of down woody material (DWM) detrital pools has largely been simulated based on forest stand attributes (e.g., stand age and forest type). The annual change in forest DWM C stocks and other attributes (e.g., size changes) was assessed using a forest inventory in the eastern United States to provide an empirical assessment of strategic-scale DWM C flux. Using DWM inventory data from the USDA Forest Service's Forest Inventory and Analysis program, DWM C stocks were found to be relatively static across the study region but with differences among size classes serving as an inidcator of potential climate change effects. Given the complex dynamics of DWM C flux, early implementation of inventory re-measurement, and relatively low sample size, numerous future research directions are suggested.

Impacts of increasingly intensive removal of forest biomass on the biodiversity of leaf litter invertebrates. Work, T. (*Université de Québec à Montréal (UQAM), Canada; work.timothy@uqam.ca*).

Removal of forest biomass has been advocated as a renewable source of bioenergy and a mitigation strategy against climate change. Ironically, in the short term, intensive harvest of forest biomass including coarse and fine woody debris as well as stumps is likely to have significant impacts on biodiversity. We compared leaf litter invertebrates collected among jack pine stands which were: (1) stem-only harvested; (2) whole tree harvested (WTH); (3) WTH with additional removal of stumps; (4) WTH with stump removal and additional blading of organic material; and (5) uncut control stands. We identified more than 250 species (>35 000 individual arthropods) of ground beetles, rove beetles, and spiders. Stem-only harvesting and WTH and stump removal plots harbored greater total abundance than bladed sites, and assemblage composition varied as a function of intensity of biomass removal.

Changes in dimensions and zones occupied by native species of the southern rain forest in Brazil due to global climate change. Wrege, M., Sousa, V., Fritzsons, E., Soares, M.T.S., Aguiar, A. (*EMBRAPA, Brazil; marcos.wrege@embrapa.br; valderes.sousa@embrapa.br; elenice.fritzsons@embrapa.br; marcia.toffani@embrapa.br; ananda.aguiar@embrapa.br*).

The Araucaria Forest is located in southern region of Brazil and belongs to the Atlantic Forest biome. It is considered a hotspot of biodiversity and the zone has been given a high priority for conservation actions because this area has suffered rapid devastation. It has been continually exploited to give way to areas currently occupied by intensive agriculture of annual crops. These crops reap much of a grain harvest in the country but less than 6% of its original forest cover remains. These remnants are very small and fragmented, and less than 8% are larger than 100 hectares. In this work, studies were conducted to verify changes of dimensions and locations in the niches of the main species of this forest. This includes *Araucaria angustifolia*, *Mimosa scabrella,* and *Illex paraguaiensis*, using ecological niche modeling, verifying the changes in their dimensions and displacements, consistent with the future projections made by IPCC. We observed a reduction of spaces occupied by Araucaria Forest and its shift to higher altitude areas where climate change will have a smaller effect, showing the populations vulnerability of forest species in this vegetation type. It is also adversely affected. This study's findings indicated populations were significantly fragmented and their numbers were reduced due to strong anthropic pressure on the main agricultural regions of the country.

Tree species, decay class, ecosite classification, and dead wood decomposition rates in the mixedwood boreal forest of Canada. Wu, L., Bergeron, C., Lee, S., Spence, J. (*University of Alberta, Canada; linhao1@ualberta.ca; cb1@ualberta.ca; seungil1@ualberta.ca; jspence@ualberta.ca*).

Dead wood is an important component of forest ecosystems, contributing to carbon storage and forest biodiversity. This research examines the effects of tree species, decay class, and ecosite classification on dead wood decomposition rates in the boreal forest of northern Alberta (Canada). Discs were cut from white spruce, trembling aspen, and balsam poplar trees felled live in different ecosites in 2002, and these same trees were resampled as dead wood in 2013. Differences in biomass per unit volume were taken to represent decomposition rate, and these differences were related to tree species and ecosite. Five decay classes have generally been used to describe the extent of decay and are thought to be strongly correlated with dead wood density. However we found a large variation in wood density within decay classes and within single pieces of coarse woody debris. Differences in decomposition rates were also observed among ecosites and in relation to canopy closure, shrub cover, and extent of contact with the ground. This study revealed that several factors influence the decomposition rate of dead wood and, thus, such variation is important for understanding carbon budgets in boreal forest.

Community characteristics and species diversity of *Castanopsis fargesii* community in Three Gorges Reservoir area in China. Xiao, W., Xiao, W. (*Chinese Academy of Forestry, China; chengrm@yeah.net; xiaowenf@caf.ac.cn*).

Three Gorges Reservoir area is located in the sub-tropical moist region of China. The total area is about 54 000 km^2, and evergreen broadleaf forest is the zonal vegetation type. *Castanopsis fargesii* forest is one of main vegetation types. The research on the community structure and species diversity of *Castanopsis fargesii* forest will have a long-term meaning for the biodiversity conservation in the area and the regional economic development. According to the data from 18 plots, the forest was divided into three community types. The vertical structure of all community types is obvious, it could be divided into tree layer, shrub layer, and herb layer. The trend of species richness index, diversity index of different layers in all community types is shrub layer>tree layer>herb layer. Due to the strong disturbance of human activities, the trend of these indices along the altitude gradient is not obvious. At the same time, environment pollution should not be overlooked. For example, acid rain has been found in this area and affected the forest.

Short-term impact of whole tree harvest at thinning on cation dynamics in a Japanese cedar forest ecosystem. Yamada, T., Hirai, K. (*Forestry and Forest Products Research Institute, Japan; yamadan@ffpri.affrc.go.jp; hirai@ffpri.affrc.go.jp*), Takenaka, C. (*Nagoya University, Japan; chisato@agr.nagoya-u.ac.jp*), Nishizono, T., Amano, T., Kodani, E., Shibata, M., Yagihashi, T. (*Forestry and Forest Products Research Institute, Japan; nishizo@ffpri.affrc.go.jp; chisho@ffpri.affrc.go.jp; kodani@ffpri.affrc.go.jp; shibarin@ffpri.affrc.go.jp; yagihasi@ffpri.affrc.go.jp*).

The change of nutrient dynamics in a forest ecosystem by utilization of forest biomass is becoming an increasingly important topic for forest management. The harvesting of biomass, not only stems but also branches and leaves, should have large impacts on forest soils and tree growth. To evaluate the short-term impact of whole tree harvest (WTH) on forest soils, we conducted a thinning with WTH and investigated the changes of the dynamics of exchangeable base cations (BC) by using ion-exchange resin in a Japanese cedar forest, northern Japan. Efflux of BC through the forest soil at 50 cm depth was affected more by WTH than stem only harvest (SOH) 2 years after the harvest. This result indicated that the harvest of branches and leaves brought the change of nutrient dynamics in the forested ecosystem and might suggest the importance of treatment of branches and leaves for sustainable forest management.

Evaluation of broad leaf tree diversity in artificial forests at the landscape level. Yamada, Y., Kosaka, S. (*Nagoya University, Japan; yozo@agr.nagoya-u.ac.jp; kosaka.sayumi@mbox.nagoya-u.ac.jp*).

The conservation of biodiversity in forests is important for preserving the various functions of forests, ranging from ecosystem functions to timber production. In Japan, this requires the sustainable management of artificial forests, focusing on the conservation of biodiversity, because 28% of the country is covered by artificial forest. One way to achieve this goal is to increase biodiversity at the landscape level by planning the optimal distribution of compartments containing broadleaf trees. It is difficult to determine the biodiversity of artificial forests at the landscape level, as few studies have examined methods to evaluate this. This is a major problem, especially for forest managers who must conserve biodiversity. Therefore, we developed a method to evaluate biodiversity in artificial forests at the landscape level that can be used by forest managers. This method first evaluated the diversity of broad leaf trees in subcompartments using several species diversity indices, and then examined diversity at the landscape level using network indices in a geographic information system (GIS).

Dynamic variation of the rainfall infiltration in the deep soil of the drifting sand in main desert lands of China. Yang, W., Dang, H. (*Chinese Academy of Forestry, China; hzdang@sina.com; hzdang@caf.ac.cn*).

Soil moisture, the key constraint in the arid ecosystem, has become the hotspot in arid-area research and eco-restoration. However, little quantitative data on the amount of deep soil infiltration water from rainfall are available. This study measured the amount of the rainfall infiltration below 150 cm with the YWB-01 deep soil leakage recorder in four sandy lands/deserts: Mu Us sandy land, Ulan Buh desert, Tengger desert, and Badain Jaran desert. The consecutive 2-year data showed: 1) The total infiltration water in Wushen Banner sandy land can reach 508.4 mm, 58.4% of the concurrent rainfall amount, and 23.8 mm and 13.9% in Dengkou desert, but no infiltration occurred in Alxa Left Banner and Alxa Right Banner. However, the stronger the precipitation, the more infiltration recharge occurred for shifting sandy land in arid and semi-arid areas; 2) The seasonal variation of the infiltration is nearly consistent with the rainfall in the areas with plentiful rainfall; and 3) For the one-time intensified rainfall, there is a peak value of leakage after 40–55 hours of the rainfall, during which, the infiltration rate increased rapidly before the peak and decreased slowly after. The infiltration course can last about 150 h.

A quantitative analysis of hydrological variability associated with afforestation of degraded croplands in South China. Yu, P., Wang, Y., Pan, S., Xiong, W., Xu, L. (*Chinese Academy of Forestry, China; yupt@caf.ac.cn; wangyh@caf.ac.cn; apeterpan@163.com; Xiongwe@163.com; xulih@caf.ac.cn*).

The Grain for Green Project is a country-wide ecological program in China since 2002, to promote the conversion of marginal agricultural land to forest. In order to understanding the influence of this afforestation, the Guansihe Hydrological (GSH) Model was used in the Guansihe basin, South China. The model simulation showed that runoff generation after conversion to forests was strongly dependent on whether the land was initially covered by dry croplands or paddy fields. The watershed runoff generated from a rainfall event showed very little change when dry croplands were converted to forest. However, the runoff would strongly decrease when paddy fields were converted to forest. As water barriers in croplands, the effect of terraces on runoff generation depends on rainfall magnitude and antecedent moisture in fields. In paddy fields, the combined effect of terracing and afforestation on total runoff and peak flow reduction under heavy rainfall exceeds 10% and 15%, respectively. These mean that there is a living threshold for terraces due to the mechanism of saturation excess runoff in this region. It was demonstrated that afforestation and terracing has the potential to mitigate flooding in southwestern China. However the level of impact is strongly dependent on watershed characteristics.

Determination of soil carbon sequestration by using humic content in pure and mixed stands of beech in Kheyroud Forest, Iran. Zahedi Amiri, G., Azizi, N., Salehi, M., Marvie Mohadjer, M., Shirvani, A. (*University of Tehran, Iran; ghavamza@ut.ac.ir; nabi.azizi@gmail.com; m.salehi89@ut.ac.ir; mohadjer@ut.ac.ir; shirvany@ut.ac.ir*).

This study was done in two pure and mixed stands of beech in Kheyroud Forest north of Iran to determine soil carbon sequestration by using humic content. For measuring carbon content in mineral horizons, 30 profiles were dug in each stand. In organic horizons, humic and fulvic acids and carbon sequestration were determined. Percentage of carbon in various horizons in both pure and the mixed stands showed significant differences, but there were no significant differences between two stands. Among all of the horizons in terms of humic and fulvic acids in both stands, there was a significant difference, but the percentage of acids did not show significant differences in two stands. In the three organic horizons, significant differences in carbon sequestration were seen between stands. There were no significant differences in the measured parameters between the two stands which can be explained because tree composition and litter quality in both stands were similar. Another factor that may be involved is topographical conditions of the sampling sites.

The species and functional diversity variation along secondary succession of tropical lowland rain forest on Hainan Island, China. Zang, R., Bu, W., Ding, Y. (*Chinese Academy of Forestry, China; zangrung@caf.ac.cn; bws2007@163.com; ydingcaf@gmail.com*).

Recently, we used functional traits and functional diversity to greatly improve our understanding about the ecological functioning and recovery of the secondary forest. In this study, we explored functional traits and diversity along a chronosequence of

secondary forest plots ranging from 18 to 60 years since abandonment after shifting cultivation on Hainan Island of south China. We included two old-growth forest plots for comparison. Our results showed that species richness and Shannon-Weaver index increased with the process of succession. Specific leaf area, leaf nitrogen content, leaf phosphorus content, and leaf total organic carbon content decreased and leaf dry matter content, wood density, and potential maximum height increased with succession. Leaf potassium content did not show significant change with succession, however. Functional richness, functional evenness, functional dispersion, and Rao's entropy index decreased first and then increased with the process of succession. Functional divergence peaked in the 60-year-old secondary forest. Functional traits and diversity (species and functional diversity) along succession were affected by different environmental factors. The key environmental factors driving functional traits and biodiversity in 18-, 30-, and 60-year-old secondary forest and old-growth forest were pH and soil organic matter, canopy openness, soil total potassium content, and available phosphorus content, soil phosphorus content, respectively.

Short-term variability of the spring and stream water chemical composition in catchment with different antropopressure (Carpathian, Southern Poland). Żelazny, M. (*Jagiellonian University, Poland; miroslaw.zelazny@uj.edu.pl*), Małek, S. (*University of Agriculture in Krakow, Poland; rlmalek@cyf-kr.edu.pl*), Astel, A. (*Pomeranian University, Poland; astel@apsl.edu.pl*), Joanna Paulina, S., Amanda, K. (*Jagiellonian University, Poland; joanna.siwek@uj.edu.pl; amanda.kosmowska@uj.edu.pl*).

Southern Poland used to be one of the most polluted regions in the world in the period 1970–1990. Trees began to die across the Skrzyczne Massif in the Silesian Beskid region in the 1990s due to air pollution and acid rain. Forest loss affected significant parts of the ridge area of the massif. This outcome also affected water content in the region and the chemistry of springs and small streams. Daily changes in water chemistry were investigated in near-surface soil layers in order to assess the effect of environmental pollution. The concentrations of main ions and biogenic compounds were analyzed. Other parts of southern Poland were analyzed for comparative purposes including the Carpathian Foothills and Tatra National Park, both areas much less affected by human activity.

The impact of forest vegetation change on water yield in the subalpine region of southwestern China. Zhang, Y., Liu, S. (*Chinese Academy of Forestry, China; zyd@caf.ac.cn; liusr@caf.ac.cn*).

Forest harvest increases annual water yield, which is a general conclusion from paired catchment experiments in forest hydrology. However, there have been many studies suggesting that harvesting subalpine forests decreased annual water yield in Yangtze River upper reaches. In this study, meta-analysis for compiling data from many former studies was used to analyze annual water yield changes resulting from changes in vegetation in Yangtze River upper reaches. Our results showed that old dark coniferous forests have a lower annual ET and a higher annual water yield compared with shrubs, naturally regenerated forests, and spruce plantations after harvests. Water yield increased rapidly in the first 3 years after the harvest of old growth forests and returned to the original level at the 6th year but then declined continuously to a relatively lower level over a long period that corresponded to the vegetation succession into the shrubs, secondary broad-leaved forests, mixed forests, or spruce plantations. The period with a relatively lower annual water yield could sustain more than a century. We recommend that paired catchment experiment should be carried out to provide effective decision support for forest restoration and management practices in the region.

Changes in carbon density for three old-growth forests on Changbai Mountain, Northeast China. Zhou, L. (*Chinese Academy Sciences, China; zhouli930@iae.ac.cn*).

The old-growth forests on Changbai Mountain have been well protected from human activities and provide a living laboratory for studying forest carbon sequestration under natural environmental conditions. We used data from permanent plots periodically measured in 1981 and 2010 to quantify carbon densities for Korean pine-broadleaf mixed forest, coniferous forest, and Erman's birch forest on Changbai Mountain. Carbon pools were divided into tree stems, leaves, branches, coarse woody debris, tree roots, and soil. Although the mixed forest experienced minor wind damage, every forest component except for coarse woody debris experienced increases in carbon density, and the total forest carbon density increased from 233 to 317 t C/ha. The coniferous forest was severely damaged by wind, so carbon content in trees decreased, but the total forest carbon density still increased from 298 to 327 t C/ha. The birch forest gained much carbon in trees but the soil carbon pool remained relatively stable, and its total carbon density increased from 226 to 281 t C/ha. The old-growth forest was more resilient to disturbance than previously thought. The positive increases in carbon for the three old-growth forests suggest that forest landscapes on Changbai Mountain are indeed carbon sinks.

Spatial heterogeneity of soil available nutrients in black willow plantation in Gonghe Basin, Qinghai-Tibet Plateau. Zhu, Y., Jia, Z. (*Chinese Academy of Forestry, China; zhuyajuan80@gmail.com*; *jiazq@caf.ac.cn*).

Spatial heterogeneity of soil nutrients is an important characteristic in semi-arid ecosystems. After the establishment of a shrub plantation, spatial distribution of soil nutrients may affect community structure and function. In this study, soil was collected at different locations of black willow plantation on an inter-dune in Gonghe Basin (e.g. windward outside, windward under, inside, leeward under and leeward outside shelterbelt) to measure organic matter, total and available nitrogen, phosphorus and potassium content. The results indicate organic matter or total potassium was similar at different locations. Total nitrogen accumulates at the surface (0–10 cm) at windward under shelterbelt. Total phosphorus accumulates at deeper depths (20–50 cm) at windward outside shelterbelt. Available nitrogen accumulates at windward under shelterbelt or inside shelterbelt at 0–5 cm depth; at windward outside shelterbelt at 5–10 cm depth; and at windward outside or under shelterbelt at 10–20 cm depth. Available phosphorus accumulates at windward outside shelterbelt and in surface soils (0–5 cm). Available potassium accumulates in surface soils (0–5 cm) inside or at leeward under shelterbelt. Therefore, spatial heterogeneity of soil nutrients was induced by wind in black willow plantation in alpine sandy land, especially for available nitrogen and phosphorus.

GENERAL POSTER SESSIONS

IUFRO Division 9: Forest Policy and Economics

Administration and management of state and non-state forests in Romania: one law, two perspectives. Abrudan, I. (*Transilvania University of Brasov, Romania; abrudan@unitbv.ro*).

The paper assesses the post-1990 legislation regarding the administration and management of state and non-state forests in Romania and its different provisions according to forest ownership status. After three forest restitution laws and several institutional reforms undertaken in the last two decades, the present forest legislation distinguishes between the administration and management of state and non-state forests, whilst sustainable forest management is the main principle in both cases. The differences are reflected by the institutional and organisational arrangements (state forest districts versus private forest districts), supervisory and inspection procedures, and fiscal/budgetary restrictions. Some of these differences have a positive impact on the development of the non-state forest sector, but other provisions represent an undue burden on the progress of forestry in Romania.

How ideas, interests, and institutions may block or further policy integration: an evaluation of the forest and agricultural sectors in Ghana. Arts, B. (*Wageningen University, Netherlands; bas.arts@wur.nl*), Sarpong, Y. (*Kwame Nkrumah University of Science and Technology, Ghana; amosarpong@gmail.com*).

"Integrated natural resource management" (INRM) is one of the new buzzwords in the field of use, management, and conservation of natural resources (NR). But INRM is not easily realized, because NR sectors and their policies and management are often organized along the lines of rather closed sectors—or pillars—in most countries around the world. This paper analyses attempts in Ghana to achieve integration at the policy level as well as in natural resource management on the ground. The focus is on the forest and agricultural sectors, which are the two main Ghanaian NR sectors (besides oil). Hence, the authors focus on policy integration both from a horizontal perspective (issue-specific sectors) and from a vertical perspective (policy and management levels). Various programs have been established in Ghana to integrate issues at different levels of forestry and agriculture. Five recent programs were chosen for consideration in this paper: the National Forest Plantation Development Programme (NFPDP), Community Forest Management Project (CFMP), National Resources and Environmental Governance Programme (NREG), Ghana Rural and Agricultural Finance Programme (RAFiP), and Northern Region Poverty Reduction Programme (NORPREP). Since the success (or lack thereof) of these initiatives remains to be seen, the authors will analyse and evaluate these programs in this paper.

Behind the scenes—revealing true volume of wood production and markets in a developing economy: Tanzania. Arvola, A., Kanninen, M. (*University of Helsinki, Finland; anne.arvola@helsinki.fi; markku.kanninen@helsinki.fi*).

International climate change discussions and negotiations, and the Rio +20 Conference, have given a clear signal of global need and willingness to move towards a green economy and green investments. On the other hand, official global statistics show that global wood consumption per capita is decreasing rapidly. The reality at the national level is very different from the global trend in countries with rapidly growing populations and economies, such as Tanzania. Official statistics often reveal only a part of an ongoing transformation process, in which trees grown are increasingly grown on farms and small woodlots to meet the market demands for construction and fuelwood. Tree farming is still a no-man's-land because neither forest authorities nor agricultural sector authorities have interest in taking the responsibility of tree farming. This paper builds a more comprehensive picture of Tanzania tree farming and its importance in national wood markets and of the challenges and barriers tree farmers face in the absence of a supportive environment. The analysis is based on data collected from existing national records, from interviews at both the national and the farmer level, and from the National Forest Resources Monitoring and Assessment project (NAFORMA).

Deforestation causes in the Huila department of Colombia—a jurisdictional REDD+ approach. Becerra, M. (*International Forestry Students Association, Colombia; cata007201@gmail.com*).

Currently in the Huila department of Colombia, about 10 000 ha of natural forests are lost annually, a situation that has spurred a variety of organizations to consider ways to effectively deal with deforestation processes. The Corporación Autonoma Regional del Alto Magdalena (*CAM*) and ONF-Andina, with support from the Corporación Autonoma del Rio Grande de la Magdalena (CORMAGDALENA) have led the way in identifying the main causes of deforestation and degradation in the Huila region. This is the first step towards development of a jurisdictional REDD system, which in the future would allow implementation of alternatives that would mitigate these processes and would contribute to the global effort to reduce deforestation in developing countries through a REDD + program. Surveys and interviews were conducted to determine potential agents of deforestation. Results obtained from the surveys and secondary information were revised. Subsequently a workshop was held in the city of Neiva to validate the preliminary results. A final list of direct and indirect causes of deforestation was drawn up. The workshop also served as a forum to raise community awareness about the ways drivers of deforestation influence operations in the department and in the hotspots identified. Of the major results, this paper highlights those related to the expansion of specific crops and the expansion of extensive cattle ranching activities in areas of difficult access.

Interrogating safeguards for Jurisdictional REDD+: a study of overseas jurisdictional REDD+ offsets in California's Global Warming Solutions Act. Blanchard, E., Vira, B. (*University of Cambridge, UK; blanchard.libby@gmail.com; bv101@cam.ac.uk*).

In 2006, the State of California (USA) passed into law Assembly Bill 32, requiring the reduction of statewide greenhouse gas (GHG) emissions to 1990 levels by 2020. California's cap-and-trade program took effect in 2012, and in 2013, the state made its final recommendations for the incorporation of international REDD+ offsets into its cap-and-trade program. California proposes buying carbon credits from international REDD+ projects in "Partner Jurisdictions" overseas to offset its emissions, which raises

particular social and biodiversity considerations. Proponents say that these "jurisdictional REDD+" credits will keep compliance costs of affected California industries within a workable range. However, critics argue that the offsets may not reduce total GHG emissions, and that offsetting may reinforce or worsen preexisting inequalities, despite proposed safeguards. This paper examines the environmental and social safeguards that have been proposed for these jurisdictional REDD+ offsets, how monitoring of these safeguards will be enforced, and how tradeoffs between socioeconomic and conservation goals are negotiated within jurisdictional REDD+ project design and implementation. The study identifies social, economic, and environmental risk factors that may jeopardize the sustainability of these ecosystem service-based agreements, and results discuss the broader policy implications of a jurisdictional REDD+ approach to other multilateral and subnational GHG reduction initiatives.

Maintaining forestry archives for the future. Bridle, O., Petrokofsky, G. (*University of Oxford, UK; oliver.bridle@bodleian.ox.ac.uk; gillian.petrokofsky@zoo.ox.ac.uk*).

The University of Oxford has a long history of providing information services for forestry. Although collections of forestry material at Oxford have moved several times, they still provide an important and often unique archive of forestry publications spanning more than a century. This poster highlights the recent work at the Radcliffe Science Library to catalogue the contents of the Forestry Research Programme (FRP) archive. The FRP was a long-term programme of the UK government's Department for International Development (DfID), which ended in 2006 with the archives from the project subsequently deposited at the library. The archive contains extensive documentation for projects and publications produced as part of the FRP, along with relevant administrative records. In 2012 work was undertaken to organise and catalogue these archives so that they can now be found through the publically available library catalogue (SOLO) and associated online finding aids. This example demonstrates the crucial role libraries continue to play in making data and publications from forestry projects accessible to future researchers, communities and policy-makers. In an increasingly digital information world, this project also shows the importance of preserving physical collections, which are often in danger of loss or dispersal.

Forest management in the long term: participatory scenario evidence from Slovakia. Brodrechtova, Y., Navrátil, R., Sedmák, R. Tuček, J. (*Technical University in Zvolen, Slovakia; brodrechtova@tuzvo.sk; navratilr@tuzvo.sk; sedmak@tuzvo.sk; tucek@tuzvo.sk*).

Forest management is being significantly challenged by competing demands for forest ecosystem goods and services as a result of changing environmental, economic, and social conditions. The search for answers to the question of future forest-related conditions and their consequences for forest management is complex, especially in countries like Slovakia that have undergone institutional upheaval in the last 20 years. By using scenarios, foresters can imagine various futures (e.g., in 25–30 yr). Thus, a qualitative participatory scenario process was conducted with regards to forest management practices in Slovakia. Two case study areas, Podpoľanie and Kysuce, were selected as representing current trends and tensions among forestry, environmental protection, and the timber industry in Europe. Building on previous research (theoretical and empirical analysis of structural and agent-based factors), the authors conducted participatory scenario-building workshops with 13 national and local stakeholders, structural analysis, and morphological analysis. This process resulted in the elaboration of three or four exploratory scenarios for each case area. Despite Slovakia's size, the preliminary results revealed notable diversity in future drivers (e.g., bioenergy market, population, non-wood ecosystem services, codes of conduct) and subsequently in scenarios for long-term forest management.

Kaldor-Hicksim improvement study on social welfare of families in state-owned forest areas under China's logging ban. Cao, Y., Liang, Y. (*Northeast Forest University, China; yc_liang@126.com; 3262526@qq.com*).

A ban on logging has been in effect in China for 10 years. The ban was renewed in 2011 after its initial success. The objective of this research is to evaluate the effects of this ban, with a focus on the primary implementation in northeast China and Inner Mongolia. The quantitative analysis method was used to evaluate the impacts based on data from 1997, 2005, and 2009. Results indicate that the ecological effect is significant, with the value of forest carbon sequestration being twice that of the corresponding inputs of the project. Results also show that social welfare has been greatly improved even though the welfare of those families with children in school and elderly people is relatively lower than that of other groups. These families have higher monetary marginal utility. An improvement in their welfare would offset or even more than offset the cost. If a Kaldor-Hicksim improvement were made, it would enhance the overall welfare of the state-owned forest area. Substantial suggestions are also given in this paper.

Analyzing direct and underlying drivers of deforestation and forest degradation for REDD+ in Cameroon: methodology development and pilot test. Carodenuto, S., Merger, E. (*UNIQUE Forestry and Land Use, Germany; sophia.carodenuto@unique-landuse.de;eduard.merger@unique-landuse.de*), Parfait Essomba, E. (*University of Sheffield, UK; epjessombangono1@sheffield.ac.uk*).

Cameroon is currently undertaking the necessary analytical work for preparing a national REDD+ strategy. The first step in preparing this strategy is a systematic assessment of the drivers of deforestation, which provides quantitative and qualitative results that inform policy. This study proposes a methodology for assessing underlying and proximate drivers in a comprehensive framework that allows for the participation of relevant stakeholders, including national and local institutions, while following international best practices regarding technical aspects. The methodology was tested in a pilot area and received critical feedback during a 2-day national workshop. The methodology incorporates the priorities of Cameroon as outlined in its REDD+ Readiness Proposal, including the need to allow for full and effective participation of indigenous people and local communities as well as adaptation to the country's five diverse agro-ecological zones. The added value of this methodology's bottom-up approach is that it allows for a better understanding of the economic incentives, social and environmental co-benefits, and underlying causes associated with the identified deforestation and forest degradation drivers and agents. The results include forest area loss, carbon emissions, and opportunity costs associated with the drivers/deforestation agents. These elements provide crucial background information for developing REDD+ strategy options for the country.

The cost of desertification in China: a literature review. Cheng, L. (*Chinese Academy of Forestry, China; chengleilei@caf.ac.cn*), Low, P. (*Universiti Kebangsaan Malaysia, Malaysia; plow@ukm.my*), Qi, L., Gong, L. (*Chinese Academy of Forestry, China; luqi@caf.ac.cn*); *gongliyan@caf.ac.cn*).

The UN Convention to Combat Desertification (UNCCD) 2nd Scientific Conference in 2013 focused on economic assessment of desertification and its addressing policies and practices. More attention has been paid to economic assessment of desertification, which may be more helpful in designing and identifying appropriate actions for combating desertification than only physical assessment. However, so far no consensus estimate of desertification cost exists in China as well as worldwide, let alone a commonly agreed methodology. This paper reviews the key estimates of desertification cost in China in the existing literature, as well as the methodologies they based on, and the problems they were fraught with. Direct costs including land abandonment and agricultural production loss were estimated by using opportunity cost approach and change in productivity approach respectively. Indirect costs comprising siltation of rivers, reservoirs and irrigation canals and transportation loss were estimated by using replacement cost approach. The existing studies are limited by double counting between different costs, confusion of short-term costs and long-term costs, and lack of necessary adjustment of price parameters. Besides overcoming these limitations, the up-to-date information should be used and more scientific and matured assessment framework should be developed to improve the accuracy of estimate of desertification cost.

An international examination of tax and accounting rules and the impact on forest land ownership. Cushing, T. (*Clemson University, USA; tcushin@clemson.edu*).

The objective of this paper was to look at how forest landowners are taxed internationally. Landownership is changing in the United States as demographics change. Corporate strategies have evolved with the tax code as well as with a greater understanding of comparative advantages. At the same time, global trade has increased. Those trying to influence tax policy desire a better understanding of the costs of growing trees in other countries. In addition, U.S. accounting rules will be changing in 2014 to better align these rules with those of the international community. This change will have an impact on the balance sheets of U.S. forest products companies and investors. This paper examines and compares the taxation and accounting rules in countries that export wood. The focus is on understanding how these rules affect a country's competitiveness in global trade of wood.

Small-scale and community forestry: policies behind the tree-planting movement in Kuningan District, West Java, Indonesia. Damayanti, E., Prasetyo, L. (*Bogor Agricultural University, Indonesia; ellynk.damayanti@gmail.com; lbprastdp@yahoo.com*), Suharfaputra, U. (*Kuningan District Forestry and Estate Crops Office, Indonesia; suharfaputra_ukas@yahoo.com*), Sumirat, U. (*Forestry Service, Kuningan District Government, Indonesia; suharfaputra_ukas@yahoo.com; baraya_pathana@gmail.com*), Nasihin, I. (*University of Kuningan, Indonesia; e03498033@yahoo.com*), Purwadi, H. (*Kuningan District Forestry and Estate Crops Office, Indonesia; purwadi.hd@gmail.com*).

A study in Kuningan District (West Java Province) by Prasetyo, Damayanti, & Masuda (2012) showed that forest cover decreased in 1997–1999 and increased between 1999 and 2009, during Managing Forest Resources with Communities (PHBM) implementation. Reforestation was successful in PHBM villages because the people were aware of the current and future benefits of the PHBM, and people realized that the government was acknowledging the property rights of local people. Further study (Damayanti and Prasetyo, 2013) incorporated a longer period of forest cover change data (1978–2009) and a household survey of kebun and private forest owners. Results showed that people in Kuningan District enthusiastic about planting trees. Among the reasons for their interest were: modest input required for tree planting, passive management, lack of water for planting agricultural crops, and the increasing price of timber. The current study will address the policies of the Kuningan District Government in relation to land use planning, reforestation, land rehabilitation, and people's welfare, as well as local communities' perspective on the policies. Tree planting is one of the district government's programs that have been introduced on government lands (developed as botanical gardens and villages' urban forest), and it also touches every aspect of people's lives, including development of private forest.

Capacity development needs assessments for improved governance of community forestry. De Bruyn, T., Greijmans, M. (*Center for People and Forests (RECOFTC), Thailand; toon.debruyn@recoftc.org; martin.greijmans@recoftc.org*).

Community forestry is seen by many to be a credible tool for the pursuit of sustainable forest management. Successful governance in community forestry is highly dependent upon who is involved, and upon the capacity of those participants to realize rights to and responsibilities for access, use, and management of forest resources. There are many prescriptions for capacities needed for community forestry development, but a systematic approach to assess the actual needs is not available. This is underlined by the lack of research in this area. The paper will explore the pre-conditions for the identification of capacity needs, presenting and commenting on a nested approach to assess the needs. It will present a framework for this approach that reflects the experiences of practitioners that used this guideline in six countries in Asia. It will also share key findings, and give recommendations for future assessments and for the role of the assessments in developing successful governance of community forestry. The governance implications cover participation, accountability, transparency, effectiveness, efficiency, and fairness/equity of community forestry development.

Efficiency in development cooperation: the experience of the Ibero-American Model Forest Network and its Model Forests. De Camino, R. (*Red Iberoaméricana de Bosques Modelo (RIABM) – CATIE, Costa Rica; rcamino@catie.ac.cr*), Carrera, F., Villalobos, R. (*CATIE, Costa Rica; fcarrera@catie.ac.cr; rvillalo@catie.ac.cr*).

Model Forests (MF) are local social platforms created through an international initiative for the management of forest-rich territories. As a bottom-up approach, they provide good governance to territorial constituencies committed to sustainable human development. Nowadays, international resources are scarce and sometimes too donor-driven. The 25 Model Forests and 15 member countries of the Ibero-American Model Forests Network have shown resilience against the scarcity of resources as well as a very high resources multiplier. Preliminary estimates suggest that this multiplier is more than 20. After consultation with the network's secretariat, the study reviews the contributions of the member countries and of the individual Model Forests to the

operation of the system. This study shows that MFs are creative in formulating ideas and are capable of channeling local, national, and international cooperation resources, not only for local projects but also for initiatives that cover more than one country and more than one MF. Additionally, MFs receive support from national and local governments, which consider them a useful governance platform for the implementation of national natural resources policies. The paper concludes that with proper focus and will, it is possible to implement many sustainable-development initiatives benefiting forests and people, even when resources are limited.

Local team leadership for sustainable development: the case of the Model Forests of the Ibero-American Network. De Camino, R. (*Red Iberoaméricana de Bosques Modelo (RIABM) – CATIE, Costa Rica; rcamino@catie.ac.cr*), Villalobos, R., Lorenzo Lemire, J. (*CATIE, Costa Rica; rvillalo@catie.ac.cr; josique@catie.ac.cr*).

Conventional wisdom states that the success of any enterprise is linked to leadership. However, there are different types of leadership and different qualities associated with it. In relation to the sustainable development of forest-rich territories, the decisions should not be made by a single authority or individual; instead, given the complex mixture of rights and interests at the territorial scale, agreement should be reached through participatory processes. The objective of this research is to compare the principles, design elements, and enabling conditions of empowered participatory governance (EPG)—a concept introduced by A. Fung and O. Wright in 2003—by analyzing the experience of the 29 Model Forests and 15 member countries which belong to the Ibero-American Model Forest Network (RIABM). The authors identify new variables that are important in a rural/forest context and that need to be addressed in the concept of EPG; they then show how these variables operate at the Model Forest level. The key element identified is team leadership, precisely because of the complexity of the interactions and the diversity of stakeholders with their particular and sometimes conflicting interests. Examples of the meaning of "team leadership" in the praxis are given.

Identifying potential sources of conflict in different types of intervention to community land and forests. Dhiaulhaq, A., Gritten, D., De Bruyn, T., Greijmans, M., Oro, J. (*Center for People and Forests (RECOFTC), Thailand; ahmad.dhiaulhaq@recoftc.org; david.gritten@recoftc.org; toon.debruyn@recoftc.org; martin.greijmans@recoftc.org; jephraim.oro@recoftc.org*).

Conflict over land and forest management is widespread and often unavoidable due to competing interests and values. One of the most common types of conflicts is community-outsider conflict, which often takes place when external actors do interventions (e.g., plantation development) on land and forests that has been managed by the local community. To minimize the negative impacts of conflict and to inform proper approaches to conflict transformation, identification of the conflict sources is essential. This study presents an analytical framework to identify possible sources of impairment during the process of external intervention on community land and forest, which may result in conflict. The framework was developed from an extensive literature review and was tested on 14 conflicts or potential conflict sites in six Asian countries. Preliminary results show the potential relevance of the framework, for example in helping to flag issues that may lead to conflict and therefore require greater attention in the process of any external forest and land intervention. The framework can serve as a useful methodological foundation for future research on this type of conflict. The results of this study can be applied to other types of intervention such as REDD+, foreign direct investment, and protected area development.

Restoring nature: combining "new" and "old" policy instruments in Swedish forests. Eckerberg, K. (*Umeå University, Sweden; Katarina.eckerberg@pol.umu.se*), Hjälten, J. (*Swedish University of Agricultural Sciences, Sweden; joakim.hjalten@slu.se*).

Ecological restoration (ER) is seen as a means for solving many of today's environmental challenges, such as climate change mitigation/adaptation and safeguarding ecosystem services, including biodiversity and flood protection. Several political actors, including states and international organizations, such as UNEP, have declared their commitment to engage in ER. Sweden is a country dominated by forests and characterized as being one of the world's forerunners in environmental policy, but how to implement its forest-environmental policy has engendered much public controversy. Sweden thus serves as a case study for studying how "new" and "old" policy instruments for ER are combined and with what results. ER activities are taking place, both as part of the general call for "environmental considerations" in the Forestry Act, as projects within the context of several public funding programmes aiming at ecological sustainability or nature conservation, and as part of the voluntary forest certification systems of Forest Sustainability Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC), which cover more than half of Sweden's forested area. This presentation discusses the complementarity as well as the tensions between the present policy mixes, and to what extent different notions of ER are supported by the different types of instruments.

Collaborative forest governance of a community forest in western Canada: What is the role of social learning? Egunyu, F., Reed, M. (*University of Saskatchewan, Canada; felicitas.egunyu@usask.ca; mgr774@mail.usask.ca*).

Community forestry is designed to improve the livelihood of local people while protecting forestry resources through sustainable use. Community forestry is intended to be participatory in nature, providing opportunities for people to learn as they manage forestry resources. It is acknowledged and documented that social learning contributes to forest governance in both developed and developing country settings. However, there is a need to further investigate how learning occurs, what is learned, and the effect of learning on forest governance. This study investigates the contribution of social learning to forest governance in the Harrop-Proctor Community Forest in British Columbia, Canada. Semi-structured interviews of 28 community members, five key informant interviews with representatives from government and not-for-profit organizations, and two community-level focus groups were conducted in June–July 2012. Documentary evidence was also collected. Throughout the data collection period, community forestry activities were observed. Results show that most participants started engaging in community forestry with limited knowledge and learned as they participated in lobbying for the community forestry licence, doing management planning, and implementing operations. However, as the community forest became more well-established, many of the learning opportunities and outcomes became more restricted. The presentation will provide details of this apparent paradox.

Fully mobilizing forest potential in the Kyoto Process: on potential future convergence across the REDD+ and LULUCF frameworks. Ellison, D., Petersson, H., Lundblad, M. (*Swedish University of Agricultural Sciences; ellisondl@gmail.com;hans.petersson@slu.se; mattias.lundblad@slu.se*).

The principle of "Common But Differentiated Responsibilities" has dominated UNFCCC-based Kyoto climate conferences. In Durban, however, this principle gave way to calls for a 2020 legal regime that begins to dispose of the distinction between Annex I and non-Annex I states (Aldy/Stavins 2012), and all countries now submit emission reduction commitments under the new post-Kyoto framework. On the periphery of negotiations, the role of forests in the climate policy framework has been discussed in at least two distinct forums: for the developed countries, LULUCF rules have been elaborated under the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP). For the developing non-Annex I countries, Agriculture, Forestry and other Land Uses (AFOLU) and REDD+ have been discussed and developed in the framework of the Ad hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA). Convergence in Kyoto processes begs the question: Can forests also play a more meaningful role in the international climate policy framework? Key points in the development of an overarching framework concern the compatibility of rules governing forest-based carbon accounting across LULUCF and REDD+, and their inclusion in global emission trading schemes.

Multifunctional and integrated forest management in Italy: policy failures and possible solutions. Favero, M., Pettenella, D., Secco, L., Leonardi, A. (*University of Padova, Italy; matteo.favero86@gmail.com; davide.pettenella@unipd.it; laura.secco@unipd.it; alessandro.leonardi@unipd.it*).

The Italian forestry sector counts for very little in the national economy, despite the vast expanse of domestic forests. This marginal contribution to the economy is the result of technological and entrepreneurial backwardness, and several policy and administrative issues, such as inappropriate governance reforms and strong command-and-control regulations. More recently, the review of public spending has further weakened the link between practitioners in the field and public governance institutions. As a result, multifunctional and integrated forest management has been adopted only sporadically thus far. Moreover, national and forest law, policies, and regulations, along with international ones, appear uncoordinated, inefficient, or ineffective. To better highlight these trends, three regions with very different socioeconomic, administrative, and environmental features were selected as case study areas: Veneto, Molise, and Sicily. Interviews were carried out with local forest stakeholders, and collected information triangulated with data from secondary sources and other qualitative information. The paper argues that the absence of conflicts in the allocation of forest resources is the main problem from which the Italian forest sector suffers. Possible actions to overcome these issues are also discussed, particularly referring to the promotion of voluntary and market-based mechanisms applied to products and services others than wood provision.

Reaching out: the role of Argentine Model Forests in the implementation of the federal forest policy. Gabay, M., Sá, M. (*Directorate of Forestry, Argentina; mgabay@ambiente.gob.ar; msa@ambiente.gob.ar*).

This paper presents the experience of Argentine Model Forests as local-level governance platforms implementing the National Program for the Protection of Native Forests (NPPNF). The NPPNF was established by the Argentine Congress in 2007 within the framework of Law No. 26,331 of Minimum Environmental Standards for the Protection of Native Forests. The program aims at promoting sustainable forest management (SFM) taking into account forest communities and minimizing negative environmental impacts. Argentine Model Forests foster SFM while seeking to improve marginalized and low-income forest communities' livelihoods. The methodology consists of a mixed methods multiple case study involving three Model Forests representing different forest regions. The study analyzes the outcomes of the programs developed through the collaboration local, provincial, and national stakeholders. The prioritized activities involve, among others, bioenergy production, production forestry, non-timber forest products, local added value (capacity building), and silvopastoral activities. The results provide insights into consensus-building processes within multistakeholder partnerships, and the contributions of Law No. 26,331 to enhancing sustainable local livelihoods in forest ecosystems.

Innovative legislation for natural and planted forests in Iran. Ghilichkhani, M. (*Tarbiat Modares University, Iran; masghel52@yahoo.com*).

Most of Iran's 18 million ha of natural forests are in mountain areas, are uneven-aged, and are of mixed species composition. On the other hand, the country's planted forests are around cities and on rangelands or have been planted on forest land after logging. Many methods have been used in the management of these forests, including clearcutting, shelter wood cutting, and selection cutting. Some of these practices under previous legislation contributed to overutilization of forest resources. As conflicts arose over utilization and maintenance of biodiversity, new environmental legislation was introduced. Today regulations and other legislation are being proposed and adopted to mitigate threats to forests, reduce conflicts among user groups, and oversee management of all of Iran's forests for the long term. Scientific research from around the world, views of disparate stakeholders, and local experience have informed this legislation. As a result, a practical and comprehensive legal framework is being established to support biodiversity through management that promotes close-to-nature forests and sustainability.

Demonstration sites for community forestry: Addressing the fundamental challenges of sustainable forest management in Asia? Gritten, D., Suzuki, R., Triraganon, R., Atkinson, J., Dhiaulhaq, A. (*Center for People and Forests (RECOFTC), Thailand; david.gritten@recoftc.org; regan.suzuki@recoftc.org; julian.atkinson@recoftc.org; ahmad.dhiaulhaq@recoftc.org*), Etue, E., Greijmans, M.

Many Southeast Asian countries have ambitious targets for area of forest land under community management; however, with the exception of Vietnam these targets are not being met. The challenges are numerous, including poor understanding of community forestry (CF), and regulatory barriers and capacity issues for government officials and local communities. In order to address these and other challenges, CF demonstration sites are being established in Cambodia, Laos, Myanmar, Thailand, and Vietnam. Aims of the demonstration sites include: (1) ability to compare sites as an opportunity to share lessons; (2) capacity development

for key stakeholders (government officials, members of civil society organizations, and members of other communities); (3) improvement of CF in the sites and beyond, such as by monitoring the impact of targeted activities and identifying best practices, with the idea of scaling up or replicating the activities in other appropriate sites; and (4) visits by relevant stakeholders to see targeted activities (thereby increasing the profile and understanding of community forestry). The aim of this paper is to present frameworks for site selection and for documenting best practices. Anticipated results include understanding whether CF in the region is relevant only on a subsistence level, or whether through various interventions CF can help to address some of the fundamental challenges to sustainable forest management in the region.

Rural livelihood, voluntary partnership agreements, and social safeguards in Ghana. Hansen, C., Pouliot, M., Treue, T. (*University of Copenhagen, Denmark; cph@ifro.ku.dk; mapo@ifro.ku.dk; ttr@ifro.ku.dk*).

The paper assesses the perceived need for social safeguards targeting forest-dependent households in Ghana to mitigate adverse socioeconomic impacts of the voluntary partnership agreement (VPA) under the Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan. Livelihood outcomes of the VPA are assessed against detailed data on forest and livelihood linkages from 478 randomly selected households in two forest-fringe communities as well as national data on logging and timber trade. The paper finds that timber harvesting for subsistence and cash contribute little to rural households' total incomes, which means the direct impact of the VPA on rural livelihoods is likely to be limited. Rather, it is the formal timber industry, small-scale carpenters, and those involved in timber theft and the illegal timber trade who will be negatively affected. But social safeguards aimed at compensating groups for their losses from giving up their illegal activities would be difficult to justify. Social safeguards would thus be unnecessary or immoral, or both. However, long-term positive impacts of the VPA on rural livelihoods and, hence, on forest conservation could be realized, if the agreement helps to bring about governance and forest tenure reforms that enhance rural communities' rights to timber resources and revenues.

Economic instruments to enhance multi-functional forest management of Zagros forests in western Iran. Henareh Khalyani, J. (*University of Tehran, Iran; jhenareh@gmail.com*), Namiranian, M. (*University of Tehran, Iran; namirani@nrf.ut.ac.ir*).

The paradigm of sustainable forest management recognizes that forests are managed for a wide variety of ecological, economic, and social benefits. This approach has become the common theme in forestry throughout the world today. Here the authors explore how to achieve such management from a human-environment perspective using economic instruments. Selected forests in each of the 11 western provinces of Iran in the Zagros region were surveyed concerning programs available to customary forest owners for their livelihoods. These owners manage the forests to provide fodder for livestock, wood for fuel and construction, and land that can be cleared for under-canopy farming. The Iranian government provides incentive programs in non-industrial Zagros forests. The authors performed an institutional analysis of the formal and informal rules of the programs based on a review of the literature and discussions with government officials and local owners. Results indicated that the main reason for mismanagement of Zagros forests is weak social acceptance of management plans. Indigenous people's dependence on the forest for their livelihood showed that local people enjoy substantial economic benefit from forests. Therefore, the needs of people whose livelihoods depend on the forest must be incorporated into sustainable forest management by economic instruments.

Integrated management of forest goods and ecosystem services to achieve sustainability in forest management in the mountainous Zagros forest of Iran. Henareh Khalyani, J., Namiranian, M., Makhdoom, M. (*University of Tehran, Iran; jhenareh@gmail.com; namirani@nrf.ut.ac.ir; majidfmekhdoum@yahoo.com*), Mobarghei, N. (*Shahid Beheshti University, Iran; n_mobarghei@yahoo.com*).

Forest ecosystems deliver goods and services of enormous value to people. Zagros forests, which make up 40% of the national forests in Iran, are the primary site for this study. Population growth, shortage of productive lands, rural poverty, and local communities' intensive utilization of forest, have caused demand for goods and services from the Zagros forest to exceed the ability of traditional management to meet demand. The authors used the concept of human-environment systems as the rationale for this research. Detailed information was obtained from a survey of local communities through quantitative and qualitative participatory methods. The study revealed that livelihood of most people in the Zagros forest is based on a combination of forest products, animal husbandry, and dry agriculture, all of which are highly dependent on forest lands. To achieve balance in supply and demand for forest goods and ecosystem services based on the integrated management approach, a soil-based productive agricultural system should be the top priority. Furthermore, rural communities in the Zagros forest should be of primary consideration in sustainable forest management. Promotion of sustainable use of non-timber forest products is recommended to alleviate poverty and conserve forest. Results from the study will help in the development and implementation of management models that consider forest ecosystem goods and services.

Current status and potential for forest certification in Vietnam. Hoang, H. (*Kyoto University, Vietnam; hai.htn@gmail.com*).

Although Vietnam is one of Southeast Asia's largest exporters of wood products, its enterprises have to import 80% of their raw materials, making them vulnerable to fluctuations in wood supply and price. Forest certification was introduced in the 2000s with the aim of bringing economic, social, and environmental benefits. There are several factors hindering implementation of forest certification. First, the institutional and legal framework is not complete. Although the timber-processing industry has developed rapidly, it is still unstable, lacks strategic vision, and is in a weak competitive position. Second, most of Vietnam's wood-processing industry is small or medium-size. Third, awareness of the importance of forest certification is limited. On-the-ground forest managers and employees of forest management businesses do not have a good understanding of what it entails and what it offers. Fourth, the certification fee is high. Finally, investment remains a problem in Vietnamese forestry. Under the 2006–2020 strategy, $400 million is needed annually, yet current investment from public and private sources is only $50–60 million. However, there are opportunities for forest certification. Forestry has become a market-oriented enterprise involving many sectors. The Vietnamese government set a target for, 30% of forest production to be certified by 2020. A national system for certification is being developed. With forest certification, Vietnam is making progress in sustaining its resource.

Cost-benefit analysis of producing and refining cellulosic ethanol from *Pennisetum purpureum.* Huang, M. (*National Chiayi University, China-Taipei; myhuang@mail.ncyu.edu.tw*), Chiang, A. (*National Chengchi University, China-Tapei; eliot.chiang@gmail.com*), Liu, K. (*National Chaiyi University, China-Taipei; s1000091@mail.ncyu.edu.tw*).

China-Taipei imports about 97% of its energy from other countries. Because of worldwide instability, this country may face great uncertainty in its energy supply. Further, concern about the increasing scarcity of some fossil fuels and about greenhouse gas emissions from combustion of fossil fuels has led to international interest in bioenergy as one alternative energy source. This study develops a management plan of cellulosic ethanol production using *Pennisetum purpureum.* The study is based on the report of the National Renewable Energy Laboratory in 2011 and evaluates the management plan by applying cost-benefit analysis. The two scenarios set two different levels of biomass input from *P. purpureum*: basic scenario 1 (pilot plant scenario) with 14 million tons of inputs and basic scenario 2 (commercial scenario) with 70 million tons of inputs. Each scenario then incorporates grants for fallow land and carbon-trading sub-scenarios in a separate step. As a result, there are no economic incentives in the basic scenarios. However, if both fallow-land grants and carbon-trading sub-scenarios are included in basic scenario 1, the pilot plant would have positive economic gain. For basic scenario 2, in contrast, the addition of either fallow-land grants or the carbon trading sub-scenario generates good economic revenue.

Long-term structural drivers of sawnwood consumption in Europe. Hurmekoski, A., Hetemaki, L.(*European Forest Institute, Finland; elias.hurmekoski@efi.int; lauri.hetemaki@efi.int*).

Sawnwood demand modeling typically uses explanatory variables that mostly reflect business cycles of economic activity, and there is limited empirical research on the structural determinants of sawnwood demand. The first of the two objectives of the study is to identify potential factors that affect the observed differences in the long-term level of sawnwood consumption in Europe, i.e., the market share of wood compared to other construction materials. The empirical analysis uses consumption per capita as the dependent variable. Adjusting for population (i.e., the size of the markets) makes the model more comparable among different regions and is seen to better account for structural drivers in the sawnwood markets, compared to absolute values. Differences in the level of consumption between aggregate regions appear to be rather persistent, but major changes in the per capita consumption of sawnwood have occurred on a country level. These changes likely cannot be explained by the traditional demand shifters based on microeconomic theory alone. In order to discuss the possibility of similar changes elsewhere and on a larger scale, the second objective of the study is to identify and evaluate potential factors that cause changes in the market share of wood in the construction markets, which the demand equations reflecting business cycles and the size of economy are less suited to capture.

Adaptation to climate change through community forestry programs – case studies in vulnerable uplands of the Philippines. Jarzebski, M. (*University of Tokyo, Japan; marcin.jarzebski@yahoo.com*), Tolentino, P. (*University of the Philippines, Philippines; plmtolentino@gmail.com*), Yamamoto, H. (*University of Tokyo, Japan; yama@k.u-tokyo.ac.jp*), David, C. (*University of the Philippines, Philippines; cp.david@yahoo.com*).

Adaptation to climate change is a crucial issue for sustainability. For the Philippines, projected changes in climate include droughts, excessive precipitation, and an increase in temperature. These changes will negatively affect agricultural crops and the life of people across the country. Especially vulnerable are uplands where community forestry programs are mostly located, as these areas are subject to reforestation and conservation of forest. In addition to reforestation, the Community Based Forestry Management program provides livelihood assistance as cash crops and training. However, it is uncertain if the program is building adaptation to changing climate. For this study four areas located in the Philippines were analyzed in terms of climate change adaptation. The first step was to forecast climate change by the year 2050, by using the Modeling System for Agricultural Impacts on Climate Change (MOSAICC). The second step was to assess Community Based Forest Management's strategies, including varieties of plants, cash crops, and trees that have been promoted, and capacity-building programs. Research showed that there is low preparedness for climate change, which may cause hindrances for future development of forest-dependent communities. The current agenda has been advanced with the purpose of making communities more resilient in current conditions, but does not deal with adaptation to forecast climate changes.

Legal aspects of non-wood forest products in Western Balkan countries. Keca, L. (*University of Belgrade, Serbia; ljiljana.keca@sfb.bg.ac.rs*), Avdibegović, M. (*University of Sarajevo*, *Bosnia and Herzegovina; mavdibegovic@gmail.com*), Keca, N. (*University of Belgrade, Serbia; nenad.keca@sfb.bg.ac.rs*).

The aim of this paper is to analyze the legal framework pertaining to non-wood forest products (NWFPs) in the Western Balkan countries. The collection and use of NWFPs have a long tradition in WB countries because of this region's very rich biodiversity. Although in the last few years WB countries have enacted some updated laws and regulations pertaining to forestry, some articles of which regulate NWFPs, it is important to emphasize that these products are covered by laws in other areas, particularly those dealing with nature and environmental protection. Research for this paper is based on a review and comparative analysis of laws and regulations in the areas of forestry, nature conservation, and environmental protection in selected WB countries. The goal of this paper is to determine legislative points governing NWFPs through examination and analysis of WB laws and other legal documents.

Development of marketing activities in production of logs in Serbia. Keca, L., Keca, N. (*University of Belgrade, Serbia; ljiljana.keca@sfb.bg.ac.rs; nenad.keca@sfb.bg.ac.rs*), Avdibegović, M. (*University of Sarajevo, Bosnia and Herzegovina; mavdibegovic@gmail.com*).

This article deals with product placement of logs in Serbia with the goal of identifying commercial marketing opportunities. The aim of the research is to demonstrate the importance of marketing activities in forestry and the wood processing industry, especially for sale of wood from small-dimension logs and finished products in Serbia. To analyze marketing instruments for the production and sale of logs and products made from them, the authors used the concept of the marketing mix (the four Ps:

product, price, place, promotion). This concept is useful for enterprises that are striving to increase demand for their products. Logs are mainly produced from pines. The authors' research area focused on the range for European black pine, and on log production in Kremna, about 30 km from Užice (Serbia). Log production and sales increased in the period 2005–2009. Log prices are not determined by market forces but are set by the method of costs. Distribution largely occurs through short channels (producer, consumer), and, in some cases, extended channels (producer, industrial distributor, industrial customer). Promotional activities are very modest, such as participation in fairs and advertising in catalogs and flyers.

Local community participation in forest management in Lombok, Indonesia. Kim, I. (*University of British Columbia, Canada; inae.kim@alumni.ubc.ca*), Bae, J. (*Korea Forest Research Institute, Republic of Korea; forestory@forest.go.kr*), Latifah Endang Sunarya, S. (*University of Mataram, Indonesia; slatifa23@yahoo.com*).

The purpose of the research is to identify how the people of Lombok participate in forest management. A participatory rural appraisal was used. A focus group discussion and household survey in 14 villages around West Rinjani, Lombok were conducted. Although social forestry programs have been in place in Indonesia since 1998 (reformasi), the programs face challenges and opportunities in on-the-ground implementation. Community-led social forestry includes community forestry (Hutan Kemasyarakatan), the planting of forests by people (Hutan Tanaman Rakyat), and village forests (Hutan Desa). The government-led social forestry program is the rural community's participatory forest management program (PHBM). In Lombok, community forestry has positive impacts on the local communities. However, getting a permit for community forestry programs is a complex and expensive process. The community forestry program is not easy to implement on the ground, but the local forestry agency does initiate agreements with local communities for sustainable forest use and has implemented a forest watch program that is the modern version of the traditional forest watch. The local forestry agency plays a key role viable options for institutionalized social forestry programs in the West Rinjani protection forest, Lombok.

Wildfire economics: historical challenges and future directions for estimating ecosystem service values of fuels management in western U.S. forests. Kim, Y. (*Northern Arizona University, USA; ysk@nau.edu*), Wu, T. (*Arizona State University, USA; tongwu86@gmail.com*).

The management of forest fuels to address wildfires is a longstanding environmental issue in the United States, and one that will become more urgent with the continuing encroachments of residential development and climate change. Despite a lengthy history of fuels management, the economic impacts of past policies, and the likely outcomes of current efforts, have been the subject of much debate. The cost-benefit balance of fuels management, especially with relation to wildfire risk reduction and ecosystem service values, is a particularly vague area. A summary and synthesis of the existing literature and case studies will be presented, highlighting the conceptual bases and empirical weaknesses of our current understanding of wildfire economics. The authors hope to generate constructive discussions to identify future research directions.

Discount options as a financial instrument supporting REDD+. Krasovskii, A., Khabarov, N., Obersteiner, M. (*International Institute for Applied Systems Analysis (IIASA), Austria; krasov@iiasa.ac.at; khabarov@iiasa.ac.at; oberstei@iiasa.ac.at*).

This research is focused on developing financial instruments in the framework of REDD+. The proposed microeconomic model deals with the interaction of the forest owner, electricity producer, and electricity consumer. The producer initially has a fixed installed capacity of technologies varying in costs and emissions. The profit maximization problem is solved by choosing the optimal capacity factors to satisfy the daily electricity demand. The electricity price that consumers are willing to pay for the given yearly production is described by their inverse demand function (linear, constant elasticity). Exploration of scenarios for rising CO_2 prices shows an increase in electricity prices and decrease in profits and emissions with nonlinearities due to technology mixes. The producer can buy discount options as a hedge against the risk of high CO_2 prices Given the market CO_2 price, the producer maximizes its profit by taking the discounted price. The producer and forest owner negotiate the "fair" option price based on their expected CO_2 prices. The authors show that the proposed financial instrument has the potential to increase the producer's profits and decrease electricity prices for the consumer, but public money might be needed to support it.

Analysis of the economic effects of community forestry on rural households in the Mid-hills of Nepal. Lamichhane, D. (*Ministry of Forest and Soil Conservation, Nepal; dlamichhane@gmail.com*), Parajuli, R. (*Louisiana State University, USA; rparaj1@lsu.edu*).

The community forestry program (CFP) has been considered as playing an important role in the rural economy of the hilly region in Nepal. The paper evaluates the impact of the CFP on the household economy of the forest users of four community forest user groups (CFUGs) from two hilly districts. Data were collected from rich, middle, and poor wealth ranks of the forest users by using a questionnaire, field observation, and focus group discussion. Monetary value for direct and indirect benefits (B), considering selected good and services, and direct and indirect cost structures (C) of a household associated with community forests were calculated and analyzed according to the wealth ranks of households. Contingent valuation methods were applied for valuing indirect benefits and costs. The research findings indicated that the net direct benefits were all positive, and net indirect benefits were all negative in the three wealth ranks. However, the B/C ratios of different benefits and costs suggested that the CFP had positive economic impact on the rich (B/C >1) but negative on the middle and poor households (B/C <1). By holding the high proportion of benefits and low proportion of costs, the rich have generated negative externalities that have an impact on households in the middle and the poor classes.

Evaluating additionality and leakage issues from voluntary participation in forest carbon offset programs. Latta, G. (*Oregon State University, USA; greg.latta@oregonstate.edu*).

An intertemporal partial equilibrium model of the U.S. forest sector is modified to assess the market, land use, and greenhouse gas implications of a voluntary carbon offset program for improved forest management. Results over a range of carbon prices and offset program rules are evaluated for market participants as well as non-participants. In this modeling exercise additionality

is demonstrated by landowners who enroll at low carbon prices with no management change, and leakage is calculated as the ratio equal to the carbon change on non-participating lands divided by the carbon change on participating land over the full range of prices. Implications of restricting offset allocations to carbon fluxes in forests with greater than average carbon stocking levels are examined, as are implications of including payments upon project initiation to participants with initial stocks greater than average stocking. In addition to quantifying additionality and leakage impacts to the U.S. forest sector, results highlight the complexity of accounting for those interactions in methodologies aimed at quantifying improved forest management emissions reductions.

Competition for biomass in a declining pulp and paper market with an evolving renewable energy policy. Latta, G. (*Oregon State University, USA; greg.latta@oregonstate.edu*), Sjølie, H., Solberg, B. (*Norwegian University of Life Sciences, Norway; hanne.sjolie@nmbu.no; birger.solberg@umb.no*).

Forests have an important role in mitigating climate change by sequestering carbon during growth and supplying raw material for bioenergy and solid wood production. Bioenergy policies, extensively applied in industrialized countries, are increasingly being used to foster the expansion of nascent biofuel and biopower industries. These targets are frequently coupled with sustainability criteria in recognition of the host of ecosystem services forests provide. Evaluating potential market responses is complex as it involves the interaction between the existing forest inventory, silvicultural investment, harvest rates, wood utilization, and industrial structure as well as the associated changes in prices and trade levels. This study uses Norway as a case study, evaluating its forest sector bioenergy potentials given a string of recent paper mill closings and an annual increment in excess of harvest levels. The authors incorporate new long-term income elasticities for paper demand to recognize the structural shift in demand due to increasing competition between paper and electronic media. Two forest sector partial equilibrium spatial models are applied in combination to endogenously determine the discrete decision timing of optimally converting existing facilities to biofuel production. These models simultaneously minimize the impacts of declining paper demand and provide comprehensive greenhouse gas accounting and detailed representation of forest management addressing sustainability concerns.

On the economics of forest carbon: renewable and carbon neutral but not emissions free. Lintunen, J., Uusivuori, J. (*Finnish Forest Research Institute, Finland; jussi.lintunen@metla.fi; jussi.uusivuori@metla.fi*).

First-best optimal forest sector carbon policy is examined. The authors show that renewability and carbon neutrality arguments do not warrant emissions-free treatment of forest bioenergy. However, emissions-free treatment of wood in material and energy use is justified under the carbon accounting followed by IPCC, but only when the supply-side policy targeting forest owners accounts for corresponding emissions. The authors show how, in the optimal policy, bioenergy from harvest residues is not treated as emissions free, although their effective emissions are below their nominal emissions, and depend on decay lifetime and discount rate. The subsidy on harvested wood products is based on product lifetimes and discount rate, whereas the supply-side policies are independent of final use of harvested timber. Numerical solution of the model shows that, although the use of wood is not emissions free, it is optimal to increase the total use of wood, including in the energy sector. The supply-side policies lead to an initial drop in harvests, which allows for accumulation of older stands, resulting in larger yield and higher wood utilization.

Overview of participatory forestry in China. Liu, J. (*Renmin University of China, China; liujinlong@ruc.edu.cn*).

This paper analyzed the achievements and contribution of participatory forestry to sustainable forest management (SFM) in China over the last decade. Participatory forestry was considered an ideology and mindset, which could be summed up as the participatory development concept in forest management. This concept has been applied in a dynamic and evolving process towards implementing SFM, to be accomplished by integrating forest management with rural development; ensuring community participation and benefits from forest management; and reforming policy, legislation, and forestry administration to adapt to rapid social changes. Over 20 years, participatory forestry has been piloted at the community level, scaled to the regional level, and institutionalized in policy at the national level. Research and practices have made great progress in improving the forest and community culture; scaling up a procedure for participatory forest management; improving forest land tenure, the economy, and the forest management model; reforming forest management; and building capacity. Participatory forestry has become one of the discourses for sustainable management of Chinese forests. However, challenges remain, such as institutional barriers, poor research and practices, and lack of successful cases as examples to be duplicated. It is recommended that to achieve a greater contribution from participatory forestry, China should require decentralization of forest management, clarification of forest tenure, and improvement of cooperation among a variety of sectors, by integrating the concept of participatory forestry into key forestry programmes and enhancing capacity building.

Brazilian national forestry production chain identification based on the 2005 Brazilian Institute of Geography and Statistics input-output matrix. Loest, M., Hoeflich, V., Nuñez, B. (*Federal University of Paraná, Brazil; mrloest@yahoo.com.br; vitor.ufpr@gmail.com; blas@ufpr.br*).

Strategic planning in the forestry industry requires accurate information reflecting real-world conditions. Only on the basis of good information is it possible to manage and stimulate the forestry industry. The forestry sector presents a complete and complex production chain, responsible for up to 3% of the world gross domestic product, and contributes extensively to many Brazilian production chains. Seventy-six percent of the sector's intermediate products are used by other production chains. Its importance is reinforced by the fact that the other 24% of its product (used by the forestry chain) accounts for 67% of the aggregate value of the forestry production chain. The strong relationship between the forestry sector and other sectors demonstrates not only the importance of this sector but also the degree of interdependence with the other sectors. The Brazilian national input-output matrix from the Brazilian Institute of Geography and Statistics (IBGE) can be used to evaluate the forestry production chain and is a resource useful in forestry sector planning. This article intends to present characteristics of the Brazilian forestry production chain in qualitative and quantitative terms based on the 2005 IBGE's input-output matrix, to identify its components, and to demonstrate the sector's interdependence.

Discussion of House Project Bill 30/2011 for Brazilian Forest Code and changes in permanent preservation areas in the basin of Rio Pardo. Lopes, M. (*Federal University of Rio Grande do Sul, Brazil; manoelasm@gmail.com*), Vassali, M. (*Federal Rural University of Rio de Janeiro, Brazil; mauriciovassali@gmail.com*).

The discussion about the changes in Brazilian Forest Code is a recurring theme in the country, generating numerous conflicts between the opinion of the rural caucus and environmentalists in Brazil. The present study aimed to evaluate the differences in permanent preservation areas (APP) in the basin of Rio Pardo, Rio Grande do Sul, through a comparative analysis between the Federal Forest Code (Law No. 4.771/1965) and House Project Bill No. 30/2011, using geotechnology. As a result, the division of APP in accordance with Law No. 4.771/1965 guarantees a protected area of 28 558 ha, including a 500-m-wide vegetation buffer on riverbanks. The APP defined under the PLC 30/2011 showed an area of 6 715 ha because the riparian buffer is only 100 m wide. Allowing a narrower buffer will only increase damage to the study area in relation to the environment and its biodiversity.

Relevant aspects of valuation of land in investment analysis. Macedo, J., Hoeflich, V. (*Federal University of Paraná, Brazil; joelzmacedo@gmail.com; vitor.ufpr@gmail.com*).

A project can be understood as a set of information internal and external to the company, collected and processed in order to analyze investment decisions. Data analysis is used to determine fixed factors and form the basis for the combination of variable factors of production, in order to obtain a final product resulting from a combination of these materials. The land factor deserves special attention in investment decisions, especially when large areas of land or heavy financial investment is involved. In economic feasibility studies of forestry projects, some authors, such as Boulding (1955) and Duer (1972), ignore the cost of land, justifying this approach by the lack of alternative land use or when land is used solely for forest production. In economic feasibility studies in Brazil, it is common to take into account alternative land uses in most regions by assigning an arbitrary land compensation, with rates ranging from 4 to 15% per year on the value of the land. However, other aspects must be considered, such as the productivity of the land available for other productive factors needed for land cultivation, marketing channels, and market price for the product.

Remuneration of land in forest investment analysis. Macedo, J., Hoeflich, V. (*Federal University of Paraná, Brazil; joelzmacedo@gmail.com; vitor.ufpr@gmail.com*).

Services that are provided by factors of production are incorporated into the production process in the form of added value. In this process, the economic system follows a basic principle according to which the owners of factors of production receive payment for use equal to the value that they create when providing productive services. When the supply factor is fixed, its contribution is considered a "pure economic rent" and its amount depends on current demand. Economic rent is the income of a factor of production in excess of its opportunity cost. Given the above, the objective of this research is to verify feasibility studies in which this methodology is used to account for the land factor in the analysis of forestry investments. The scope of this study is limited to publications in Qualis International journals A1 to B2, as indexed in Scientific Electronic Library Online (SciELO). The study of land compensation is justified by the following: If a factor of production is not being paid for correctly, the study is not properly covering all production costs. The authors' analysis of 299 articles found that all but two used an arbitrarily defined method and other remuneration, with rates ranging from 4 to 15% per year.

Sustainability impact assessment for development of a local bioenergy supply chain: a case in the Como Lake area, Italy. Martire, S. (*European Forest Institute, Finland; salvatore.martire@efi.int*).

Decision-making should be supported by assessment tools able to consider different aspects related to the sustainability of processes. Local policies aim to merge the local community's needs with the objectives of multilevel regulations. For European rural areas, the role of forests has expanded to include leading rural development, as emphasized by the EU Forestry Strategy 2013. The role of forests as a source of fuel is well known, and using local energy resources boosts energy security. Usually, the main constraint for developing local energy facilities is economic feasibility. In addition, utilization of energy supplies causes environmental impacts along the whole chain and the depletion of natural resources. The study aims to contribute to the development of integrated assessments for local planning for rural development and sustainability. The authors applied a comprehensive method capable of supporting decision-making processes at the local scale in order to understand the benefits to local stakeholders and decision-makers of combining environmental, social, and economic aspects in one analysis. Specifically, the assessment aims to support the planning of a local bioenergy chain in Italy. A sustainability impact assessment was carried out though the software ToSIA. Energy development scenarios were compared using environmental, economic, and social indicators.

Participation of women in forestry activities: the case of women as an invisible workforce in Ecuador. Mejia, E. (*Center for International Forestry Research (CIFOR), Ecuador; k.mejia@cgiar.org*), Pacheco, P. (*Center for International Forestry Research (CIFOR), Indonesia; p.pacheco@cgiar.org*).

In Ecuador, men own nearly three-quarters of land in agricultural production, even though women make up 42% of the agricultural labor force. In the Amazon region, labor markets have provided women with cash income, especially from crop and forest commodities. In order to better understand women's participation in labor markets, two research sites were selected in the Northern Amazon of Ecuador. An historical analysis was conducted on labor markets in relation to the investment and political will to increase commodities participation in the Amazon Region. Further, a semi-structured questionnaire was applied to women (n=60) using variables related to: (1) participation, (2) skills, (3) degree of responsibilities, (4) freedom to make decisions (e.g., regarding divorce or migration), and (5) land security. Preliminary results show that several shifts have occurred over time where women undertook predominantly male activities (mostly due to scarcity of labor or need of specialization). In many cases, women do not receive compensation for their work in forestry activities, but do so for agricultural activities. In addition, women receive better income than men when working for third parties on crop activities, which gives them more bargaining power when seeking legal land titling.

Human impact on the land cover in the area surrounded by the centres of past mining. Merganicova, K., Merganič, J., Sitko, R., Mistrik, M. (*Technical University in Zvolen, Slovakia; merganicova@tuzvo.sk; j.merganic@forim.sk; roman.sitko@tuzvo.sk; mistrik@tuzvo.sk*).

The land of Central Europe has long been influenced by human activities. In the Middle Ages, the areas around mining centres were affected the most because of increasing demand for wood. As early as the beginning of the 15th century, mines had inadequate wood supplies. In some cases, wood and charcoal were transported from several tens of kilometres away. The present study assesses the land cover change of the University Forest Enterprise of the Technical University in Zvolen, located in central Slovakia and surrounded by famous mining towns of the past (Banská Bystrica, Kremnica, Banská Štiavnica). The historical development of the land cover of the selected region is determined by using the historical military maps of the Austrian-Hungarian Habsburg monarchy covering the period since the late 18th century, and the archive aerial orthophotos from the recent past (1949, 1977, and 2011). Results of the study indicate that at the end of 18th century, deforested areas occurred mainly around villages. The more recent aerial photos show the reverse trend. Forest expansion in the second half of the last century is mainly related to the abandonment of farmland.

Present and future legal framework of environmental services in Argentina. Minaverry, C. (*Universidad de Buenos Aires & CONICET, Argentina; cminaverry@derecho.uba.ar*).

Argentine legislation does not regulate environmental services for all natural resources. Argentina historically has not applied a consistent approach to legal protection of natural resources. One exception is national law for the environmental protection of native forests, which stated that environmental services are "tangible and intangible benefits provided by ecosystems from native forests, which are necessary for the living of a natural and biological system as a whole, and in order to improve people's life quality." Environmental law should create a technical mechanism which internalizes payment for environmental services provided by all natural resources. To implement this system, environmental services will have to be evaluated economically, just as a value is put on damages to the environment, bearing in mind that this monetary quantification is very difficult to calculate.

Legacies of historical land use on present forest structure in mixed beech-silver fir forests in the Northern Apennines. Motta, R., Meloni, F. (*University of Turin, Italy; renzo.motta@unito.it; fabio.meloni@unito.it*), Garbarino, M. (*Marche Polytechnic University, Italy; m.garbarino@univpm.it*), Berretti, R. (*University of Turin, Italy; roberta.berretti@unito.it*), Urbinati, C. (*Marche Polytechnic University, Italy; c.urbinati@univpm.it*), Bottacci, A., Borchi, S., Bresciani, A.

This study was carried out in three forests characterized by a different past land use and located in the "Foreste Casentinesi, Monte Falterona, Campigna" National Park. The "Verna" forest has been managed by the Franciscan religious order for centuries, the "Camaldoli" forest has been managed by Camaldolese monks for centuries and, more recently, by the Corpo Forestale dello Stato (State Forestry Corps), and the "Sasso Fratino" forests have been sporadically managed in the last centuries. The three forests are characterized by the presence of silver fir, a conifer closely tied to the history of the religious orders, which applied different silver fir "monastic silviculture." The authors analysed forest and coarse woody debris structure and forest regeneration in a network of 30–40 sampling plots in each forest. Even though the three forests have been protected (Sasso Fratino) or managed with a low intensity silviculture (Camaldoli and Verna) in recent decades, legacies of land use activities continue to influence ecosystem structure and function. Current dynamics reflect both the different past land use and the different spiritual expectations of the monastic orders.

New national forest policy of the Russian Federation: basis for solving forest sector problems. Nikitin, V., Sanaev, V. (*Moscow State Forest University, Russian Federation; nick@mgul.ac.ru; rector@mgul.ac.ru*).

The ecological, economic, and social value of Russian forests make it necessary for the Russian Federation to have a long-term state forest policy. The basic provisions of the National Forest Policy of Russia adopted in October 2013 follow. (1) Management: The State provides sustainable forest management even as it utilizes the resources of the forests. The forest management system is based on the separation of powers between central and local authorities. (2) Use: Use of forest resources must be focused on preservation and enhancement of the social and ecological importance of forests as well as on the satisfaction of society's demand for forest resources. (3) Environment: Forest management in Russia promotes preservation of the ecological potential of forests and their capacity for adaptation to climatic changes. (4) Science and education: Forest science plays a key role in gaining new knowledge about the nature of forest ecosystems, which in turn provides a basis for forest management. (5) Society: The State guarantees free access for citizens to forests and to utilization of food and non-wood resources. (6) International aspects: Russia considers the international processes on forests vital for its own economy and ecology, and treats them as a condition of world economy stabilization and preservation of biospheric balance on the planet.

Voluntary Partnership Agreement on Forest Law Enforcement, Governance and Trade between the Republic of Indonesia and the European Union: Who gains the benefits? Nurrochmat, D., Dharmawan, A. (*Bogor Agricultural University, Indonesia; dnrochmat@yahoo.com; aryahadidharmawan@yahoo.com*).

The Voluntary Partnership Agreement (VPA) on Forest Law Enforcement, Governance and Trade (FLEGT-VPA) between the Republic of Indonesia and the European Union was signed in Brussels, Belgium, on 30 September 2013. This agreement recognised the Indonesian Timber Legality Verification System (*Sistem Verifikasi Legalitas Kayu*/SVLK), which deals with the mechanism, process, and establishment of forest management and trade of timber whose legality is guaranteed, in compliance with the European standards. However, the benefits of SVLK compared with several other timber trade policies, such as Log Validation Certificate (SKSKB), Timber Origin Certificate (SKAU), the state mandatory certification system for sustainable forest management (PHPL), and the third party voluntary sustainable forest management certifications, need to be evaluated scientifically. As a part of timber trade policies, the SVLK has to consider political and social-economic priorities, including paying attention to the voices of the poorest and the marginalized. This study determines whether the implementation of SVLK is in accordance with the principles of efficiency, effectiveness, and equity. These have to be able to work together with the pillars of sustainable forest management, and the system shall also support the creation of a transparent, accountable, and law-abiding timber trade.

Addressing the drivers of deforestation: exploring synergies between REDD+ and forest policy. Obersteiner, M., Kraxner, F., Mosnier, A., Bocqueho, G., Khabarov, N., Havlik, P. (*International Institute for Applied Systems Analysis (IIASA), Austria; oberstei@iiasa.ac.at; kraxner@iiasa.ac.at; mosnier@iiasa.ac.at; bocqueho@iiasa.ac.at; khabarov@iiasa.ac.at; havlikpt@iiasa.ac.at*).

This presentation will contribute to increased understanding of the drivers of tropical deforestation and degradation. Key opportunities for new forest sector lead collaborations and more effective future interventions based on forest and land-use policies will be identified. The latest research on drivers and the status of current demand- and supply-side forest sector initiatives will be presented. An overview of new, innovative ideas, which can feed into the UNFCCC negotiations on drivers and other government, industry, and multistakeholder forums will be discussed. Models of unlocking forest finance will be presented. Public finance is used to leverage private finance at the scale of capital markets with the goal of developing a financing model which can alleviate the pressure leading to deforestation, restore land, and move commodity production to sustainable systems, as well as conserve forest and promote sustainable rural development. Public and private sector efforts will be analyzed and transition scenarios towards sustainable REDD+ implementation will be sketched out. The authors will conclude with a set of high-level policy recommendations in view of integrating the three Rio Conventions.

An investigation into the interactions between climate change initiatives in Ghana. Opoku, P., Weber, N. (*Dresden University of Technology, Germany; opoku_patrick@yahoo.com; nweber@forst.tu-dresden.de*).

The international community has developed policy instruments intended to conserve forest and mitigate climate change in developing countries. These measures include the programmes REDD+ (Reduced Emissions from Deforestation and Forest Degradation), the Voluntary Partnership Agreement, and the Non Legally Binding Instrument on all Types of Forest. Each of these initiatives has its own objective, and could interact with and have different impacts upon the national economy, environment, and stakeholders. The nature of these interactions and impacts is not yet known, however. The purpose of this research is therefore to assess the interactions and impacts of international forestry initiatives for climate protection in Ghana. The study is part of an ongoing research study under the Alexander von Humboldt climate protection fellowship program in Germany. Data collection will involve focus group discussions and in-depth stakeholder consultation as well as expert interviews in Ghana and Germany with support from the Institute of Forest Economics and Forest Management Planning, Technical University of Dresden, Germany. The findings and perceptions are to provide a basis from which to derive recommendations for improved implementation and coordination of international initiatives in Ghana in order to increase the effectiveness of climate protection measures.

Market conditions for forestry contractors in Slovakia. Palus, H., Kaputa, V. (*Technical University in Zvolen, Slovakia; kaputa@tuzvo.sk*).

The objective of this paper is to present the conditions of the forestry contractors market in Slovakia with emphasis on silviculture and harvesting operations. It analyses the relations between contractors and forest owners, contract negotiation conditions, contract terms, perception of transaction costs, occurrence of specific investments, and opportunistic behaviour in the context of a transaction cost economy. The main method for collecting information about the market was a standardized interview with selected contractors and forest owners. Three different forest owners and seven contractors were interviewed in areas relating to company characteristics, public policy measures, contracts, social and environmental influences, and anticipated future market development. Analyses of the interview results showed that contactors strove to offer as wide a range of services as possible and, at the same time, they tried to avoid specific investments unless they were guaranteed either by the time period of the contract or by the volume of contracted works in order to cover at least half of the specifically required investments. Conditions regarding the time flexibility of contracts, subcontracting activities, consideration of transaction costs, and the parties' negotiation positions are also discussed.

Wood flow analysis in the Slovak forest industry. Parobek, J., Palus, H. (*Technical University in Zvolen, Slovakia; parobek@tuzvo.sk; palus@tuzvo.sk*).

This paper deals with modeling wood use in the forest products industry and related industries under the principles of sustainability in Slovakia. Two different approaches were used for the analysis: wood balance and wood resources balance. The wood balance model covered the basic relationships between the resources and uses of wood and quantified consumption of wood. The wood resources balance model covered all possible applications of wood in various forms, including flows of wood material and wood residues. The wood resources balance method required collecting data through empirical research. Because the cascade use of wood was considered, the wood resources balance model calculated higher consumption of wood (12 million m^3) compared to the wood balance model (8.4 million m^3). Moreover, results indicated that the sawmilling industry consumed 43%, wood-based panels industry 15%, pulp and paper industry 26%, energy sector 10%, and households 6% of the total domestic wood consumption. The paper also presents a comprehensive model of wood flows between the resources and utilization of wood in different sectors.

Preferences of new forest owners in Serbia. Petrovic, N. (*University of Belgrade, Serbia; nenad.petrovic@sfb.bg.ac.rs*), Pezdevšek Malovrh, Š. (*University of Ljubljana, Slovenia; Spela.PezdevsekMalovrh@bf.uni-lj.si*), Avdibegović, M. (*University of Sarajevo, Bosnia and Herzegovina; mavdibegovic@gmail.com*).

The total share of private forests in Serbia is 47%, a percentage that has not changed drastically since the process of nationalization in 1946. Nationalization was carried out by depriving large forest owners of their forests and establishing the maximum amount of land that a private individual could own. This policy reduced the total area of private forest, but left the significant presence of a large number of private forest owners with relatively equal amounts of forest land in their control under the legal maximum. After the restitution of forests to churches and religious communities beginning in 2006 and the 2010 law on general restitution, the stage was set for restitution to large forest owners. The heirs of once large forest owners are new stakeholders with potentially different preferences for the use of forests in comparison with the current small forest owners, whose wood is usually

used to meet personal needs. The heirs are new actors in the forest policy arena, representing different values, interests, and power from those of the usual participants. For the purpose of adjusting the existing forest policy to take into account the new forest owners, this study will investigate their preferences for forest management and the use of their recently inherited forest property.

Mill capacity to utilize logging residues for bioenergy production in the southern United States. Pokharel, R., Grala, R. (*Mississippi State University, USA; rpokharel@cfr.msstate.edu; rgrala@cfr.msstate.edu*).

The potential for utilizing logging residues as a feedstock for bioenergy production by mills in the southern United States depends on their willingness to utilize, pay for, and haul logging residues. A mail survey was sent in 2012 to southern mills to study their capacity to utilize woody residues and determine their willingness to utilize, pay for, and haul additional logging residues for bioenergy production. About 11% of mills were willing to utilize additional logging residues. Mills were willing to pay an average gate price of US$16/ton and haul logging residues over 65 miles. Willingness to utilize additional logging residues had a significant impact on gate price and hauling distance. The price mills were willing to pay at gate was significantly different between mills with differing capacities, but there was no effect of capacity on hauling distance. High transportation cost was the most important limitation for additional utilization of logging residues, followed by limited storage space, processing capacity, and available equipment. Results indicated that there was a potential and willingness of southern mills to utilize logging residues, suggesting that there is an an opportunity to increase woody residue utilization. These findings will be helpful in developing policies related to wood-based energy production.

Linking science and policy: changing policy-maker behavior through action research in forest value chains. Purnomo, H. (*Center for International Forestry Research (CIFOR) & Bogor Agricultural University, Indonesia; h.purnomo@cgiar.org*), Shantiko, B., Achdiawan, R. (*Center for International Forestry Research (CIFOR), Indonesia; b.shantiko@cgiar.org; r.achdiawan@cgiar.org*).

Imbalanced distribution of added value among participants in forest value chains weakens the sustainability of forests and forest products. Regional trade policies such as the China-Association of Southeast Asia Nations (ASEAN) free trade agreement can worsen the situation of small-scale producers in Indonesia, if such policies are not strengthened. Much research on forest and forest products has been done, but can the behavior of policy-makers change? This paper describes the link between science and policy throughout the research process underlying the development of a long-term furniture strategy plan to improve value added for smallholders. It explores the problem in Jepara district, Central Java, which is the center of furniture manufacturing in Indonesia with an export value of US$120 million annually. The authors have been doing action research, outcome mapping, and innovation diffusion to boundary partners at different levels in an effort to make science count in policy formulation and implementation. The authors found that clear links between science and policy exist due to the action research. They recommend using action research and outcome mapping at various levels to facilitate better governance in support of better management of forests and the forest industry and fair distribution of their value added.

Formulating a proposal for a strategy to prevent and control fires in protected areas by means of governance criteria. Rivera Coria, W. (*National Federation of Municipal Governments of Bolivia (FAM), Bolivia; riveraw@gmail.com*).

Bolivia has adopted an integrated management system that allows settlers in protected areas to be present at and take part in management processes concerning these areas. According to the Servicio Nacional de Áreas Protegidas (SNAP; National Service for Protected Areas), fires constitute a powerful threat to the resources located in these areas and poor production practices related to the use of fire in agricultural work were found to be the main underlying cause. Fire is regarded as an efficient low-cost resource that is used to prepare land for cultivation and pasture purposes. The present paper outlines a strategy to prevent and control fires in protected areas. The author addresses systematic measures initiated to change production patterns and a new approach to the organization of production, certified production, and regulation of ownership in order to stabilize the borders of agricultural land with strictly protected areas. The work builds on a methodological formulation regarding the governance of natural resources (GTZ, 2004) based on the Institutional Analysis and Development Framework (Ostrom, 1999). It was expanded upon in cooperation with SNAP, validated in a participatory way by the directors of 19 protected areas in the country and key actors, and published as a working document in 2008.

Analysis of the non-state forest sector in Slovakia. Sarvasova, Z., Moravcik, M., Schwarz, M., Lásková, J. (*National Forest Centre, Slovakia; moravcik@nlcsk.org*; *schwarz@nlcsk.org; laskova@nlcsk.org*), Šálka, J. (*Technical University Zvolen, Slovakia; salka@tuzvo.sk*), Dobšinská, Z., Hricova, Z.

Non-state forestry in Slovakia has been investigated under the research project APVV -0057-11 VYNALES (Research of the impact of non-state forest ownership on forest related policies). One of the partial objectives of the project was to analyze the non-state forestry sector using the SWOT methodology approach, which identifies four basic attributes of non-state forestry: strengths (S), weaknesses (W), opportunities (O), and threats (T) related to private forestry. The paper analyses the internal and external environment and the strategic scenarios resulting from synthesis of the SWOT analysis outcomes. SO strategy is aimed at private-sector opportunities linked to the existence of associations, leaders, and active members who are involved in fund-raising opportunities. ST strategy uses strengths to avoid external threats and presents a more appropriate strategy due to the predominance of external threats and internal strengths. WO strategy describes opportunities to minimize or overcome internal weaknesses to exploit opportunities that result from the fragmentation of ownership and association members. WT strategy is based on obtaining the relative unity of the associations to avoid the negative financial impact of the external environment.

Comparison between Western and Eastern historical views of sustainability (Nachhaltigkeit) principles of forest use. Shiba, M. (*University of the Ryukyus, Japan; mshiba@agr.u-ryukyu.ac.jp*), Jemali, N., Binti Ahmad Zawawi, A. (*Kagoshima University, Japan; idiana0303@yahoo.com; azitazawawi@gmail.com*), Chinen, Y. (*University of the Ryukyus, Japan; akamayaa@yahoo.co.jp*).

The Yambaru region located in the northern part of Okinawa's main island belongs to a subtropical marine climate zone. This climate has created the bountiful forests of Yambaru, and those forests have nurtured important habitats for a large number of internationally recognized, widespread native species. Efforts are being made to designate the Yambaru forest as a national park because of its inscription on the UNESCO World Heritage list. On another front, during the age of the Ryukyu Kingdom (1609–1879), the Yambaru forest was respectfully managed under the Somayama (Royal Forest) system established by Sai On (1682–1761), who was one of the three chancellors of the Ryukyu Court. At Somayama the community people acquired all wood for building, heating, and production of utensils necessary for village life. After removing timber, they reforested areas, thereby protecting the forest through application of traditional practical knowledge. At the same time, the concept of sustainability was being expressed by Hans Carl von Carlowitz (1645–1714), director of the mines in Saxony, who wrote Sylvicultura Oeconomica in 1713. The authors discuss sustainable forestry based on community-level activity from the perspectives of Western and Eastern historical views of sustainability (Nachhaltigkeit).

Forest, climate mitigation and choice of policy means: How well suited are various bioenergy policies for combating climate change? Sjølie, H. (*Norwegian University of Life Sciences, Norway; hanne.sjolie@nmbu.no*), Latta, G. (*Oregon State University, USA; greg.latta@oregonstate.edu*), Solberg, B. (*Norwegian University of Life Sciences, Norway; birger.solberg@umb.no*).

Most industrialized countries have implemented policies to foster the use of bioenergy with the objective of mitigating climate change. With forests as the primary biomass source in many of these countries, the increased demand could trigger more harvesting which, depending on forest characteristics, could be incompatible with reductions of short-term atmospheric CO_2 levels. However, forest-based energy can also come from byproduct sources with very different CO_2 impacts. Furthermore, clearing land increases its albedo and therefore has a cooling effect on the climate. Thus, there are several factors which pull in different directions, complicating the overall climate impact of increased use of forest-based energy. By evaluating the greenhouse gas fluxes and albedo effects associated with an array of potential schemes, the authors attempt to provide insight into the following question: How well suited are various bioenergy policies to combat climate change? A partial equilibrium model of the Norwegian forest sector is used to simulate forest management and growth, harvest, wood processing, consumption, trade, greenhouse gas fluxes, and albedo effects over the next century. The results provide insight for policy-makers designing bioenergy policies in forest-rich countries with important albedo effects.

Response in forest policy as a result of reduced risk of stream salinity associated with timber harvesting in a changing climate. Stoneman, G., Kinal, J. (*Department of Parks and Wildlife, Australia; geoff.stoneman@dpaw.wa.gov.au; joe.kinal@dpaw.wa.gov.au*).

Precautionary salinity management practices have operated for more than 20 years in the lower rainfall areas of the jarrah and karri forests, guided by earlier hydrological research. These practices aimed to retain a minimum vegetation density in space and time, during timber harvesting and subsequent regeneration, to minimise the potential rise in groundwater levels and stream salinity. Substantial changes in silvicultural practices mean that the disturbance is now less intense than examined in previous hydrological studies. Declining annual rainfall has resulted in declining groundwater levels and stream salinity; groundwater levels that were near the surface in the 1970s and 1980s are now deeper than 5 m in much of the forest. Annual rainfall and groundwater levels are projected to decline further. As a part of the development of the Forest Management Plan 2014–2023, forest policy was reviewed and revised such that phased harvesting in second-order catchments in lower rainfall areas of much of the jarrah and karri forests is no longer necessary because the salinity risk has declined significantly and will remain low for the foreseeable future. Ongoing monitoring of groundwater level is to continue so that management can be responsive in the event of a return to a wetter climate.

Sustainability of slash pine forest stands in the southern United States under climate change. Susaeta Larrain, A. (*University of Florida, USA; asusaeta@ufl.edu*).

This paper analyzes the impacts of different levels of forest productivity scenarios due to changes in global temperatures and precipitation patterns in the context of climate change, on the economics of slash pine (*Pinus elliotti* var. *elliotti*) in the lower Coastal Plain in the southern United States. The ecophysiological model 3PG (Landsberg and Waring, 1997) was combined with the growth and yield model (Pienaar *et al*., 1996) to account for changes in total commercial volume, carbon stock, and proportion of forest products generated by the forest stand. A generalized economic model was used to determine the impacts of climate change on the land expectation values and carbon sequestration on hectare basis, and optimal harvesting decision. This economic model allows for estimating the impacts of both current and future changes in forest productivity on the current optimal harvesting decision. This work will also explore the effects of changes in tree planting density and site productivity index on the net economic rents for landowners, carbon sequestration, and optimal harvest age in light of changing climatic conditions.

Industry perspectives on wood as a structural green building material. Wade, A., Sinha, A., Knowles, C. (*Oregon State University, USA; wadeal@onid.orst.edu; arijit.sinha@oregonstate.edu; chris.knowles@oregonstate.edu*).

Green building is becoming an increasingly popular trend around the world, creating positive growth in green building materials markets. The purpose of this research is to understand the role of wood as a green building material in the structural system of new buildings. The study also aims to identify areas in which information is lacking with respect to reducing the environmental burden of structural building materials and to identify gaps in access to or availability of green building materials. Semi-structured group interviews composed of industry professionals representing all stages of the design and build process (i.e., architects, engineers, contractors) and experiences in different scales and functionalities of buildings will be used to gather information for this study. Interviews will be conducted in different regions of Oregon (USA) where the most growth is occurring, including the Portland metropolitan region, Corvallis, Eugene, and Bend. Results will focus on the role of green building rating systems in material selection, resources used by industry professionals to research green building materials, and understanding constraints and biases against using wood for structural systems of green buildings.

The value of adaptation to climate change for European forestry. Yousefpour, R. (*Max Planck Institute for Meteorology, Germany; rasoul.yousefpour@mpimet.mpg.de*).

Adapting to climate change implies revisiting of forest management decisions in different European case studies. However, the questions in most of the cases are (1) to make the most-adaptive decisions, (2) to find the best timing for switching from business-as-usual to the adaptive decision, and (3) to update information about forest and climate conditions over time and revisit adaptive decisions again if necessary. Adaptive decisions could be implemented now or postponed to benefit from the productivity of mature forests vulnerable to climate change impacts over a long time horizon. However, this is highly dependent on the age of the stands. Instead of supporting highly productive sites, it is more crucial to identify and support low productivity sites, which support ecosystems that are sensitive to climate change, with adaptation measures. Otherwise loss in productivity is expected to be 28–152%, as compared with a loss of 0.4–2.8% of expected productivity in more productive sites. However, in comparison with the worst (non-adaptive) decision, the largest possible gain (with an adaptive decision made with perfect information about climate change and impacts) could be up to 122% (23–122%) of land expectation value. Adaptation to climate change is not a one-time action and may be revisited at many decision points in response to new information about climate change and monitored impacts.

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