Complexity of agroforestry cropping systems in the undergrowth of Guadeloupe

Romane Chaigneau, David Hammouya, Philippe Tormin, Marie Bezard, Emilie Drillet, Teresa Castro Nunes, Jean-Louis Diman

4th World Congress on Agroforestry

20-22 May 2019
Montpellier, France

Book of Abstracts

Under the High Patronage of
Mr Emmanuel MACRON
President of the French Republic

4th World Congress on Agroforestry

20-22 May 2019
Le Corum - Montpellier, France

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Compiled by Alpha Visa Congrès

Edited by Christian Dupraz, Marie Gosme and Gerry Lawson with
the members of the Scientific Committee of the Congress.

Design and layout by Alpha Visa Congrès

RESEARCH PROGRAM ON Forests, Trees and Agroforestry

CGIAR

Landscape approaches to tackle climate change, and achieve sustainable development and food security

Aerial view of the landscape around Halimun Salak National Park, West Java, Indonesia. Photo by Kate Evans/CIFOR

What is FTA?

The CGIAR Research Program on Forests, Trees and Agroforestry (FTA) is the world's largest research for development program to enhance the role of forests, trees and agroforestry in sustainable development and food security and to address climate change. CIFOR leads FTA in partnership with Bioversity International, CATIE, CIRAD, INBAR, Tropenbos International and the World Agroforestry Centre. FTA's research contributes to 14 of the SDGs.

What do we work on?

- Tree genetic resources
- Forests, trees and agroforestry for smallholder livelihoods
- Sustainable value chains and investments
- Landscape dynamics, productivity and resilience
- Climate change adaptation and mitigation
- Gender, evaluation and impact assessment

A woodseller trades at Montée Parc Market in Yaoundé, Cameroon. Photo by O Girard/CIFOR

foreststreesagroforestry.org @FTA_CGIAR foreststreesagroforestry

FTA IS LED BY

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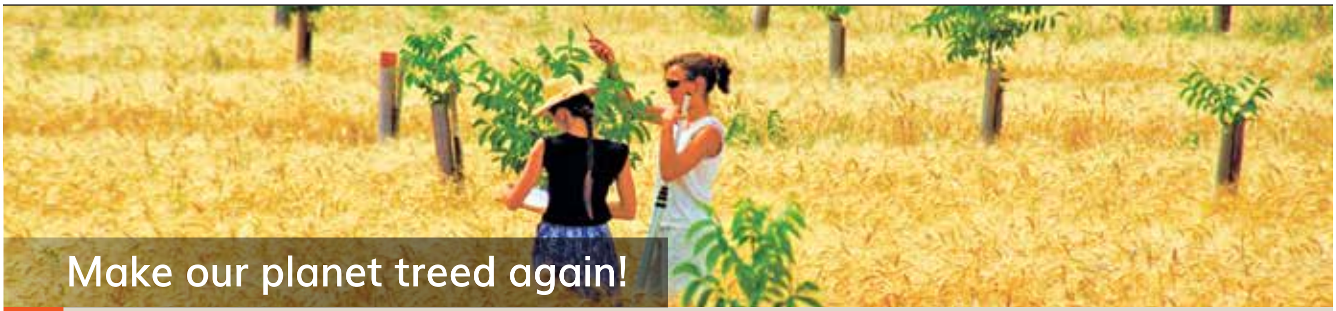
FTA's work is supported by the CGIAR Trust Fund: cgiar.org/funders/



Measuring young trees in an agroforestry plantation, Restinclières, Hérault, France © C. Dupraz

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Abstracts of Parallel sessions

Fondation de France

Fondation de France: The leading philanthropic network in France

Backed by almost 50 years of experience, the Fondation de France is the leading philanthropic network in France. It gathers together founders, donors, volunteer experts, employees and thousands of organizations, each committed and driven by the desire to act.

Meet today's challenges: provide solutions for tomorrow's

Across all areas of general interest, the Fondation de France acts in the present and prepares for the future:

-by meeting the needs of the vulnerable, with initiatives that improve social ties while respecting their dignity and their autonomy;

-by developing promising solutions in the areas of innovation and social progress, including medical research, the environment, education, culture and training.

Our actions in Agroforestry

Why is it important?

After a century of continuous progress made by intensive farming in developed countries, output is stagnating and biodiversity is becoming worryingly impoverished. Agroforestry, which consists in integrating trees into agricultural farming systems, could provide a fair answer to this situation.

Our actions

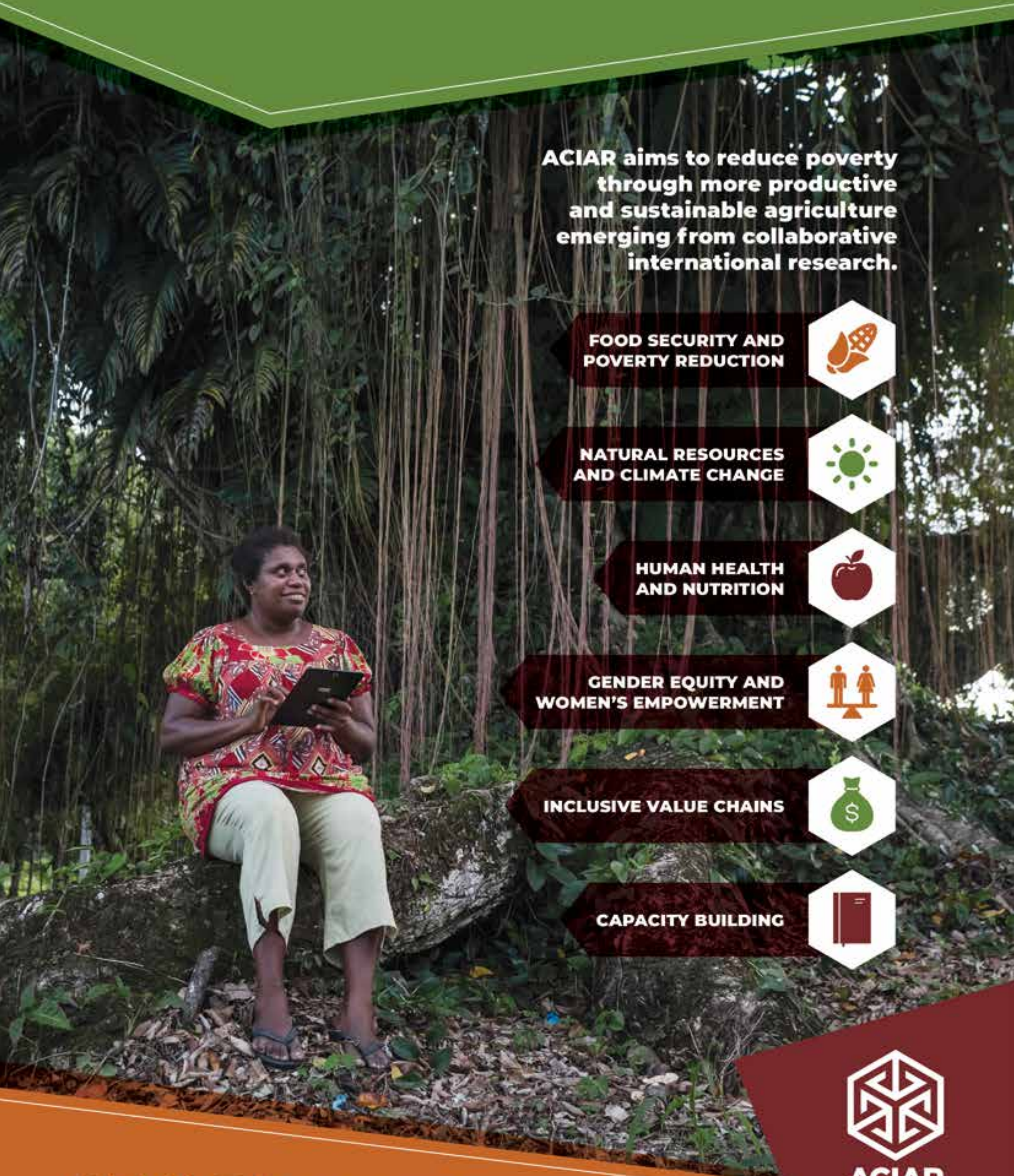
While modern agroforestry systems have been developed over the past 20 years, research on the subject remains underdeveloped in France. Traditional know-how has been partially lost and basic knowledge is still fragmented. The Fondation de France awards subsidies to encourage students to discover or expand this field of research as part of a high performance team working on these questions.

Abstracts of Parallel sessions

Australian Government

Australian Centre for International Agricultural Research

Australian Aid



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Canopy of agroforest with Shorea javanica trees, krui, Sumatra, Indonesia © E. Torquebiau

WELCOME ADDRESS

Welcome to the 4th World Congress on Agroforestry!

On behalf of the Organising and Scientific Committees, we would like to welcome you in Montpellier.

Montpellier, home of one of the oldest French Universities, is proud to host in 2019 the World Congress on Agroforestry for the first time in Europe! Today's 'Montpellier University of Excellence' (MUSE I-Site) gathers the forces of 19 institutions towards a common ambition: create a thematic research-intensive university that will be internationally recognised for its impact in the fields of **agriculture, environment and health**. In 2019, the University made it in the top 300 of the world's best universities and first in the Shanghai world ranking in ecology. CIRAD and INRA, members of the MUSE I-Site and co-organisers of the congress, are proud to be associated to this world recognition. Together with their partners from Agropolis International, World Agroforestry and the MUSE I-Site, they have worked hard to prepare your congress and make your stay in the South of France a memorable one.

We will offer you the most recent national and international developments in agroforestry. Over three days at the Corum Conference Centre, you will have the possibility to listen, to discuss and to exchange about the concepts and the discoveries in your own field of research and beyond. You will be able to listen to world-class keynote speakers addressing major world challenges such as climate change, food security and sustainable development goals, under an agroforestry lens. You will be confronted to the successes and failures of agroforestry research and challenged by innovative approaches for tomorrow's research.

The scientific programme is organised with plenary and parallel sessions covering a wide range of topics: climate change, biodiversity, agroecology, land degradation and restoration, public policies, adoption, finance, germplasm, landscapes, etc.

Side-events, field trips and a rich social programme will keep you busy during an entire week in order to make sure that students, science researchers, policy makers, donors, and professionals from agroforestry exchange and discuss.

We thank our many sponsors that generously support us to 'Make our planet treed again!'. You can visit their exhibition stands in the lobby.

Enjoy your scientific journey in Montpellier and take time to discover a modern, 1.000 year-old city!

Emmanuel Torquebiau (CIRAD) and
Christian Dupraz (INRA)
On behalf of the Organising and Scientific Committees

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From left to right: Nathalie Villemejeanne, Sylvain Rafflegeau, Brigitte Cabantous, Laure Corbarieu, Nathalie Curiallet, Emmanuel Torquebiau, Sandrine Renoir, Christian Dupraz, Marie Gosme

ORGANISERS

CIRAD
Centre de coopération internationale en recherche agronomique pour le développement
https://www.cirad.fr
42 rue Scheffer
75016 Paris - France

Avenue Agropolis
34398 Montpellier Cedex 5 - France

INRA
Institut National de la Recherche Agronomique
http://institut.inra.fr
147 rue de l'Université
75007 Paris - France

2 place Pierre Viala
34000 Montpellier - France

World Agroforestry
https://www.worldagroforestry.org
United Nations Avenue
Nairobi 00100 - Kenya

Agropolis International
https://www.agropolis.fr
1000 Avenue Agropolis
34394 Montpellier Cedex 5 - France

MUSE
Montpellier Université d'excellence
https://muse.edu.umontpellier.fr
163 rue Auguste Broussonnet
34090 Montpellier - France

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EXHIBITORS

Sunday 19 May		Monday 20 May	
	PRE-CONGRESS EVENTS	⏲	PLENARY SESSIONS
10:00 AM - 5:00 PM	*Corum Conference Centre level 3 (Esplanade) & level 2* Conferences & various events on Agroforestry for the general public (in French) *'Des arbres dans nos assiettes'*	8:00 AM 9:00 AM	**Welcome desk opening** *Hall (level 0)* **P1 - Opening Plenary** *(Plenary talks)* *Berlioz auditor. (level 0)*
		10:30 AM	**Coffee break** *(level 0, 1, 2)*
		11:00 AM	**P2 - Agroforestry and climate change** *(Short talks + round table)*
		12:30	**Lunch** *(level 3)*
		⏲	PLENARY SESSIONS
		2:00 PM	**P3 - Agroforestry, Food security and Nutrition** *(Plenary talks)* *Berlioz auditor. (level 0)*
3:00 PM	**CONGRESS CHECK-IN** *Berlioz Hall (level 0)* **& Poster installation** *(level 0, 1, 2)* **& Side-events** *(level 1)*	4:00 PM	**Coffee break** *(level 0, 1, 2)*
		4:30 PM	**P4 - Agroforestry funding and the private sector** *(Short talks + round table)* *Berlioz auditor. (level 0)*
		6:00 PM	Opening of Posters exhibition & European Agroforestry Tour *(level 0, 1, 2)*
6:30 PM	**Welcome drink** ***at the Botanical Garden***	6:30 PM	**Side-events**

	Tuesday 21 May		Wednesday 22 May
	11 PARALLEL SESSIONS		11 PARALLEL SESSIONS
8:00 8:30 AM	**Welcome desk opening** *Hall (level 0)* **L10.1** - AF in practice **L2.1** - Adaptation to CC **L4.1** - Biodiversity **L13.1** - Adoption **L3** - Land Degradation **L12.1** - Economics of AF **L18** - Annual crops AF **L22** - Pests & diseases **L25** - Open session **L15** - Urban AF **L14** - AF landscapes	8:00 8:30 AM	**Welcome desk opening** *Hall (level 0)* **L1.2** - Mitigating CC **L2.2** - Adaptation to CC **L13.2** - Adoption **L17.2** - Perennial Crops AF **L19** - Silvopastoralism **L21** - AF Germplasm **L9** - Value chains **L24** - Modelling **L20** - Agroecology **L23** - Root issues **L7** - Jobs & business
10:00 AM	POSTERS SESSIONS & **Coffee break** (level 0, 1, 2)	10:00 AM	POSTERS SESSIONS & **Coffee break** (level 0, 1, 2)
11:00 AM	***Parallel sessions*** *(continued)*	11:00 AM	***Parallel sessions*** *(continued)*
12:15	**Lunch** (level 3)	12:15	**Lunch** (level 3)
	11 PARALLEL SESSIONS		PLENARY SESSIONS
2:15 PM	**L10.2** - AF in practice **L1.1** - Mitigating CC **L4.2** - Biodiversity **L17.1** - Perennial Crops AF **L12.2** - Economics of AF **L11** - Public policies **L5** - Water **L16** - AF mapping **L6** - Social issues **L8** - Scaling up	2:00 PM	**P5 - Agroforestry and Sustainable Development Goals** *(Plenary talks)* *Berlioz auditor. (level 0)*
3:30 PM	POSTERS SESSIONS & **Coffee break** (level 0, 1, 2)	3:30 PM	**Coffee break** *(level 0, 1, 2)*
4:30 PM - 6:00 PM	• ***Parallel sessions*** *(continued)* including **L26** 'The European Agro-forestry Innovation AFINET network' *Room Joffre 4*	4:00 PM 5:30 6:00 6:15 PM	**P6 - A road map for agroforestry** *(Plenary talks)* *Berlioz auditor. (level 0)* **Tribute to PK Nair** **Congress wrap-up + Poster prizes** **Award Ceremony: Agropolis Fondation Louis Malassis + OLAM prizes**
		6:45 PM	**Free time for dinner** (not included)
7:00 PM	**Congress evening reception** (optional)	8:45 PM	**Cultural evening** *Pasteur auditor. (level 1)*

Thursday 23 & Friday 24 May

Thursday 23 May

8:00 to 9:00 AM

Departure for 1-day and 2-day Field trips

9:00 PM

Centre Rabelais

Film projection and round table on cocoa agroforestry

(open to all)

Friday 24 May

2-day Field trips

(continued)

9:00 PM

Centre Rabelais

Make our planet treed again!

Agroforestry films and debate

(open to all)

PARALLEL SESSIONS

- L1.1 - L2.1 - L20: Einstein auditor. (level 0)
- L2.2 - L3 - L8: Room Antigone 1 (level 2)
- L4.1 - L4.2 - L9: Room Antigone 3 (level 2)
- L13.1 - L17.1 - L24: Room Barthez (level 2)
- L21 - L25 - L26: Room Joffre 4 (level 1)
- L5 - L13.2 - L14: Room Joffre 5 (level 1)
- L12.1 - L12.2 - L19: Room Joffre A (level 1)
- L11 - L18 - L23: Room Joffre B (level 1)
- L6 - L22 - L17.2: Room Joffre C (level 1)
- L7 - L15 - L16: Room Joffre D (level 1)
- L1.2 - L10.1 - L10.2: Room Rondelet (level 2)

Sunday 19 May

3:00 PM to 6:00 PM **Congress check-in** (Berlioz hall, level 0) **& Poster installation** (levels 0, 1 & 2) **& Side-events**

6:30 PM **Welcome drink** — Botanical Garden

Monday 20 May

8:00 AM **Welcome desk opening** — Berlioz hall, level 0

Berlioz auditorium, level 0

9:00 AM **Opening Plenary**

Chaired by Karen Coleman

Plenary talks

- Philippe Saurel - Mayor of Montpellier and President of Montpellier Mediterranée Métropole
- Vincent Labarthe - Vice-president in charge of Agriculture of the Occitanie Region, France
- Philippe Augé - President of University of Montpellier
- Michel Eddi - President Managing Director, CIRAD
- Philippe Mauguin - President Managing Director, INRA
- Maria-Helena Semedo - Deputy Director General, FAO
- Rosalie Matondo - Minister of Forest Economics, Republic of the Congo
- H.E Dr. Eyasu Abraha Alle - State Minister of Agriculture and Natural Resource of Ethiopia
- Didier Guillaume - Minister for Agriculture and Food, France

- Christian Dupraz - INRA, Chair, 4th World Agroforestry Congress Scientific Committee
- Virendra Pal Singh - Chair, Third World Agroforestry Congress (2014), New-Delhi, India

10:30 AM **Coffee break** — Levels 0, 1 & 2

Berlioz auditorium, level 0

11:00 AM **Plenary session 2 - Agroforestry and climate change**

Moderated by Karen Coleman and chaired by John Vidal

Short talks + round table

- Cheikh Mbow - Executive Director of START-International
- Seydou Kaboré - Manager of the Guié Agroforestry farm, Burkina Faso
- Margaret Muchanga - Farmer, Kenya
- Chad Frischmann - Vice President & Research Director, Drawdown
- Sarah Magida Toumi - Tunisian Entrepreneur, Desertification and Tree planting

12:30 AM **Lunch** — Level 3

Monday 20 May

Berlioz auditorium, level 0

2:00 PM **Plenary Session 3 - Agroforestry, Food security and Nutrition**
Moderated by Karen Coleman and chaired by Patrick Worms

Plenary talks

- H.E Dr. Eyasu Abraha Alle - State Minister of Agriculture and Natural Resource of Ethiopia
- Saul Morris - Director of Programme Services, Global Alliance for Improved Nutrition (GAIN)
- Andrew Campbell - Chief Executive Officer, Australian Centre for International Agricultural Research
- Catherine Muthuri - World Agroforestry
- Kami Melvani - Charles Darwin University
- Rowan Reid - Farmer, Author of 'Heartwood: the art and science of growing trees for profit'
- Gary S. May - Chancellor, University of California Davis
- Patrick Caron - Chairperson, High Level Panel of Experts of the UN Committee on world Food Security, Vice President, University of Montpellier

4:00 PM **Coffee break** Levels 0, 1 & 2

Berlioz auditorium, level 0

4:30 PM **Plenary Session 4 - Agroforestry funding and the private sector**
Moderated by Karen Coleman and chaired by Erik Hoffner

Short talks + round table

- Hervé Bourguignon - Moringa Fund
- Tony Simons - Director General, World Agroforestry
- Rachel Kolbe Semhoun - Strategic Plan Manager, Fondation INVIVO
- Jean-Manuel Bluet - Vice-chair of Alliance pour la Préservation des Forêts, Director of Sustainable Development at Nestlé France
- Tristan Lecomte - PurProjet

6:00 PM to 7:00 PM **Opening of Poster Exhibition & European Agroforestry Tour by EURAF** Levels 0, 1 & 2

6:30 PM **Side-events**


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Tuesday 21 May

8:00 AM **Welcome desk opening** Berlioz hall, level 0

PARALLEL SESSIONS

8:30 AM **Room Rondelet (level 2)**

L10.1 - Agroforestry in practice

Chairs: Hesti Tata & Raju Soolanayakanahally

Keynote talk

- LEGESSE KURA Abiyot - Dilla, Ethiopia: Changes and continuities of Indigenous Agroforestry Knowledge of the Gedeo people, Southern Ethiopia

Regular talks

- SOUSA Fernando - Sikasso, Mali: Effects of Gliricidia sepium agroforestry systems associated with maize, cotton and sorghum on soil productivity in Mali
- PARIS Pierluigi - Porano, Italy: Hybrid poplars for timber with arable crops in Italy: innovating the tradition facing Global Changes
- GODARD Léo - Cananéia, Brazil: Transition to agroforestry in a large-scale project, challenges and results, example of the São Pedro Farm in Brazil
- SURENDRA Sharma - Dehradun, India: Benefits of practicing agroforestry - a case study from India

8:30 AM **Einstein auditorium (level 0)**

L2.1 - Agroforestry and adaptation to climate change

Chairs: Marie Gosme & Adolfo Rosati

Keynote talk

- MOREL Alexandra - London, United Kingdom: A framework for resilience to climate shocks in agroforestry systems

Regular talks

- KINDT Roeland - Nairobi, Kenya: Towards a climate change atlas for Africa: results of ensemble suitability modelling for 150+ native tree species
- GOSME Marie - Montpellier, France: Diachronic study of the effect of growing trees on grapevine yield: 24 years of experience in the South of France
- ASHEBER Merry Negasi - Mekelle City, Ethiopia: Gender based impacts of climate change and adaptation strategies
- GNONLONFOUN Isidore - Cotonou, Benin: Farmers' perception of vulnerability and resilience of agroforestry systems to climate change in Benin, West Africa

8:30 AM **Room Antigone 3 (level 2)**

L4.1 - Agroforestry and biodiversity conservation

Chairs: Alejandra Martínez-Salinas & Olivier Deheuvels

Keynote talk

- ROUSSEAU Guillaume - São Luis, Brazil: Tree and litter composition influences soil macrofauna in multi-strata agroforestry systems of Talamanca, Costa Rica

Regular talks

- ACHARYA Bhoj K. - Gangtok, India: Alpha and beta diversity patterns of butterflies along forest-agroecosystem gradient in Sikkim Himalaya, India
- BOINOT Sébastien - Montpellier, France: Plant diversity in understory vegetation strips of alley cropping agroforestry systems
- GUILLERME Sylvie - Toulouse, France: Agroforestry and beekeeper-agriculturist relations in arable land (France)
- DEHEUVELS Olivier - Cajica, Colombia: Plant diversity level does not affect cocoa productivity: The case of Colombian agroforestry systems

8:30 AM **Room Barthez (level 2)**

L13.1 - Socio-economic and cultural constraints on technology adoption in agroforestry systems

Chair: George Curry

Keynote talk

- CURRY George - Perth, Australia: Breaking open the black box: the socioeconomic factors explaining adoption or rejection of innovations in agroforestry

Regular talks

- PROAÑO Rossana - Quito, Ecuador: Integrated farm planning and its potential to motivate the adoption of agroforestry practices in Ecuador
- DHAKAL Arun - Kathmandu, Nepal: Examining the likelihood of agroforestry adoption with respect to conventional agriculture in Dhanusha district of Nepal
- BROCKINGTON James - Bangor, United Kingdom: The importance of farmers' attitudes for the adoption of agroforestry: a case study in India
- JACOBSON Michael - University Park, United States: The (un)broken promise of agroforestry: case study of adoption of improved fallows in Zambia

8:30 AM **Room Antigone 1 (level 2)**

L3 - Agroforestry for combating land degradation and desertification in dry areas

Chairs: Alain Olivier & Paxie Chirwa

Keynote talk

- APPLEGATE Grahame - Maroochydore, Australia: Investment in agroforestry systems as an integral component of tropical peatland restoration

Regular talks

- NYIRENDA Harrington - Salima, Malawi: Land use and management effects on vegetation characteristics and termite distribution in Malawian Miombo ecosystems
- KHAN Sahibzada Irfanullah - Islamabad, Pakistan: Agroforestry in Dryland: Supporting Farmer Initiatives for Rehabilitation of Degraded Arable Lands
- CELENTANO Danielle - Sao Luis, Brazil: Agroforestry Systems for land restoration and food security in eastern Amazon

8:30 AM **Room Joffre A (level 1)**

L12.1 - Economics of agroforestry: the link between nature and society

Chairs: Michael Jacobson & Nathalie Cialdella

Keynote talk

- GOSLING Elizabeth - Freising, Germany: Robust land-use modelling informed by farmer knowledge – assessing the socio-economic potential of agroforestry systems

Regular talks

- PENOT Eric - Montpellier, France: Beyond economic advantages of agroforestry systems: what role and place of externalities in farmers' strategies?
- GASSNER Anja - Laguna, Philippines: Rethinking agroforestry - Shifting the income incentives from the agricultural component to the tree component
- PENOT Eric - Montpellier, France: A holistic approach to analyze agroforestry heterogeneity at the cropping system and landscape scales in Madagascar
- FEINTRENIE Laurène - Turrialba, Costa Rica: Forest or agroforestry systems, farmers value trees for ecosystem services provision in Nicaragua

8:30 AM **Room Joffre B (level 1)**

L18 - Cereals and annual crops in agroforestry

Chairs: Shibu Jose, Delphine Mézière & Andrea Vityi

Keynote talk

- PARDON Paul - Merelbeke, Belgium: Silvoarable agroforestry systems in temperate regions: impact of tree rows on crops, soil and biodiversity

Regular talks

- GILL Rishi - Ludhiana, India: Interventions to improve productivity and sustainability of poplar-based agroforestry system in Indo Gangetic plains
- ARENAS-CORRALIZA M. Guadalupe - Plasencia, Spain: Shade improves physiological performance and grain yield in barley cultivars in central Spain
- PANOZZO Anna - Legnaro (PD), Italy: Durum wheat in an olive orchard: impact on yield, yield components and morphology of different durum wheat cultivars
- MARTINEZ-GARCIA Jaume - Bellaterra, Spain: How to deal with too close neighbors: from model systems to crops

8:30 AM **Room Joffre C (level 1)**

L22 - Agroforestry: pests, diseases and weeds

Chairs: Jacques Avelino & Rolando Cerda

Keynote talk

- SOW Ahmadou - Montpellier, France: Vertebrates contribute to natural control of the millet head miner in tree-crop agroforestry systems

Regular talks

- DURAND-BESSART Clémentine - Montpellier, France: Analysis of the interactions of shade trees on coffee leaf diseases and coffee yield in complex agroforestry systems
- MOTISI Natacha - Montpellier, France: Antagonistic effects of shade on the epidemiological mechanisms driving coffee berry disease
- IMBERT Camille - Avignon, France: Pests, but not predators, increase in mixed apple tree - cabbage plots as compared to control cabbage plots
- MERLE Isabelle - Montpellier, France: Estimating microclimate in agroforestry systems based on nearby full sun measures to forecast coffee rust development

8:30 AM **Room Joffre 4 (level 1)**

L25 - Open session

Chairs: Virendra Pal Singh & Patrick Jagoret

Keynote talk

- DUPRAZ Christian - Montpellier, France: From Agroforestry to Agrivoltaism : an extension of the mixture concept

Regular talks

- ASMARA Degi Harja - Quebec City, Canada: Agroforestry on post-mining restoration: a multispecies and multifunctional approach
- LANDICHO Leila - College, Philippines: Agroforestry and Food Security of Households in Selected Upland Farming Communities in the Philippines
- DOUNIAS Edmond - Montpellier, France: Eliciting Children's culture: Sustainable hunting in backyard agroforests by budding trappers in the Congo Basin
- MELVANI Kamal - Darwin, Australia: Farmers' values sustain forest gardens

8:30 AM **Room Joffre D (level 1)**

L15 - Urban and peri-urban agroforestry for food and nutritional security

Chairs: Mohan B Kumar, Simone Borelli & Hubert de Foresta

Keynote talk

- MOLLEE Eefke - Bangor, United Kingdom: Linking urban homegarden agroforestry and child nutrition: A case study from Kampala, Uganda

Regular talks

- SCHULZ Jennifer - Potsdam, Germany: Food forests as complex agroforestry systems for creating multifunctional urban green spaces through community gardening
- LA MANTIA Tommaso - Palermo, Italy: The ancient urban agroforestry systems of the Conca d'Oro (Palermo, Italy) need protection to defend the city
- RIMLINGER Aurore - Montpellier, France: Genetic diversity of a tropical fruit tree (Dacryodes edulis), from Yaoundé home gardens to Cameroonian agroforests
- MCMULLIN Stepha - Nairobi, Kenya: Filling food harvest and nutrient 'gaps' in local diets through site specific food tree and crop portfolios

8:30 AM **Room Joffre 5 (level 1)**

L14 - Agroforestry landscapes

Benefits of Landscape Strategies for Agroforestry

Chairs: Tobias Plieninger & Louise Buck

Keynote talk

- BUCK Louise - Ithaca, United States: Scaling-up agroforestry to transform landscapes, with examples from Ecuador and Northeast USA

Regular talks

- ZINNGREBE Yves - Göttingen, Germany: Trees on Farms as a negotiation tool to bridge food production and conservation goals
- KAY Sonja - Zürich, Switzerland: Benefits of temperate agroforestry landscapes - economic evaluation of the marketable and the non-marketable outcomes
- ORDONEZ Maria - Bogota, Colombia: Agroforestry for Conservation: planning sustainable landscapes in the Colombian Amazon
- BORIES Olivier - Toulouse, France: Filming agroforestry: producers shaping landscapes

10:00 AM **Poster sessions & Coffee break** — **Levels 0, 1 & 2**

PARALLEL SESSIONS (continued)

11:00 AM **Room Rondelet (level 2)**

L10.1 - Agroforestry in practice

Chairs: Hesti Tata & Raju Soolanayakanahally

Regular talks

- PRAMESWARI Diana - Bogor, Indonesia: Sustaining economic and ecological contribution to local community through participatory agroforestry practice
- IVEZIĆ Vladimir - Osijek, Croatia: Walnut and crop yields in walnut orchards intercropped with wheat
- DO Hung - Hanoi, Vietnam: Assessment of the economic and environmental benefits of on-farm agroforestry practice in Northwest Vietnam
- DURAND Lucie - Paris, France: Activity analysis of coffee growers in complex agroforestry systems, understanding the farmers' practices
- DUGUMA Lalisa - Nairobi, Kenya: Changing the discourse from 'tree planting' to 'tree growing' to achieve restoration targets through agroforestry

11:00 AM

Einstein auditorium (level 0)

L2.1 - Agroforestry and adaptation to climate change

Chairs: Marie Gosme & Adolfo Rosati

Regular talks

- CÓRDOVA Raúl - Quito, Ecuador: Sustainability and vulnerability to climate change of small-holding agroforestry systems in tropical highlands, Ecuador
- GEORGE Anjaly - Thrissur, India: Impact of past climate change and socio-economic drivers on different crops in agroforestry systems of Wayanad, India
- BORDEN Kira - Toronto, Canada: Shade trees affect soil resource acquisition strategies of cocoa in suboptimal climates
- GIDEY BEZABEH Tesfay - Adigrat, Ethiopia: Using Yield-SAFE model to assess impacts of climate change on yield of Coffee under agroforestry and monoculture systems
- SESERMAN Diana-Maria - Cottbus, Germany: Growth vulnerability of hybrid-poplar and black locust to prospective climatic changes

11:00 AM

Room Antigone 3 (level 2)

L4.1 - Agroforestry and biodiversity conservation

Chairs: Alejandra Martínez-Salinas & Olivier Deheuvels

Regular talks

- KISS-SZIGETI Nóra - Sopron, Hungary: Ecological role of grassy and forest habitats in soil-related biodiversity in an intensive agricultural area
- YUNG Loïc - Montbéliard, France: Taxonomic and functional diversity of insects within a nettle-poplar plantation on a sediment landfill
- ANDRIEU Emilie - Castanet Tolosan, France: How trees in agricultural landscapes structure pollinator communities ?
- RACHMAWATI Rina - Malang, Indonesia: The effect of land use types on insect diversity and composition in tropical agroforestry system
- SALAKO Kolawolé Valère - Cotonou, Benin: Homegardens in Benin: countrywide flora and contribution to conservation of threatened species and crop wild relatives

11:00 AM

Room Barthez (level 2)

L13.1 - Socio-economic and cultural constraints on technology adoption in agroforestry systems

Chairs: Chair: George Curry

Regular talks

- NUNOO Isaac - Kumasi, Ghana: Factors influencing the adaption of agroforestry systems in mitigating climate change in Ghana: Case of Bongo District
- LABANT Pierre - Les Quatre Routes du Lot, France: Agroforestry at the crossroads of fields
- ISRAELY Liron - Hararit, Israel: Social marketing of agricultural practices supporting biodiversity conservation
- DUFFY Colm - Galway, Ireland: Agroforestry Extension and Gender Impacts on Self Rated Knowledge
- UMEMURA Helio Makoto - Fuchu, Japan: How can we accelerate shade tree planting on West African cocoa family farms for mitigating the rapid climate change?

11:00 AM

Room Antigone 1 (level 2)

L3 - Agroforestry for combating land degradation and desertification in dry areas

Chairs: Alain Olivier & Paxie Chirwa

Regular talks

- BAYALA Roger - Thies, Senegal: Association with Guiera senegalensis speeds up crop development in a Sahelian agroforestry system
- SHEPHERD Keith - Nairobi, Kenya: Measuring changes in soil health under agroforestry

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- MIHĂILĂ Elena - Voluntari, Romania: Shelterbelts for crop protection as the main type of agroforestry system in Romania
- BA Ousseynou - Dakar, Senegal: Valorisation of salty soils by using phosphogypsum and peanut shell on growth of 3 forest trees under salt conditions
- SAKAI Yuji - Hachioji-shi, Japan: Afforestation and agricultural production through salt-affected soil amelioration with coal bio-briquette ash in China

11:00 AM **Room Joffre A (level 1)**

L12.1 - Economics of agroforestry: the link between nature and society

Chairs: Michael Jacobson & Nathalie Cialdella

Regular talks

- FAYE MANE Ndeye Fatou - Dakar, Senegal: Planting trees to increase food security? The case study of the groundnut basin of Senegal
- MAKOVSKIS Kristaps - Salaspis, Latvia: Different tree specie and management system economics as buffer zones in Baltic climate conditions
- SMITH Joanne - Newbury, United Kingdom: Making hedgerows pay their way: the economics of harvesting hedges for bioenergy
- PADOVAN Maria Penha - Vitoria, Brazil: Dealing with financial constraints in a complex agroforestry system in the Brazilian rainforest
- PARROT Laurent - Montpellier, France: The Alliance Approach to Innovation in agro-forestry: Agro-ecological innovations, Alliance, and Agency

11:00 AM **Room Joffre B (level 1)**

L18 - Cereals and annual crops in agroforestry

Chairs: Shibu Jose, Delphine Mézière & Andrea Vityi

Regular talks

- FALL Dioumacor - Bambey, Senegal: Importance and trees management of Senegalia senegal on soil fertility and yield of associated crops in northern Senegal
- PONTES Laíse - Ponta Grossa, Brazil: Corn yield in different integrated crop-livestock systems: the effect of shade
- BÉRAL Camille - Anduze, France: Agroforestry impacts tomatoes production in a vegetable organic alley cropping temperate system
- HODGE Kim - Regina, Canada: Measuring impact of shelterbelts on canola yield in the Canadian Prairies
- TEMANI Fida - Montpellier, France: Effect of water gradient on the intensity of competition and productivity of annual crops intercropped with olive trees

11:00 AM **Room Joffre C (level 1)**

L22 - Agroforestry: pests, diseases and weeds

Chairs: Jacques Avelino & Rolando Cerda

Regular talks

- CERDA Rolando - Turrialba, Costa Rica: Coffee agroforestry systems that reduce crop losses due to pests and diseases, while providing ecosystem services
- AVELINO Jacques - Turrialba, Costa Rica: Shade effects on coffee rust (Hemileia vastatrix)
- SCHNEIDER Monika - Frick, Switzerland: Do cacao agroforestry systems increase pest and disease incidence? Evidences from a long-term system comparison trial
- ALWORA Getrude - Ruiru, Kenya: Shade and leaf retention: an aspect of effective Coffee Leaf Rust management
- AKOUTOU MVONDO Etienne - Yaoundé, Cameroon: Effects of complex cocoa-based agroforests on Citrus trees dieback

11:00 AM **Room Joffre 4 (level 1)**

L25 - Open session

Chairs: Virendra Pal Singh & Patrick Jagoret

Regular talks

- TSHIDZUMBA Phillip - Pretoria, South Africa: The potential of introducing multipurpose trees in the rural landscapes of KwaZulu-Natal, South Africa
- KAFOUTCHONI Konoutan - Cotonou, Benin: Species Richness, Cultural Importance and Prioritization of Wild Spices for Conservation in Benin (West Africa)
- WARLOP François - St-Marcel-Lès-Valence, France: DEXiAF: a new ex-ante assessment tool for co-designing sustainable agroforestry systems
- OLLIVIER Guillaume - Avignon, France: Mapping the structuration of topical communities in Agroforestry research. A scientometric overview
- GUILLET Philippe - Le Mans, France: Why farmers are not adopting agroforestry systems? To a hazy future of our trees…

11:00 AM **Room Joffre D (level 1)**

L15 - Urban and peri-urban agroforestry for food and nutritional security

Chairs: Mohan B Kumar, Simone Borelli & Hubert de Foresta

Regular talks

- GONZALEZ DE LINARES Paloma - Budapest, Hungary: Planning multipurpose trees in the city
- LACOURT Simon - Versailles, France: Preparing Potager du Roi of Versailles for the future. A historical kitchen garden in an urbanized setting
- LLEWELLYN Elizabeth - Cape Town, South Africa: Agroforestry and Urban Policy Development: case studies of home gardens in the Cape Flats, South Africa
- MUJURU Lizzie - Bindura, Zimbabwe: Urban agroforestry: potential for climate change adaptation and mitigation
- LAMICHHANE Dhananjaya - Kathmandu, Nepal: Growing Agroforestry Crops in Peri-urban Areas of New Cities : Ignored or Forgotten?

11:00 AM **Room Joffre 5 (level 1)**

L14 - Agroforestry landscapes

Sociological and Biophysical Processes in Agroforestry Landscapes

Chairs: Tobias Plieninger & Louise Buck

Regular talks

- DUMRONGROJWATTHANA Pongchai - Bangkok, Thailand: Land use change and driving factors in a fragile coastal rainfed lowland rice - sugar palm system of southern Thailand
- AUMEERUDDY-THOMAS Yildiz - Montpellier, France: Agroforestry within broader anthropogenic landscapes: indigenous and local knowledge, concepts and practices
- TUBENCHLAK Fernanda - Rio de Janeiro, Brazil: (Agro)Forest Transitions: Upscaling Landscape Restoration through Agroforestry
- ARCA Bachisio - Sassari, Italy: Application of wildfire simulators for the management and protection of Mediterranean agroforestry systems
- PAUL Carola - Göttingen, Germany: Can agroforestry enhance multiple ecosystem services? Examples from a modelling approach in three tropical landscapes

12:15 AM **Lunch** **Level 3**

PARALLEL SESSIONS

2:15 PM **Room Rondelet (level 2)**

L10.2 - Agroforestry in practice

Chairs: Lojka Bohdan & Raju Soolanayakanahally

Keynote talk

- MEINHOLD Kathrin - Kleve, Germany: Agroforestry food product development: enhancing food security and livelihoods using the baobab tree in Kilifi, Kenya

Regular talks

- KUYAH Shem - Nairobi, Kenya: Can agroforestry enhance ecosystem services provision without reducing productivity?
- MUGENDI Daniel - Embu, Kenya: Long-term effects of hedgerow intercropping on maize productivity in the central highlands of Kenya
- ASADI Farhad - Sari, Iran: Effect of spacing on the yield in intercropping of poplar and alfalfa (case study: Alborz Research Station, Karaj, Iran)

2:15 PM **Einstein auditorium (level 0)**

L1.1 - Mitigating climate change with agroforestry

Chairs: Rémi Cardinael & Maren Oelberman

Keynote talk

- HÜBNER Rico - Freising, Germany: China's legacy in agroforestry may help to combat climate change: a meta-analysis of soil carbon sequestration rates

Regular talks

- BREWER Kelsey - Davis, United States: Impacts of sheep integration on carbon sequestration and soil health in Northern California coastal vineyard systems
- RASOARINAIVO Angelina Rondrotsifantenana - Antananarivo, Madagascar: Does soil carbon storage in agroforestry reach the 4 per 1000 objectives? A diachronic analysis in Madagascar
- BAZRGAR Amir Behzad - Guelph, Canada: Long-term monitoring of soil carbon sequestration in woody and herbaceous bioenergy crop production systems in Canada

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2:15 PM **Room Antigone 3 (level 2)**

L4.2 - Agroforestry and biodiversity conservation

Chairs: Kushalappa Cheppurida & Olivier Deheuvels

Keynote talk

- KULKARNI Charuta - Milton Keynes, United Kingdom: EARNEST: Examining the agroforestry landscape resilience in India to inform socioecological sustainability in the tropics

Regular talks

- SAMBOU Antoine - Ziguinchor, Senegal: Farmers' contributions to the conservation of tree diversity in the Groundnut Basin, Senegal
- SIMAMORA Trifosa Iin - Bogor Barat, Indonesia: Biodiversity conservation value of swidden agroforestry systems vs. RSPO oil palm in West Kalimantan, Indonesia
- MILZ Joachim - La Paz, Bolivia: Dynamic agroforestry, a systemic approach of farming in the tropics improving biodiversity, soil fertility and yields

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2:15 PM **Room Barthez (level 2)**

L17.1 - Challenges, opportunities and trade-offs of agroforestry with perennial crops

Chairs: Philippe Vaast & Eduardo Somarriba

Keynote talk

- ASARE Rebecca - Accra, Ghana: The research and policy pathway to climate-smart cocoa and REDD+ in Ghana

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Regular talks

- GARCIA Claude - Zurich, Switzerland: Understanding coffee farmers: using games to explore future coffee agroforestry landscapes in the Western Ghats (India)
- KRISHNAN Smitha - Bangalore, India: Ecological and agricultural intensification and the associated trade-offs on coffee pollination and fruit-set
- JAGORET Patrick - Montpellier, France: Agroforestry: Lifeline of world cocoa production. Utopia or credible alternative?

2:15 PM **Room Joffre A (level 1)**

L12.2 - Economics of agroforestry: the link between nature and society

Chairs: Eric Penot & Nathalie Cialdella

Keynote talk

- MELVANI Kamal - Darwin, Australia: Forest gardens increase the financial viability of farming enterprises

Regular talks

- ESTEGHAMAT Mina - Tehran, Iran: Traditional agroforestry as a sustainable customary land use system in the protected and conserved areas of Iran
- KUMAR Sanjeev - Hazaribagh, India: Agroforestry as a source of enhancement of livelihood options in rural areas of Jharkhand state of India
- DIAZ Javier - La Lima, Honduras: Honduran farmers' perception of cacao agroforestry systems

2:15 PM **Room Joffre B (level 1)**

L11 - Agroforestry in public policies

Chairs: Paul Burgess & Valentina Robiglio

Keynote talk

- SCHULTZ Maria - Stockholm, Sweden: Agroforestry: Linking Local Action, National Policies and Global Frameworks

Regular talks

- MONTES LONDOÑO Irene - Panama, Panama: How public/private investment in processing facilities could increase biodiversity in large agroforest. systems in LATAM
- MAGNIN Léo - Lyon, France: How to protect French hedges? The power of the local agroforestry associations
- LIMA RESQUE Antonio Gabriel - Belem, Brazil: Institutional markets as a driver public policy for the adoption of agroforestry systems in the Brazilian Amazon

2:15 PM **Room Joffre 5 (level 1)**

L5 - Agroforestry for water quality and watershed restoration

Chairs: Norbert Lamersdorf & Naresh Thevathasan

Keynote talk

- UDAWATTA Ranjith - Columbia, United States: A Paired Watershed Evaluation of Agroforestry and Bioenergy Effects on Water Quality on a Corn/Soybean Rotation

Regular talks

- BARDULE Arta - Salaspils, Latvia: Mitigation of macronutrient leaching by agroforestry system of hybrid aspen and perennial grasses
- BASKERVILLE Meg - Elora, Canada: Land-use comparison of temporal greenhouse gas emissions of riparian systems in Southern Ontario, Canada
- DUNFIELD Kari - Guelph, Canada: Shifts in N- cycling microbial communities associated with riparian buffers in Southern Ontario agricultural systems

2:15 PM

Room Joffre D (level 1)

L16 - Agroforestry mapping

Chair: Anthony Kimaro

Keynote talk

- SARRON Julien - Montpellier, France: Plant diversity and productivity in Senegalese mango orchards: evidences from UAV photogrammetry

Regular talks

- MENEGUZZO Dacia - Saint Paul, United States: Agroforestry map products for the central United States
- RIZVI Raza - Jhansi, India: Spatial analysis of area and carbon stock in Populus deltoides based agroforestry systems in Punjab state, India
- NDAO Babacar - Dakar, Senegal: A remote sensing based approach for optimizing sampling strategies in tree monitoring and agroforestry systems mapping

2:15 PM

Room Joffre C (level 1)

L6 - Social issues in Agroforestry systems (gender, migration)

Chairs: Laurène Feintrenie & Delia Catacutan

Keynote talk

- SAWANT Yogesh - Pune, India: Wadi: a agroforestry model for transforming lives and livelihoods

Regular talks

- SMITH DUMONT Emilie - Nairobi, Kenya: Gender relations at the forest-farm interface in West Africa: prospects for transformative processes in agroforestry
- KEITA Saran - Conakry, Guinea: 'Silakouda' or how rural women's entrepreneurship preserves and values a local agroforestry resource in Upper Guinea
- VAN NOORDWIJK Meine - Bogor, Indonesia: Migration, gender and agroforestry in Indonesia

2:15 PM

Room Antigone 1 (level 2)

L8 - Scaling up of agroforestry innovations

Chairs: Kiros Hadgu & Josiane Seghieri

Keynote talk

- BARTLETT Tony - Deakin, Australia: Achieving transformational impact from agroforestry research

Regular talks

- FERREIRA Joice - Belem, Brazil: Potential for managing natural regeneration by family farmers in the Amazon: making the most of biodiversity
- ARAIA Woldeamlak - Keren, Eritrea: Agroforestry systems and research in Eritrea: Review of concepts, practices and research findings
- CROSSLAND Mary - Bangor, United Kingdom: Developing livelihood trajectory models for screening and scaling agroforestry options

3:30 PM **Poster sessions & Coffee break** Levels 0, 1 & 2

PARALLEL SESSIONS (continued)

4:30 PM to 6:00 PM

Room Rondelet (level 2)

L10.2 - Agroforestry in practice

Chairs: Lojka Bohdan & Raju Soolanayakanahally

Regular talks

- LI Joanne - Hong Kong SAR, China: Rubber-Based Agroforestry System in South China: Gaining Ground with Farmers

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- ARI Susanti - Yogyakarta, Indonesia: Smallholders' oil palm agroforestry adoption: an opportunity to improve productivity and sustainability?
- GUILLET Philippe - Le Mans, France: 30 years of agroforestry poultry system against climate change in Sarthe (West of France)
- CERDÁN Carlos R. - Ibagué, Colombia: Evaluation of chronological changes of trees and coffee bushes in permanent plots within a gradient of coffee management
- AMATYA Swoyambhu Man - Kathmandu, Nepal: What Sustains Nepalese Agroforestry Practices?
- NYAGA John - Nairobi, Kenya: Evaluating factors influencing heterogeneity in agroforestry adoption and practices within smallholder farms in Kenya

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4:30 PM to 6:00 PM

Einstein auditorium (level 0)

L1.1 - Mitigating climate change with agroforestry

Chairs: Rémi Cardinael & Maren Oelberman

Regular talks

- NAVARRETE Diego - Bogota, Colombia: Agroforestry for conservation: mitigating climate change in the Colombian Amazon
- LANG Rong - Stuttgart, Germany: Converting natural forest to rubber plantations affects soil CO2 and CH4 fluxes
- MENICHETTI Lorenzo - Uppsala, Sweden: A nonlinear method to estimate the agroforestry sequestration potentia
- MORENO Gerardo - Plasencia, Spain: Carbon sequestration of Iberian dehesas offsets emissions of their livestock
- GUILLOT Esther - Montpellier, France: Soil quality is improved in a Mediterranean agroforestry system compared to a conventional cropping system
- MOSQUERA-LOSADA Maria - Lugo, Spain: Effect of the land use on the carbon storage in the soil fractions in the South of Portugal

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4:30 PM to 6:00 PM

Room Antigone 3 (level 2)

L4.2 - Agroforestry and biodiversity conservation

Chairs: Kushalappa Cheppurida & Olivier Deheuvels

Regular talks

- THIAW Ibrahima - Dakar, Senegal: Tree species effect on natural control of H. albipunctella de Joannis in a millet agroforestry system in Senegal
- VILLANUEVA LÓPEZ Gilberto - Villahermosa, Mexico: The richness of tree in agroforestry systems favors the diversity of soil macroarthropods in the humid tropics of Mexico
- WURZ Annemarie - Goettingen, Germany: Vanilla boom in North-Eastern Madagascar: A chance for a sustainable land-use transformation?
- SUÁREZ SALAZAR Juan Carlos - Caqueta, Colombia: First typology of cacao agroforests in the Colombian Amazon, based on composition, structure and light availabililty
- COUDEL Emilie - Brazilia, Brazil: Agroforestry as a restoration strategy: Motivations of farmers to plant more biodiverse systems in the Eastern Amazon
- SARI Rika Ratna - Malang, Indonesia: Carbon stocks in agroforestry systems correlate with tree diversity

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4:30 PM to 6:00 PM

Room Barthez (level 2)

L17.1 - Challenges, opportunities and trade-offs of agroforestry with perennial crops

Chairs: Philippe Vaast & Eduardo Somarriba

Regular talks

- BIRKENBERG Athena - Stuttgart, Germany: Accounting for biogenic carbon sequestration in product carbon footprints: analysing trade-offs in a coffee agroforestry
- VAN DEN MEERSCHE Karel - Montpellier, France: Nitrogen fixing shade trees in coffee agroforestry: Quantification of nitrogen transfer to the coffee plant

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- MAI PHUONG Nguyen - Ha Noi, Vietnam: Local knowledge on the role of trees in coffee agroforestry systems of Northwest Vietnam
- RIGAL Clement - Kunming, China: Young shade trees rapidly improve soil fertility in coffee-agroforestry systems
- CERDAN Carlos - Xalapa, Mexico: Traditional Mexican tropical smallholder agroforestry systems: it is possible to intercrop two ancestral crops?
- HARMAND Jean-Michel - Yaounde, Cameroon: Afforestation of savannah with cocoa agroforestry: a climate-smart sustainable agricultural practice

4:30 PM to 6:00 PM

Room Joffre A (level 1)

L12.2 - Economics of agroforestry: the link between nature and society

Chairs: Eric Penot & Nathalie Cialdella

Regular talks

- MASOODI Tariq Hussain - Ganderbal, India: Cultivation of willows for economic and ecological purpose: A sustainable livelihood option in Kashmir
- NOTARO Martin - Villa Altagracia, Dominican Republic: Contribution of plant diversity to farmers' income in cocoa-based agroforestry systems
- ASAYEHEGN Kinfe - Hawassa, Ethiopia: Role of Innovation System in Coffee Agroforestry System to Adapt to Climate Change in Kenyan Coffee and Dairy Sectors
- NUBERG Ian - Urrbrae, Australia: The Contribution of Agroforestry to Food Security in Nepal Mid-hills
- BARLAGNE Carla - Aberdeen, United Kingdom: Social innovation for multifunctional cultivated forests in Guadeloupe: Insights from the VALAB and SIMRA projects
- LE PAGE Christophe - Montpellier, France: Fostering knowledge sharing about agroforestry systems through gaming and simulation in Irituia (Northeast Para, Brasil)

4:30 PM to 6:00 PM

Room Joffre B (level 1)

L11 - Agroforestry in public policies

Chairs: Paul Burgess & Valentina Robiglio

Regular talks

- LAROCHE Genevieve - Quebec, Canada: Policies at work : key public policy features enhancing agroforestry spreading and adoption in Quebec, Canada
- BORELLI Simone - Rome, Italy: Agroforestry in REDD+ and NDCs ways to fulfill the Paris Agreement and reduce deforestation
- LAWSON Gerry - Edinburgh, United Kingdom: European Agroforestry Policy - history and future opportunities
- GARRITY Dennis - Nairobi, Kenya: Policy gaps and opportunities for scaling-up agroforestry in Africa: lessons from the Regreening Africa project
- KUMAR B. Mohan - Thrissur, India: Mainstreaming India's National Agroforestry Policy: Challenges and Opportunities
- CATACUTAN Delia - Bogor, Indonesia: ASEAN Guidelines for Agroforestry Development in the Food, Agriculture and Forestry Sector

4:30 PM to 6:00 PM

Room Joffre 5 (level 1)

L5 - Agroforestry for water quality and watershed restoration

Chairs: Norbert Lamersdorf & Naresh Thevathasan

Regular talks

- CAMERON Ashley - Sherbrooke, Canada: Can we design forested riparian buffer strips to minimize soil greenhouse gas emissions as affected by earthworms?
- BÖHM Christian - Cottbus, Germany: Short rotation riparian strips as an option to protect surface water quality in Germany
- BALAGUER Fabien - Auch, France: The Agr'eau initiative - Main results and perspectives after 6 years of implementation

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- HUNDAL Harkirat - Waterloo, Canada: Quantifying aquatic carbon and nitrogen dynamics and greenhouse gas mitigation potential of riparian agroforestry zones
- MUNSELL John - Blacksburg, United States: Agroforestry and Phosphorus Credit Trading in the U.S.A.'s Chesapeake Bay Watershed
- MATHEZ-STIEFEL Sarah-Lan - Lagos, Portugal: A review of the literature on the relationships between trees, land use, and hydrological processes in the Andes

4:30 PM to 6:00 PM

Room Joffre D (level 1)

L16 - Agroforestry mapping

Chair: Anthony Kimaro

Regular talks

- VERMA Amit Kumar - Dehradun, India: Predicting potential areas across Terai Arc Landscape for the introduction of Poplar based Agroforestry Models .../...
- LAUMONIER Yves - Montpellier, France: Fine-scale mapping and dynamics of cyclic agroforestry agriculture using UAV remote sensing in Borneo
- BROWN Sarah - Urbana, United States: A systematic map of the impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being
- VAN REES Ken - Saskatoon, Canada: Shelterbelts in Canada: century-old agroforestry systems for climate adaptation
- DESCHAMPS Jimena - Mexico, Mexico: New method to mapping coffee cover plantations in the region of Costa de Oaxaca, Mexico

4:30 PM to 6:00 PM

Room Joffre C (level 1)

L6 - Social issues in Agroforestry systems (gender, migration)

Chairs: Laurène Feintrenie & Delia Catacutan

Regular talks

- DROY Isabelle - Bondy, France: Conflicting interests around shea-tree : gender inequalities and degradation of shea parklands in Benin
- ASANTE Winston - Kumasi, Ghana: Gender perspectives of climate change adaptation in smallholder cocoa systems in the techiman municipality of Ghana
- GACHUIRI Agnes - Nairobi, Kenya: Gendered knowledge on food trees for addressing food security and nutrition in Uganda & Kenya
- CIFUENTES Jaime - Turrialba, Costa Rica: The importance of agricultural land uses in the provision of ecosystem services. A gender perspective in Nicaragua
- ZANH Golou Gizèle - Daloa, Ivory Coast: Migration and agricultural practices in the Haut-Sassandra Classified Forest (Midwest of Côte d'Ivoire)
- ADHIKARI Yuvika - Lalitpur Metropolitan City, Nepal: Migration in the Nepalese hills: Prospect for agroforestry and its gender dimensions

4:30 PM to 6:00 PM

Room Antigone 1 (level 2)

L8 - Scaling up of agroforestry innovations

Chairs: Kiros Hadgu & Josiane Seghieri

Regular talks

- SEGHIERI Josiane - Montpellier, France: Roles of Agroforestry in sustainable intensification of small farMs and food SEcurity for SocIetIes in West Africa
- GRIMALDI Juliette - Montpellier, France: How can Research & Development efficiently support the French practitioners of agroforestry?
- VANHANEN Henri - Joensuu, Finland: Opportunities for agroforestry in Finland
- LAROCHE Genevieve - Quebec, Canada: Lessons from the 'Agroforestry and Landscape Laboratory' in Rocher-Percé regional county, Quebec, Canada
- MICCOLIS Andrew - Belém, Brazil: Scaling up oil palm Agroforestry in the Brazilian Amazon: lessons learned from the SAFDENDE Project in Tomé Açu, Pará
- FANTAYE Solomon Kiros - Addis Ababa, Ethiopia: Sustainable grazing options for enhancing accelerated scaling ups and impacts of agroforestry innovations in Ethiopia

4:30 PM to 6:00 PM

Room Joffre 4 (level 1)

L26 - The European Agroforestry Innovation AFINET network: updated news about Agroforestry progresses in Europe

Chair: Anastasia Pantera

Speakers:

- AFINET Results: Rosa Mosquera, 10 min
- AFINET Results in Italy: Andrea Pisanelli, 5 min
- AFINET Results in Belgium Bert Reubens, 5 min
- AFINET Results in UK: Ian Knight, 5 min
- AFINET Results in Portugal: Joana Amaral Paulo, 5 min
- AFINET Results in Hungary: Andrea Vityi, 5 min
- AFINET Results in Poland: Robert Borek, 5 min
- AFINET Results in France: Fabien Balaguer, 5 min
- AFINET Results in Finland: Michael der Herder, 5 min
- AFINET Results in Spain: Nuria Ferreiro and Javier Rodríguez Rigueiro, 5 min
- General discussion: 35 min

7:00 PM **Congress evening reception** (optional) **Domaine des Grands Chais - Mauguio**

Wednesday 22 May

8:00 AM **Welcome desk opening** Berlioz hall, level 0

PARALLEL SESSIONS

8:30 AM **Room Rondelet (level 2)**

L1.2 - Mitigating climate change with agroforestry

Chairs: Georg Cadisch & Rosa Mosquera

Keynote talk

- SHI LINGLING - Kunming, China: Agroforestry systems: Meta-analysis of soil carbon stocks, sequestration processes, and future potentials

Regular talks

- VASCONCELOS Steel - Belem, Brazil: Soil carbon stock is higher in oil palm agroforestry than in monoculture in eastern Amazonia
- NAIR Pk - Gainesville, United States: Soil carbon storage and aggregate-size fractions under agroforestry systems
- CASANOVA-LUGO Fernando - Chetumal, Mexico: Diurnal and seasonal variations on soil CO_2 fluxes in tropical silvopastoral systems
- WEBB Bid - Bangor, United Kingdom: How do hedgerows influence soil organic carbon and carbon budgets in livestock-grazed pasture?

8:30 AM **Room Antigone 1 (level 2)**

L2.2 - Agroforestry and adaptation to climate change

Chair: Xu Jianchu

Keynote talk

- BENTRUP Gary - Lincoln, United States: Assessing the role of agroforestry in adapting to climate change in the United States

Regular talks

- MEYBECK Alexandre - Maccarese (Fiumicino), Italy: Agroforestry in National Adaptation Plans: preliminary insights
- MUGICA Marta - Copenhagen, Denmark: Assessment of resilience capacity in coffee agroforestry systems in Nicaragua
- REYES Francesco - Viterbo, Italy: Crop microclimate: can alleycropping alleviate climate change effects on durum wheat?
- PANOZZO Anna - Legnaro (PD), Italy: Adaptation to climate change: the impact of olive trees on the microclimate of the understorey durum wheat crop

8:30 AM **Room Joffre 5 (level 1)**

L13.2 - Socio-economic and cultural constraints on technology adoption in agroforestry systems

Chairs: Michael Webb & George Curry

Keynote talk

- WALLACE Helen - Maroochydore DC, Australia: Transdisciplinary approaches to commercialising indigenous agroforestry trees: Canarium indicum in the Pacific

Regular talks

- WICAKSONO Satrio Adi - Jakarta Selatan, Indonesia: Connecting the Dots: Understanding Factors Influencing Smallholders' Participation in Microcredit for Agroforestry
- KIUP Emma - Kainantu, Papua New Guinea: Adoption of coffee-vegetable intercropping intervention by farmers in the highlands of Papua New Guinea

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- PAGELLA Tim - Gothenburg, Sweden: Local agroecological knowledge reveals adoption barriers and options for tree-based diversification in northern Morocco
- GELINAS Nancy - Québec, Canada: Adoption factors of agroforestry systems: a new conceptual framework

8:30 AM Room Joffre C (level 1)

L17.2 - Challenges, opportunities and trade-offs of agroforestry with perennial crops
Chairs: Eduardo Somarriba & Philippe Vaast

Keynote talk

- WARLOP François - Avignon, France: Fruit agroforestry as a suitable candidate for new resilient food systems? A french case

Regular talks

- LING Qiang - Yangling, China: Agroforestry system enhances interspecific facilitation in a rainfed jujube orchard in the semi-arid Loess plateau
- ZEMP Delphine Clara - Göttingen, Germany: Agroforestry with oil palm: ecological and economic trade-offs
- PACHAS Nahuel - Brisbane, Australia: Agroforestry: a pathway to enhance livelihoods of smallholders in the northern Laos
- FEURER Melanie - Zollikofen, Switzerland: Ecosystem services trade-offs from tree crop expansion in Myanmar’s forest frontier landscapes

8:30 AM Room Joffre A (level 1)

L19 - Silvopastoral system: promoting rural development by increasing tree-animal-pasture relationships
Chairs: Joana Amaral Paulo & Gerardo Moreno

Keynote talk

- KERR Amber - Davis, United States: Microclimatic effects of oak trees on California rangelands: implications for cattle heat stress in a changing climate

Regular talks

- SIB Ollo - Bobo-Dioulasso, Burkina Faso: First high-density protein banks, based on Morus alba and Leucaena leucocephala, for livestock feeding in Western Africa
- FRANCA Antonello - Sassari, Italy: Improving pastures for shading conditions: adaptive responses of legume species in a Mediterranean silvopastoral system
- ZAMORA Diomy - St. Paul, United States: Silvopasture as an approach to restoring productivity of unmanaged woodland grazing in the Upper Midwest, USA

8:30 AM Room Joffre 4 (level 1)

L21 - Agroforestry germplasm
Chairs: Ramni Jamnadass, Abasse Tougiani & Isaac Nyoka

Keynote talk

- BOFFA Jean-Marc - Nairobi, Kenya: Has the time come for the systematic improvement of the shea tree (Vitellaria paradoxa)?

Regular talks

- KINDT Roeland - Nairobi, Kenya: Mapping tree species in geographical and environmental space: a comparison of vegetation and habitat suitability maps
- ABIYU Abrham - Addis Ababa, Ethiopia: Community based tree improvement enhance productivity of farm trees and provision of better quality tree seed
- PASTOR-SOPLIN Santiago - Lima, Peru: Characterization of native cocoa populations and their importance as quality seeds for Family Farming Systems in Peru
- DUANGSODSRI Teerarat - Montpellier, France: A global approach to decipher molecular basis of coffee tree adaptation to shade

8:30 AM **Room Antigone 3 (level 2)**

L9 - Value chains and certification of agroforestry systems and products

Chairs: Andrea Pisanelli & Nuria Ferreiro Dominguez

Keynote talk

- OKIA Clement - Kampala, Uganda: Increasing uptake of agricultural interventions: A case of value chain innovation platforms in Uganda and Zambia

Regular talks

- INGRAM Verina - Wageningen, Netherlands: Agroforestry as a mechanism for reforestation in Zambia: Scenarios within a REDD+ framework
- ISLAM Kazi Kamrul - Mymensingh, Bangladesh: Evolving and strengthening cooperative approach for the agroforestry farmers in Bangladesh: lesson learn from Japan
- WALLACE Helen - Maroochydore DC, Australia: Value-adding agroforestry crops to benefit smallholders in the Pacific
- PENOT Eric - Montpellier, France: Local value-chain with Coffee/Cocoa agroforestry business driven Clusters to foster social and environmental innovations

8:30 AM **Room Barthez (level 2)**

L24 - Biophysical modelling of interactions in agroforestry

Chairs: Jules Bayala & Joao Palma

Keynote talk

- ROSATI Adolfo - Spoleto, Italy: Do agroforestry models overestimate photosynthesis and RUE of understory crops?

Regular talks

- VEZY Rémi - Montpellier, France: DynA_Cof, a model for growth, yield, carbon, water, energy balances and ecosystem services of Coffea in agroforestry
- ELEVITCH Craig - Holualoa, United States: A System Identification Approach to Process-Based Plant Growth Model Reduced-Order Parameter Estimation
- VAN NOORDWIJK Meine - Bogor, Indonesia: Land Equivalent Ratios for multifunctional agroforestry: a new version 5.0 of the WaNuLCAS model
- HUTH Neil - Toowoomba, Australia: Cutting through the complexity of biophysical models: Seeing the forest for the trees

8:30 AM **Einstein auditorium (level 0)**

L20 - Agroforestry and agroecology: opportunities and challenges

Chairs: Jo Smith & Leigh Winowiecki

Keynote talk

- BARRIOS Edmundo - Rome, Italy: The 10 Elements of Agroecology: Guiding the transition to sustainable food and agricultural systems

Regular talks

- NASSUNA Alice - Kibale, Uganda: Agro-ecological evolution through agroforestry systemsin Uganda
- SALAZAR-DIAZ Ricardo - Cartago, Costa Rica: An agroecology approach to improve production: Case of tropical agroforestry
- BEDARE Ganesh - Pune, India: Agroecological benefits realized by small farmers adopting tree-based farming on degraded lands in Maharashtra, India
- XU Jianchu - Kunming, China: Agroforestry for a Better Mountain Futures

8:30 AM **Room Joffre B (Level 1)**

L23 - Root issues in agroforestry

Chairs: Alexia Stokes & Gerry Lawson

Keynote talk

- JOURDAN Christophe - Montpellier, France: Effect of coppice management of shrubs associated with cereals on their root dynamics features in dry Western Africa

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Regular talks

- TASCHEN Elisa - Montpellier, France: Do perennial alleys help to maintain arbuscular mycorrhizal communities in temperate agroforestry systems ?
- SHI Lingling - Göttingen, Germany: Competition and complementarity of agroforestry components by carbon sequestration in soil: 13C labeling and tracing
- HAIRIAH Kurniatun - Malang, Indonesia: Tree roots anchor soil and reduce landslide risk: case studies in Indonesia
- NIETHER Wiebke - Göttingen, Germany: Belowground competition and aboveground production in cocoa (Theobroma cacao L.) monocultures and agroforestry systems

8:30 AM **Room Joffre D (level 1)**

L7 - Jobs, business, finance: can agroforestry make it great?

Chairs: Patrick Worms & Fergus Sinclair

Keynote talk

- CAVATASSI Romina - Rome, Italy: Does sustainable forestry, agroforestry and new business opportunities lead to better livelihood? The DECOFOS in Mexico

Regular talks

- GARVI Josef - Zinder, Niger: Building markets for forgotten wild Sahelian tree foods. A case study of Sahara Sahel Foods
- FEUERBACHER Arndt - Stuttgart, Germany: No hassle with the hazelnut? The economy-wide impacts of a large-scale contract farming scheme in Bhutan
- NUBERG Ian - Glen Osmond, Australia: Pathways to agroforestry wealth in Nepal
- MUTUA Wangu - Stockholm, Sweden: Improving the livelihoods of 30,000 Kenyan farmers through agroforestry with milk-water-carbon value creation
- PIABUO Serge Mandiefe - Yaounde, Cameroon: The State of community forest enterprises (CFEs) as successful social enterprises: Empirical evidence from Cameroon
- STOIAN Dietmar - Montpellier, France: Not all roads lead to Rome: Inclusive business models and responsible finance in pursuit of sustainable cocoa in Ghana

10:00 AM **Poster sessions & Coffee break** — Levels 0, 1 & 2

PARALLEL SESSIONS (continued)

11:00 AM **Room Rondelet (level 2)**

L1.2 - Mitigating climate change with agroforestry

Chairs: Georg Cadisch & Rosa Mosquera

Regular talks

- BERNOUX Martial - Rome, Italy: Revisiting IPCC Tier 1 coefficients for soil organic and biomass carbon storage in agroforestry systems
- CHENU Claire - Thiverval-Grignon, France: High organic inputs explain shallow and deep SOC storage in a long-term agroforestry system
- PECCHIONI Giovanni - Pisa, Italy: The net biome production of an alley-cropping system of sorghum and poplar SRC compared to an open field cultivation
- PINHEIRO Felipe - Gainesville, United States: Soil Carbon Storage in Silvopasture in comparison with planted and native forests and pasture in a Brazilian Oxisol
- NJINE BEMEMBA Charles Baudouin - Yaounde, Cameroon: Soil-atmosphere CO2 fluxes in Central Africa humid tropics: comparative study among food crop and agroforest systems

11:00 AM **Room Antigone 1 (level 2)**

L2.2 - Agroforestry and adaptation to climate change

Chair: Xu Jianchu

Regular talks

- GUSLI Sikstus - Makassar, Indonesia: Soil organic matter connecting mitigation of/and adaptation to climate change in cocoa-based agroforestry systems
- ROUPSARD Olivier - Dakar, Senegal: 'Faidherbia-Flux': adapting crops to climate changes in a semi-arid agro-sylvo-pastoral open observatory (Senegal)
- LAMICHHANE Dhananjaya - Kathmandu, Nepal: Building climate resilient communities through package-based integrated agroforestry practices
- ALEXANDER Stephen - Copenhagen, Denmark: Implementation of the Public Goods Tool to Assess Sustainable Agricultural Practices

11:00 AM **Room Joffre 5 (level 1)**

L13.2 - Socio-economic and cultural constraints on technology adoption in agroforestry systems

Chairs: Michael Webb & George Curry

Regular talks

- LANDICHO Leila - College, Philippines: Why Farmers Adopt Agroforestry in the Philippines? Implications for Developing Agroforestry Policies
- SANOU Lassina - Koudougou, Burkina Faso: Drivers of farmers' decisions to adopt agroforestry: Evidence from the Sudanian savanna zone, Burkina Faso , West Africa
- GIGNOUX Jeremie - Paris, France: Making extension work: a field experiment on community-based training to agroforestry dairy feeds in Uganda
- TSCHOPP Maurice - Bern, Switzerland: Silvopastoral production system in the Argentinian Chaco : smallholders' motivations for adoption and policy insights

11:00 AM **Room Joffre C (level 1)**

L17.2 - Challenges, opportunities and trade-offs of agroforestry with perennial crops

Chairs: Eduardo Somarriba & Philippe Vaast

Regular talks

- SIMON Sylvaine - Saint-Marcel-lès-Valence, France: Methodology to co-design temperate fruit tree-based agroforestry systems: three case studies in Southern France
- GWALI Samson - Kampala, Uganda: Traditional practices in shea tree (Vitellaria paradoxa) conservation in Uganda: Reflections and lessons from the past
- GAUDIN Amelie - Davis, United States: Benefits and tradeoffs of integrated sheep vineyard systems in California
- THALER Philippe - Montpellier, France: Too good to be true? Permanent Rubber Agroforestry Systems. Reality and challenges in Thailand

11:00 AM **Room Joffre A (level 1)**

L19 - Silvopastoral system: promoting rural development by increasing tree-animal-pasture relationships

Chairs: Joana Amaral Paulo & Gerardo Moreno

Regular talks

- OLIVAL Alexandre - Alta Floresta, Brazil: Trees and pastures: building integrated production systems in Amazonia
- KEELEY Keefe - Madison, United States: Advancing silvopasture in temperate oak ecosystems via social, observational, and experimental approaches

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- GUTIÉRREZ-OVIEDO Fabián - Ibague, Colombia: Intake and digestibility of diets for creole lambs containing foliage of tropical trees
- BROOK Robert - Chester, United Kingdom: Silvopastoral agroforestry for off-setting greenhouse gas emissions from cattle farming systems in Costa Rica
- LUSKE Boki - Bunnik, Netherlands: Nutritional potential of fodder trees: the effect of tree species, soil type and seasonal variation

11:00 AM **Room Joffre 4 (level 1)**

L21 - Agroforestry germplasm

Chairs: Ramni Jamnadass, Abasse Tougiani & Isaac Nyoka

Regular talks

- KEHLENBECK Katja - Kleve, Germany: Domestication of baobab (Adansonia digitata L.) in Eastern Africa: results of the Baofood project in Sudan and Kenya
- CALLO-CONCHA Daniel - Bonn, Germany: Challenges of participatory tree domestication programs: lessons from the Peruvian Amazon case
- DIVAKARA Baragur - Bengaluru, India: Assessing the growth performance of pongamia pinnata l. Genotypes under multilocational trial
- KUMAR Ashok - Dehradun, India: Diverse forest genetic resources for enhanced productivity under agroforestry
- BENNADJI Zohra - Tacuarembó, Uruguay: Multipurpose trees domestication in Uruguay: synthesis of knowledge advances

11:00 AM **Room Antigone 3 (level 2)**

L9 - Value chains and certification of agroforestry systems and products

Chairs: Andrea Pisanelli & Nuria Ferreiro Dominguez

Regular talks

- OUEDRAOGO Désiré - Bristol, United Kingdom: Good forest governance: Improved income for rural communities in Burkina Faso – results from a TREE AID programme
- BALAGUER Fabien - Auch, France: From Fork to Fork - Towards market integration for agroforestry and agroecology
- BRUNORI Antonio - Perugia, Italy: PEFC endorsement process for the Certification of Trees Outside Forests
- RABANY Cédric - Montpellier, France: A new payment for ecosystem services in organic cocoa agroforestry system in Ivory Coast
- ELEVITCH Craig - Holualoa, United States: Designing generalizable agroforestry standards for regenerative agriculture

11:00 AM **Room Barthez (level 2)**

L24 - Biophysical modelling of interactions in agroforestry

Chairs: Jules Bayala & Joao Palma

Regular talks

- GRIMALDI Juliette - Montpellier, France: What are the impacts of tree shade on the absorption of light by grapevine within alley-cropped vineyards?
- CARAUTA Marcelo - Stuttgart, Germany: Modeling the adoption of agroforestry systems: Evidence from agent-based simulation
- INURRETA AGUIRRE Hector Daniel - Montpellier, France: Using the Hi-sAFe model to test the effect of tree root and branch pruning with different crop management options
- TEMESGEN Habtamu - Dilla, Ethiopia: Variation in ecosystem service values with respect to land use/cover changes in agroforestry landscape
- FELTON Michelle - Reading, United Kingdom: Dynamic modelling of potential carbon removal and sequestration by agroforestry: A UK perspective

11:00 AM **Einstein auditorium (level 0)**

L20 - Agroforestry and agroecology: opportunities and challenges

Chairs: Jo Smith & Leigh Winowiecki

Regular talks

- VERWEIJ Pita A. - Utrecht, Netherlands: Ecosystem service interactions under agroecological management transition in European almond orchards
- AKHTER Fardausi - Indian Head, Canada: Role of field boundary habitats in agro-ecosystems health and productivity
- MBAYE Gora - Dakar, Senegal: Natural Assisted Regeneration of woody species in agro-systems of Senegal: agro ecological advantages and constraints
- NAIR Vimala - Gainesville, United States: Potential for using biochar in resource-limited agro-forestry systems
- TORQUEBIAU Emmanuel - Montpellier, France: Multilayer agroforestry : the missing link

11:00 AM **Room Joffre B (Level 1)**

L23 - Root issues in agroforestry

Chairs: Alexia Stokes & Gerry Lawson

Regular talks

- HOSSEINI BAI Shahla - Bundaberg, Australia: Root studies in agroforestry systems – a case study of coffee and cocoa trees
- FUNGO Bernard - Kampala, Uganda: Forage biomass yield and soil aggregate carbon under fodder banks with contrasting management regimes
- KUNHAMU Tk - THRISSUR, India: Stand density influences on fine root dynamics in Acacia mangium Willd stands at Kerala, India
- DEB Sourabh - Agartala, India: Root biomass and nutrient (N&P) turnover in traditional agro-forestry sytems of Northeast India
- BIRHANE Emiru - Mekelle, Ethiopia: Response of Commiphora seedlings to mycorrhizal inoculation, soil fertility, and moisture deficit

11:00 AM **Room Joffre D (level 1)**

L7 - Jobs, business, finance: can agroforestry make it great?

Chairs: Patrick Worms & Fergus Sinclair

Regular talks

- WORMS Patrick - Waterloo, Belgium: A stimulus to ‘green growth’ in post-mining peri-urban Africa with elite Pongamia pinnata
- GREENE Harry - Brooklyn, United States: Marketplace approaches for context-based agrofo-restry investments and project development

12:15 AM **Lunch** **Level 3**

Berlioz auditorium, level 0

2:00 PM **Plenary Session 5 - Agroforestry and Sustainable Development Goals**

Moderated by Karen Coleman and chaired by John Vidal

Plenary talks

- Vincent Gitz - Director of the Forests, Trees and Agroforestry Programme of the CGIAR
- Godfrey Bahiigwa - African Union Commission, Director of Rural Economy and Agriculture
- Gwendolyn Yu - Company Engagement, BNP-PARIBAS
- Rakesh Bhushan Sinha - India
- Congressman Dennis Kucinich and Prof. Elisabeth Kucinich - USA

3:30 PM **Coffee break** **Levels 0, 1 & 2**

Berlioz auditorium, level 0

4:00 PM **Plenary Session 6 - A road map for agroforestry**

Moderated by Karen Coleman and chaired by Erik Hoffner

Plenary talks

- Roger Leakey - International Tree Foundation, UK
- John Munsell - Past-President, Association for Temperate Agroforestry
- Patrick Worms - EURAF
- Stephen Briggs - Farmer & Consultant, AbacusAgri, UK
- Gilles Delaunay - Farmer, France
- Emmanuel Petel and José Ruiz Espi - European Commission, DG Agriculture and Rural Development
- Tony Rinaudo - Laureate of the Right Livelihood Award (video presented by Dennis Garrity)
- Fergus Sinclair - World Agroforestry / School of Natural Sciences, Bangor University, Wales, UK

Berlioz auditorium, level 0

5:30 PM **A tribute to P. K. Ramachandran Nair**

Distinguished Professor of Agroforestry, University of Florida, Gainesville, Florida, USA

- Portrait of P. K. Nair by **Dennis Garrity**
- Concluding remarks by **P. K. Nair**

6:00 PM **Congress wrap-up by Tristan Lecomte**
Best Posters prizes

6:15 PM **Award Ceremony of 'Agropolis Fondation Louis Malassis International Scientific Prize for Agriculture and Food' + 'OLAM Prize for Innovation in Food Security'**

6:45 PM Welcome desk & cloackroom closing down - **Free time for dinner** (not included)

8:45 PM **Cultural evening:** French and World music concerts **Pasteur auditorium, level 1**

Thursday 23 May

All day **1-day and 2-day Field trips**

Centre Rabelais

9:00 PM to 11:00 PM **Can we still eat chocolate? What do tropical forests think?**
Film projection and round-table about cocoa agroforestry
(open to all public)

Friday 24 May

All day **2-day Field trips** (second day)

Centre Rabelais

9:00 PM to 11:00 PM **Make our planet treed again!**
Agroforestry film festival and discussion with the congress organisers
(open to all public)

ABSTRACTS

Agroforestry and world challenges

Agroforestry: riding to the world's rescue

- L1 -
Mitigating climate change with agroforestry

Grab it back, jack:
capture carbon with agroforestry and grasslands

Agroforestry systems are known to sequester large amounts of carbon in the tree biomass. Several publications have also shown a positive impact of agroforestry systems on soil organic carbon (SOC) stocks, especially after a conversion from croplands. These systems are also promoted to adapt agriculture to climate change and to diversify food production systems, and are therefore good candidates to reach the objectives of the 4 per Thousand Initiative.This session welcomes studies exploring changes in SOC stocks and accumulation rates in agroforestry systems compared to other land uses.
A special attention will be given to studies looking at deep SOC stocks, and mapping the spatial heterogeneity of SOC within agroforestry systems.
This session also encourages studies assessing the drivers and processes of SOC storage and dynamics in agroforestry systems. This includes a full quantification of C inputs to the soil (especially root inputs), dissolved organic carbon, C stabilization mechanisms (aggregate stability, priming effect...), but also long-term assessment of SOC storage through modeling.

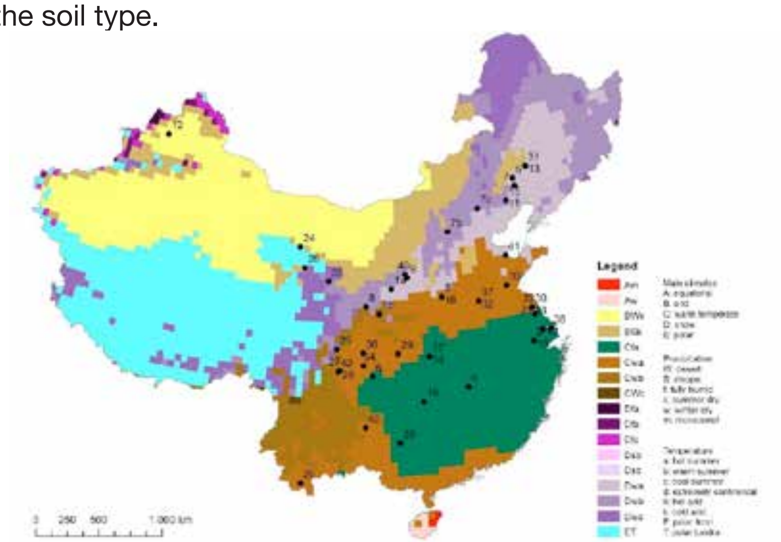
L01.1_O.01

China's legacy in agroforestry may help to combat climate change: a meta-analysis of soil carbon sequestration rates

Hübner R.[1] (rico.huebner@tum.de), Kühnel A.[2], Lu J.[1], Dettmann H.[3], Wiesmeier M.[2]

[1] *Landscape Planning & Management, Technical University of Munich, Freising, Germany*; [2] *Chair of Soil Science, Technical University of Munich, Freising, Germany*; [3] *Faculty of Forest and Environment, Eberswalde University, Eberswalde, Brandenburg, Germany*

Research on agroforestry in China is tremendous. However, no systematic review of the soil carbon sequestration rates – as one of the most important ecosystem services to protect the climate – has been undertaken.
A systematic search in English and Chinese initially returned 111 references, from which 43 were considered for analysis at 38 locations. Soil C sequestration rates were calculated for topsoils (0-20 cm, 97 sites) and two subsoil layers (20-40 cm, 73 sites; 40-60 cm, 54 sites). Applying the Random Forest model we tested the effect of the following predictor variables on the C sequestration rate independently for each soil layer: WRB soil class, agroforestry system (specified to agrosilvicultural, shelterbelt, or silvopastoral), land use of the control site, tree components, legumes and climatic properties (Köppen classification, mean annual temperature, mean annual precipitation).
We found changes in the conditional importance of the predictors for different soil layers. For the topsoil (0-20 cm) the soil class is most influential, followed by the climate zone and the agroforestry system. For the 20-40 cm depth the agroforestry system becomes most important followed by soil class and Koeppen-classification. A similar ranking of importance was found for the 40-60 cm depth with agroforestry system, climate zone and soil class in decreasing order.
With regard to a high C sequestration, not only the agroforestry system and the climate play a role, but also the soil type.



Geographical distribution and Köppen-Geiger Climate Classification of the study sites addressed in the 43 publications considered. Map source (Kottek, M. et al. 2006)

Keywords: agroforestry, carbon sequestration, soil organic carbon, ecosystem services, Random Forest.

References:

1. Kottek, M., et al., 2006, Meteorologische Zeitschrift, 15(3), 259-263
2. Montagnini, F., & Nair, P. K. R., 2004, Agroforestry Systems, 61-62(1-3), 281-295
3. Post, W. M., & Kwon, K. C., 2000, Global Change Biology, 6(3), 317-327
4. Shi, L., Feng, W., Xu, J., & Kuzyakov, Y., 2018, Land Degradation & Development, 1-12
5. Strobl, C., Boulesteix, A. L., Zeileis, A., & Hothorn, T., 2007, BMC Bioinformatics, 8, 25

L01.1_O.02

Impacts of sheep integration on carbon sequestration and soil health in Northern California coastal vineyard systems.

Brewer K. (kmbrewer@ucdavis.edu), Gaudin A.

Department of Plant Sciences, University of California, Davis, Davis, CA, United States

Integrated sheep-vineyard systems (ISVS), a type of mixed agroforestry system, utilize sheep to graze resident vegetation and/or cover crops and facilitate the provision of ecosystem services for vineyard production. However, quantification of carbon sequestration and soil health impacts from livestock integration into perennial cropping systems remain unclear. We conducted a survey study of three long term (10+ years) ISVS plots to assess soil health shifts from animal integration. SOC stocks were significantly higher at multiple ISVS plots for each depth zone (0-15 cm, 15-30 cm, and 30-45 cm). Microbial biomass C was also significantly higher at shallow depths (0-15 cm) and showed enrichment in multiple distinct functional groups including arbuscular mycorrhizal fungi, actinomycetes, saprophytic fungi, and protozoa. Fungal:bacterial ratios and total taxonomic diversity did not significantly differ, though microbial diversity indices trended higher in ISVS. Grazed plots had higher bioavailable-P content, despite lower phosphatase enzyme activity. NH_4^+ and NO_3^- were both higher in grazed plots, as were leucine aminopeptidase and urease enzyme activity. Salinity was also higher at 0-15 cm depth in ISVS. Bulk density was inconclusive and is likely dependent on grazing intensity and periodicity. Our results support that ISVS has substantial potential to increase soil C storage and improve important ecosystem synergies such as microbial functioning and biogeochemical cycling.

Keywords: C sequestration, integrated crop-livestock systems, ecosystem biogeochemistry, biodiversity, SOC fractionation.

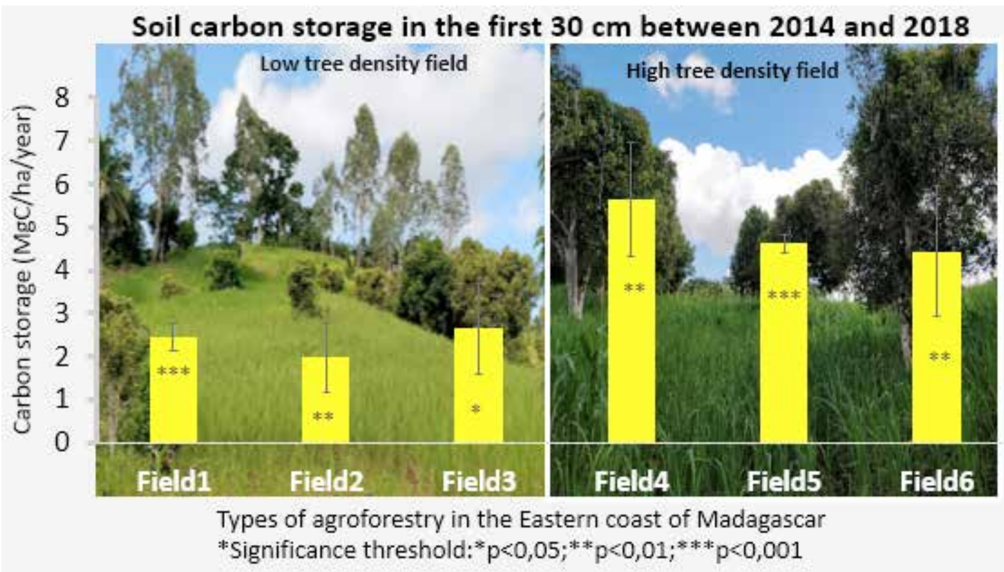
L01.1_O.03

Does soil carbon storage in agroforestry reach the 4 per 1000 objectives? A diachronic analysis in Madagascar

Rasoarinaivo A. R.[1] (tsifantenana@yahoo.fr), Razafimbelo T. M.[1], Blanchart E.[2], Chapuis-Lardy L.[2], Razakamanarivo R. H.[1], Andriamananjara A.[1], Rakotovao N.[1], Trap J.[2]

[1] *Laboratoire des Radio-Isotopes, University of Antananarivo, Antananarivo, Madagascar*; [2] *Eco&Sols, IRD, CIRAD, INRA, Montpellier SupAgro, Univ. Montpellier, Montpellier, France*

Agroforestry is recognized as a strategy to store carbon and to improve food security under the afforestation and the biomass production by crops. This work aimed to analyze the soil carbon storage in agroforestry systems in Madagascar using a diachronic approach. In 2014 and 2018, the soil carbon stocks were measured in the same fields from two types of agroforestry in the eastern coast of Madagascar differing by the tree density: low-density agroforestry with tree density less than 200 trees per ha and high-density agroforestry with tree density higher than 200 trees per ha. The first 30 cm of the soil were sampled in three fields per agroforestry type. Both type associated clove tree *Syzygium aromaticum* with rainfed rice during more than 28 years. Results showed that the mean soil carbon stocks were 90,42 MgC.ha-1 and 85.34 MgC.ha-1 in 2014, respectively in the low-density and high-density agroforestry. Soil carbon storage during the 4-years period varied from 2.35 MgC.ha-1. year-1 in the low-density agroforestry to 4.9 MgC.ha-1. year-1 in the high-density one. This induce increase of 2.6% per year and 5.74% per year, respectively in the low and high-density systems. These practices provided thus higher rate than 0.4 %, the threshold required to offset the global emissions of anthropogenically-derived greenhouse gases as promoted by 4 ‰ initiative.



Keywords: soil, Carbon storage, Agroforestry, Diachronic analysis, Madagascar.

References:

1. Razafimbelo, et al., 2018, Cah. Agric., 27, 35001, DOI :10.1051/cagri/2018017
2. Cardinael, et al., 2018, Biogeosciences, 15, 297–317, DOI : 10.5194/bg-15-297-2018
3. Cardinael, et al., 2017, Agriculture, Ecosystems and Environment, 236, 243-255
4. Teja, et al.,2011,Journal of Applied Ecology, 48, 619–629, DOI: 10.1111/j.1365-2664.2010.01939.x
5. Albrecht, et al.,2003, Agriculture, Ecosystems & Environment,99,15-27

L01.1_O.04

Long-term monitoring of soil carbon sequestration in woody and herbaceous bioenergy crop production systems in Canada

Bazrgar A. B. (abazrgar@uoguelph.ca), Coleman B., Thevathasan N.

School of environmental Sciences, University of Guelph, Guelph, Ontario, Canada

Bioenergy crop production (BCP) systems are considered as promising carbon-mitigation options because of their soil organic carbon (SOC) storage potential (Ashiq et al. 2018). However, there is a research gap in relation to long-term C sequestration comparison between herbaceous and woody biomass cropping systems. This study therefore is aimed at, (a) to quantify above and belowground carbon stocks within an 8-year-old BCP system, and (b) to quantify long term system level carbon sequestration (SLCS) potentials as influenced by woody and herbaceous species. We assessed C sequestration in poplar (*Populus spp.*), willow (*Salix spp.*), and switchgrass (*Panicum virgatum*) cropping systems by destructive sampling technique (Marsal et al. 2016). SOC stock obtained from this study was compared with existing 2009 baseline values. SLCS was determined based on the above and belowground carbon sequestered by the tested bioenergy crops. Results showed that SOC ranged non-significantly from 78.8 Mg ha^{-1} for switchgrass to 85.8 Mg ha^{-1} for willow. However, all bioenergy systems were able to increase SOC significantly in the long-term (2009-17). Findings of this study suggest significant differences in biomass carbon production in woody and herbaceous bioenergy crops and in its components. Overall, considering SLCS, bioenergy production systems can be ranked as willow (96.3 Mg ha^{-1}) > switchgrass (93.5 Mg ha^{-1}) > poplar system (85.9 Mg ha^{-1}) (Figure 1).

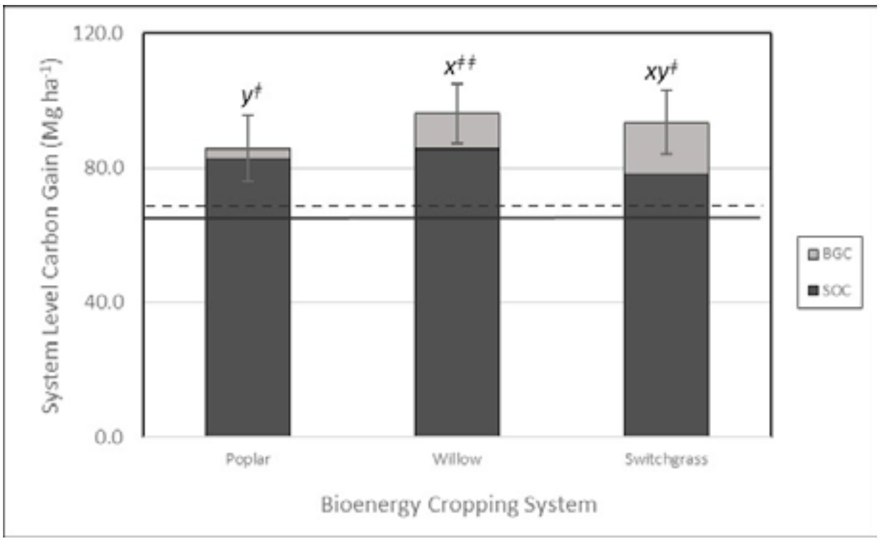


Figure 1. System level carbon (C) gain and its components, belowground biomass carbon (BGC) and soil organic carbon (SOC) in bioenergy production systems, southern Ontario, Canada. Superscripts (x-y) indicate significant differences in system level C gain between bioenergy cropping systems as determined by Duncan's new multiple range test (MRT) at α=0.05. Additionally, superscripts (ǂ) indicate significant differences between SOC in 2017 and the baseline measurements in 2009 for each cropping system, as determined by un-paired t-test (ǂ p<0.05 and ǂǂ p<0.01). Solid line indicates 2009 baseline for herbaceous and the dotted line indicates baseline for woody cropping system.

Keywords: Biomass crops, Marginal land, Climate change mitigation, Soil organic carbon.

References:

1. Ashiq et al. 2018, Can. J. Plant Sci. 98: 255–266, dx.doi.org/10.1139/cjps-2017-0220.
2. Marsal et al. 2016, Agroforestry Syst 90:773-783, DOI 10.1007/s10457-016-9893-3

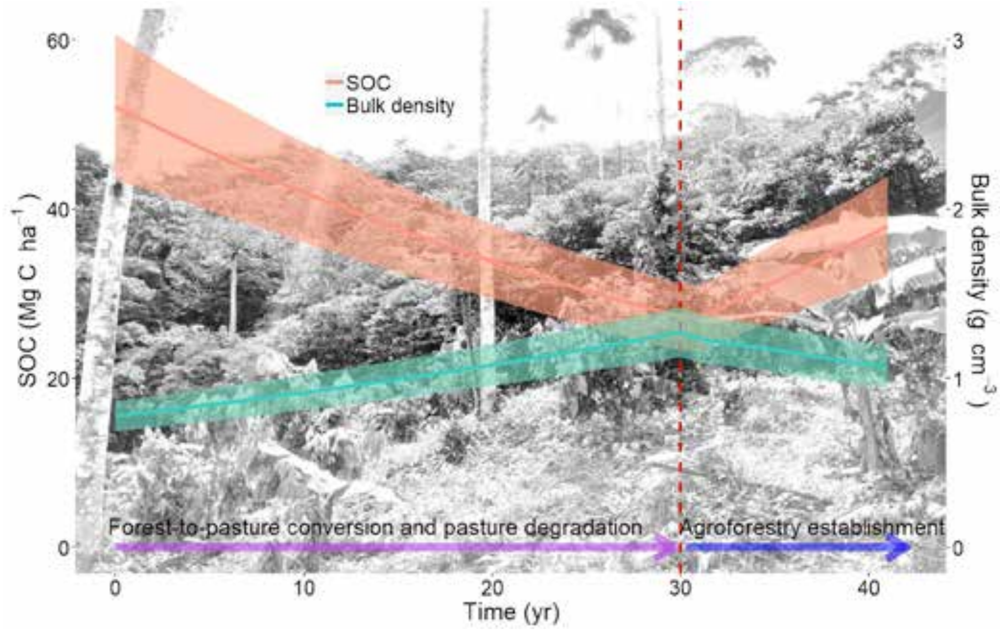
L01.1_O.05

Agroforestry for conservation: mitigating climate change in the Colombian Amazon

Navarrete D.[1] (diego.navarrete@tnc.org), Arango D.[1], Ordóñez M.[2]

[1] *Science, The Nature Conservancy, Bogota, Cundinamarca, Colombia*; [2] *Lands, The Nature Conservancy, Bogota, Cundinamarca, Colombia*

The agriculture, forestry and other land use (AFOLU) sector is the main source of anthropogenic greenhouse gas (GHG) emissions in Colombia, generating 62% of the total GHG emissions in the country. Within AFOLU, forest-to-pastor conversion and pasture degradation during the establishment of traditional cattle ranching activities in the Colombian Amazon contribute to reduce the soil organic carbon (SOC) stock by more than 20% and to increase soil compaction (Navarrete et al., 2016; see figure). The Agroforestry for Conservation (A4C) project, an initiative proposed by The Nature Conservancy and the Amazon Conservation Team under the International Climate Initiative, aims to restore natural and productive degraded ecosystems and to reduce deforestation in the Colombian Amazon by promoting the implementation of agroforestry practices. By assessing the growing of agroforestry systems and the secondary forest, the A4C project will monitor its contribution to increase SOC and reduce soil compaction in restored areas of the Colombian Amazon. Some partial results indicate that the establishment of agroforestry systems in degraded pasture areas contributes to increase SOC by 0.3 Mg C ha-1 yr-1 and to reduce soil bulk density by 0.02 g cm-3 yr-1 (see figure). These results emphasize the importance of agroforestry systems in restoring SOC stocks and soil physical properties, highlighting their contribution with the *4 per 1000 Soil for Food Security and Climate Initiative*.



Soil organic carbon and soil bulk density dynamics during forest-to-pasture conversion and pasture degradation, and agroforestry establishment

Keywords: Soil organic carbon, Soil bulk density, Agroforestry systems, Colombian Amazon, Forest-to-pasture conversion.

References:

1. Navarrete et al., 2016. Global Change Biol., 3503-3517, https://doi.org/10.1111/gcb.13266

L01.1_O.06

Converting natural forest to rubber plantations affects soil CO_2 and CH_4 fluxes

Lang R.[1] (langrong@mail.kib.ac.cn), Blagodatsky S.[1], Goldberg S.[2], Xu J.[2], Cadisch G.[1]

[1] *Hans-Ruthenberg-Institute, University of Hohenheim, Stuttgart, Germany*; [2] *East and Central Asia Regional Office, World Agroforestry Centre, Kunming, China*

The plantations of perennial tree crop-rubber (*Hevea brasiliensis*) have expanded for decades in Southeast Asia, replacing the tropical forests and shifting agricultural lands. The recent rapid expansion into northern Asian tropics have changed the greenhouse gaseous carbon fluxes and soil carbon stocks, but full understanding of the reasons at the level of processes and underlying mechanisms is still missing.

We measured soil CO_2 and CH_4 fluxes in rubber plantations of different age and in adjacent natural forest sites in Xishuangbanna, Southwest China, aiming to assess the impact of forest to rubber conversion on gaseous carbon fluxes from soil and quantify the controlling factors. Soils under young rubber plantation emitted the lowest amount of CO_2, and soils under mid-age and old rubber plantation emitted less or comparable amount of CO_2 compared to natural forest soils, depending on the soil organic carbon content in the topsoil. Soil temperature mainly controlled the temporal variation of CO_2 flux, while higher soil moisture suppressed the soil respiration in rubber soils (by up to 69%) and thus masked the temperature effect during the wet period in rainy season.

Converting forest into rubber plantations weakened the soil CH_4 sink by 58%, with cumulative CH_4 flux -2.41 ± 0.28 kg C ha^{-1} yr^{-1} and -1.01 ± 0.23 kg C ha^{-1} yr^{-1} for natural forest and rubber plantation respectively. Water-filled pore space (WFPS) was the main factor controlling temporal variation of CH_4 flux and explaining the differences between natural forest and rubber plantations. The increase in WFPS during rainy season lowered soil CH_4 uptake under rubber plantation up to 109% presumably through limiting gas exchange between air and soil. The multiple sites covering a wide range of soil texture, allowed us to separate the interfering effect of soil texture from land use change effect. Clay content explained only 19% of variation in CH_4 annual uptake and had a limited effect on WFPS within land use type.

Conversion of natural forest to rubber plantations altered the soil water regime and soil aeration, exerting a pronounced impact on processes controlling the fluxes of methane and CO_2 from soil. Compared to natural forest, the higher soil moisture under rubber plantations suppressed soil CO_2 flux under wet conditions and decreased CO_2 emission, but it limited gas diffusion for CH_4 oxidation and reduced CH_4 sink strength. More comprehensive assessments with processes based modeling is needed to quantify the GHG balance in the region and its impact on global climate.

L01.1_O.07

A nonlinear method to estimate the agroforestry sequestration potentia

Menichetti L. (lorenzo.menichetti@slu.se)

Ecology, SLU, Uppsala, Sweden

Agroforestry is seen more and more as a C sequestration method to mitigate climate change effects [1–3]. The term "agroforestry" defines a wide range of agricultural systems and the consequent broad variability in their soil organic carbon (SOC) sequestration potential[1,3] needs to be considered with a fine scale approach. One possibility, as it has been done so far[1–3], is to apply linear SOC sequestration coefficients (*zero order* kinetics) associated with each agroforestry class[1] and then aggregate the results regionally or globally. However, this approach is unrealistic because:
I) The rates of SOC accumulation varies over time as a function of the SOC in the system. A constant sequestration rate is not what is going to happen and neglects the time perspective, offering imprecise predictions with error dependent on the time scale selected. In general a constant sequestration rate would become unrealistic already after few years.
II) With time, the rates of SOC accumulation approach zero and SOC stocks reach an horizontal asymptote. What matters for policy-making is this equilibrium value, which determines how many tons we can potentially sequester per hectare. Using linear coefficients implies the C sequestration will go on forever and neglects this upper limit.
We will utilize a *first-order* compartmental SOC model, ICBM[4], for calculating from published data[1–3] a C sequestration potential at equilibrium for agroforestry systems in different climatic regions, and estimate the time needed in each system to reach it. The model will be driven by the C inputs estimated for each system according to allometric functions, with an associated uncertainty. This uncertainty will be considered by recalibrating the model with Bayesian statistics (implemented through a standard Markov chain monte Carlo algorithm), and we will rely for the calculation on the whole probability distribution of the C inputs by class and not just on one single "best estimate" value. The parameter priors for the SOC kinetics will come from the literature[5] assuming pretty narrow prior probability distributions, but both the allometric belowground:aboveground coefficients and the aboveground estimate will be considered instead with wide prior probability distributions. These prior probability distributions, general for the SOC kinetics but specific to each agroforestry class for the belowground partitioning coefficients, will in turn generate a join probability distribution of the steady state of SOC stocks for that class. These probabilistic estimates will then be used, together with conversion scenarios (based on the applicability of each agroforestry class in each climatic region), for calculating the global C sequestration potential of agroforestry. We will present results from an ongoing project.

References:

1. Feliciano D, Ledo A, Hillier J, Nayak DR.; 2018; Agric Ecosyst Environ.; 254: 117–129.
2. Chatterjee N, Nair PKR, Chakraborty S, Nair VD.; 2018; Agric Ecosyst Environ. Elsevier; 266: 55-67
3. Corbeels M, Cardinael R, Naudin K, Guibert H, Torquebiau E., 2018; Soil Tillage Res.; in press
4. Kätterer T, Andrén O.;2001; Ecol. Modell.; 136; 191-207
5. Kätterer T, Andrén O.;1997; Ecol. Appl.

L01.1_O.08

Carbon sequestration of Iberian dehesas offsets emissions of their livestock

Moreno G. (gmoreno@unex.es), Llorente M.

INDEHESA, Universidad de Extremadura, Plasencia, Cáceres, Spain

Since the publication of the FAO report Livestock's Long Shadow (Steinfeld et al 2006) many studies and inventory have emphasized the high emissions of greenhouse gases (GHG)caused by the livestock, specially by ruminants. This is being argued, among other reasons, to claim for a more vegetarian and vegan diet for increasing human population. However, most of the lands occupied by grassland and devoted to extensive livestock raising are poor for arable crops and their use for the production of grass-fed animal foods seem still the best options. There are nevertheless a need to design systems and management practices that favor carbon sequestration on soil and plants of grasslands and rangelands. The plantation/maintenance of trees in grasslands managed silvopastoral systems is view as an opportunity for the aimed low-carbon farming.

In this work we have evaluated the carbon accumulated annually in the soil and trees of more than a hundreds of dehesas (oak wood pastures) in the South Western Spain. We built a database of soil carbon measured in Spanish dehesas in the last 60 years. We retained the cases finely georeferenced and that included precise data of sampling depth, soil bulk density, processing and analytical method. For those cases (n=109) we repeated the sampling and analysis in 2018 (time lapsed ranged from 7 to 59 years). We used the data of the 2nd and 3rd Spanish Forest Inventories to calculate the biomass accumulated in the tree population of 3823 dehesa stands in a decade. The study is complemented with the direct measurement of the carbon balance with an eddy covariance station working continuously since 2004 in the dehesa of Majadas de Tiétar in CW Spain (www.fluxdata.org:8080/sitepages/siteInfo.aspx?ES-LM).

Results showed the mean content of soil C increased from 1.49 to 1.69% (in 22 years on average), what translate into a mean accumulation in the uppermost 30 cm of the soil equivalent to 754 CO2 kg ha-1 y-1. The accumulation in the trees amount up to an equivalent of 266 CO2 kg ha-1 y-1. Both together sum up 1021 CO2 kg ha-1 y-1, what approximates to the mean Net Ecosystem Exchange measured with the eddy covariance station since 2004 (~ -1000 CO2 kg ha-1 y-1). This C sequestration rate would offset most of the emissions of GHG estimated for the livestock-based foods produced in the dehesas. Including on- and off-farm emissions, Eldesouky et al (2018) have estimated emissions that range from 1066 to 1319 kg ha-1 y-1 for the extensive raising of cattle and sheep. From here we can conclude that C sequestration in soil and trees of the Iberian dehesas offset most of the GHG emissions associated to their livestock production. Nevertheless, improving pastures, grazing schemes and including more woody forages in the diet need to be explored as management strategies to reduce emissions at the time the carbon sequestration is reinforced.

Keywords: silvopastoralism, soil carbon, tree growth, low carbon farming, eddy covariance.

References:

1. Steinfeld et al 2006 . Livestock's long shadow: environmental issues and options. FAO
2. Eldesouky ET AL 2018. Journal of Cleaner Production, 200, 28-38

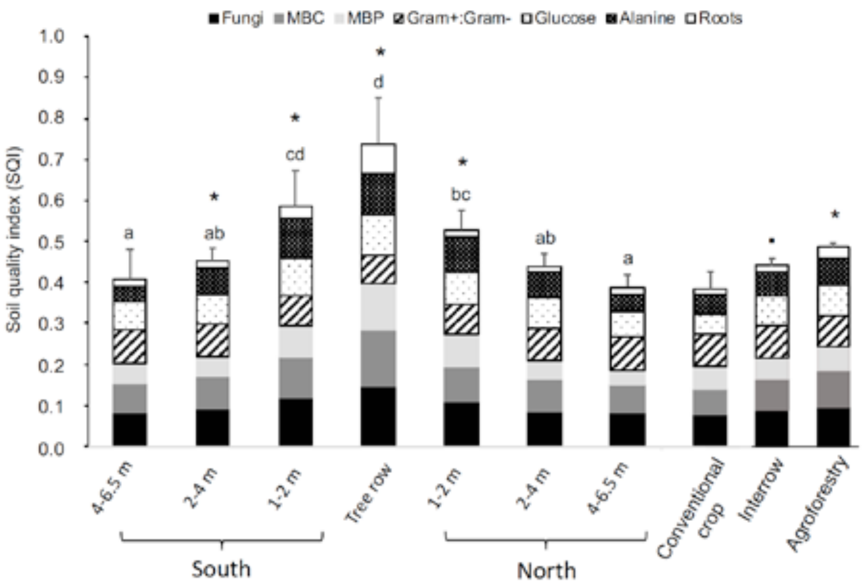
L01.1_O.09

Soil quality is improved in a Mediterranean agroforestry system compared to a conventional cropping system

Guillot E. (esther.guillot@gmail.com)

INRA UMR Eco&Sols, Montpellier, France

Agroforestry systems are of growing interest due to their capacities to provide a range of ecosystem services. However, soil quality based on multicriteria approach has, to our knowledge, never been comprehensively assessed in temperate agroforestry systems, especially considering the spatial heterogeneity created by those systems. Our aims were to evaluate if (i) an alley-cropping agroforestry system can lead to spatial gradients of soil quality from the tree row to the middle of the cropped interrow and (ii) soil quality is different between an agroforestry and a conventional plot. The soil was sampled in 7 contiguous areas along a transect from the middle of the interrow on each side of the tree row (13 m in total) in an alley-cropping agroforestry plot and in an adjacent conventional plot at Restinclières (France). We measured physical, chemical and biological indicators such as soil texture, SOC, N and P contents, microbial biomass, activity and microbial community structure. Those indicators were integrated in soil quality indices (SQI). Within the agroforestry plot the biological soil quality occurred to be significantly improved until 2 m from the tree row in the cropped interrow (**Fig. 1**). The SQI weighted average of the agroforestry plot was significantly higher than the one calculated for the conventional plot. The higher input of organic litters in the agroforestry plot compared to the conventional plot is likely at the origin of this soil quality improvement.



Biological soil quality index based on fungal biomass (Fungi), microbial biomass C (MBC) and P (MBP), Gram+:Gram- bacteria ratio, glucose induced respiration and alanine induced respiration, total root biomass (Roots). Data are shown for the tree row and at 1-2 m, 2-4 m and 4-6.5 m from the center of the tree row in the agroforestry plot either on the North (N) or South (S) side of the tree row, in the conventional crop plot (Conventional crop), for the interrow in the agroforestry plot (Interrow) and for the total agroforestry plot (Agroforestry). Data are mean values bars + standard deviation (n = 5), lowercase letters indicating significant differences between positions from the agroforestry plot, '*' indicating significant difference compared to the conventional crop plot ($P < 0.05$) and '.' indicating significant difference at $0.05 < P < 0.01$.

Keywords: Agroforestry, Soil quality, Spatial gradient, Microbial activities, Organic matter.

L01.1_O.10

Effect of the land use on the carbon storage in the soil fractions in the South of Portugal

Ferreiro-Dominguez N.[1] (nuria.ferreiro@usc.es), Paulo J.[2], Palma J.[2], Rigueiro-Rodríguez A.[3], Mosquera-Losada M. R.[4]

[1] *Crop production and project engineering, Univ. Santiago Compostela, Lugo, Lugo, Spain*; [2] *ISA, Lisbon, Portugal*; [3] *Univ. Santiago Compostela, Lugo, Spain*; [4] *Crop production and project engineering, Univ. Santiago Compostela, Lugo, Spain*

Soils play an important role in climate change mitigation by storing carbon and decreasing greenhouse gas emissions in the atmosphere. The carbon associated to the different soil fractions can vary over time due to several factors including biological system characteristics, climatic conditions or land use. The aim of this study was to evaluate the amount of carbon stored in each soil fraction (250-2000 μm, 53-250 μm, and <53 μm) in the three main land uses traditionally encountered in the semi-arid areas of the South of Portugal (natural forest vegetation, agroforestry and agricultural). The experiment was carried out in three plots of the Perímetro Florestal of Contenda located in the Baixo Alentejo province, South of Portugal. The three selected plots were: i) a plot with natural forest vegetation, dominated by uneven aged *Quercus rotundifolia* L. trees established through natural regeneration, ii) a plot with an agroforestry land use (montado), in which uneven aged *Quercus rotundifolia* L. trees were established and are currently at a low density (66 trees ha-1) and combined with an extensive grazing with sheep, iii) a plot with an agricultural land use in which during the last six years the soil was tilled to sow a mixture of grasses (triticale, oat and wheat) and legumes (clover) for livestock feeding. In these plots soil samples were collected at a soil depth of 25 cm in March 2017. In the plots with natural forest vegetation the soil samples were collected under the trees and in the agroforestry plots the soil samples were collected under the trees and in those areas not affected by the trees. In the laboratory, soil samples were physically fractionated in macroaggregates (250–2000 μm), microaggregates (53–250 μm) and silt + clay (< 53 μm). The percentage of carbon in the three soil fractions was analysed using a LECOTM CNS Elemental Analyzer. The percentage of carbon was used to calculate the carbon storage per hectare (Mg C ha-1) in the soil fractions. The obtained results showed that the land use modified the carbon storage in the soil fractions, mainly due to the different inputs of organic matter to the soil and the management activities associated with each land use such as the soil tillage or the livestock grazing. In this study, the trees established in the plots increased the carbon storage per hectare in the macroaggregates and in microaggregates probably due to the high inputs of organic matter to the soil coming from the tree leaves and roots. Therefore, in semi-arid areas such as those in this study it could be recommended the implementation of agroforestry systems such as the montado as a land use to mitigate the effect of the climate change, allowing agricultural production.

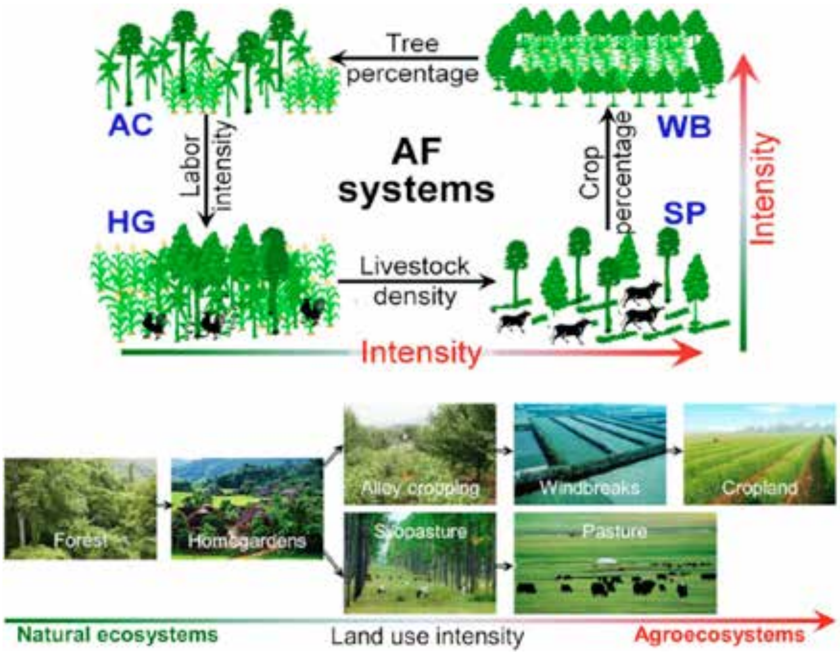
L01.2_O.01

Agroforestry systems: Meta-analysis of soil carbon stocks, sequestration processes, and future potentials

Kuzyakov Y.[1] (ykuzyakov@yandex.com), Shi L.[2], Xu J.[2]

[1] *Institute of Environmental Sciences, Kazan Federal University, Kazan, Russia*; [2] *ICRAF East and Central Asia, KIB, CAS, Kunming, China*

Agroforestry (AF) has the potential to provide a broader range of ecosystem services such as carbon (C) sequestration and biodiversity. Advantages and processes for global C sequestration in AF are unknown. We used a meta-analysis of 427 soil C stock data pairs grouped into four main AF systems—alley cropping, windbreaks, silvopastures, and homegardens—and evaluated changes in AF and adjacent control cropland or pasture. Mean soil C stocks in AF (1-m depth) were 126 Mg C·ha–1 , which is 19% more than that in cropland or pasture. The highest C stocks in soil were in subtropical homegardens, AF with younger trees, and topsoil (0–20 cm). Increased soil C stocks in AF were lower than aboveground C stocks in most AF systems, except alley cropping. Homegardens stored the highest C in both aboveground and belowground, especially in the subsoil (20–100 cm). Advantages of AF ecosystem services focusing on mechanisms of belowground C sequestration were analyzed. AF could store 5.3 × 109 Mg additional C in soil on 944 Mha globally, with most in the tropics and subtropics. AF systems could greatly contribute to global soil C sequestration if used in larger areas. Future investigations of AF should include (a) mechanistic- and process-based studies (instead of common monitoring and inventories), (b) models linking forest and crop growth with soil water and C and nutrient cycling, and (c) accurate assessments of the AF area worldwide based on the remote sensing approaches .



Schema of four dominating agroforestry (AF) systems: Alley cropping (AC), homegardens (HG), silvopastures (SP), and windbreaks (WB). Top: Depending on land use intensity, labor intensity, percentage of cropland and trees, and livestock. Bottom: AF systems according to increasing land use intensity and anthropogenic impacts on crops and trees

Keywords: agroforestry management, carbon sequestration, ecosystem services, homegardens, meta-analysis.

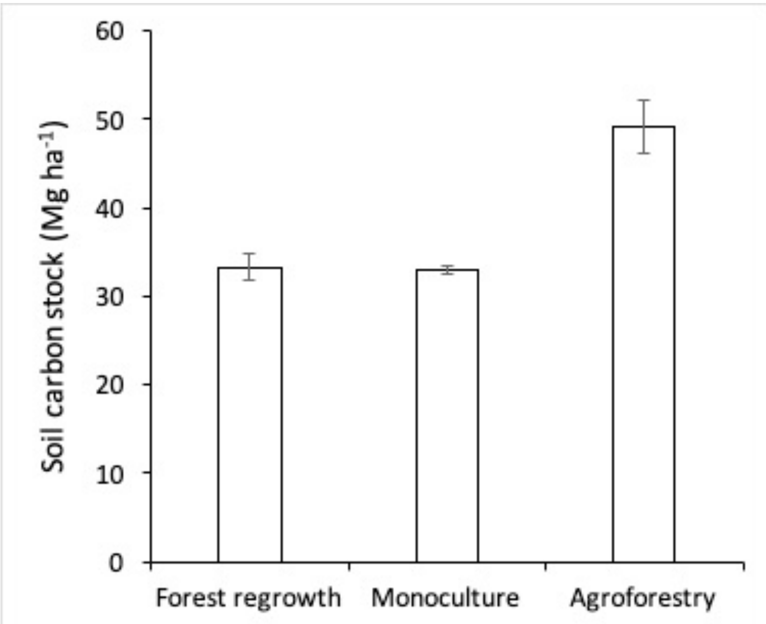
L01.2_O.02

Soil carbon stock is higher in oil palm agroforestry than in monoculture in eastern Amazonia

Vasconcelos S.[1] (steel.vasconcelos@embrapa.br), Costa N.[1], Castellani D.[2], Kato O.[1]

[1] *Embrapa Eastern Amazon, Belem, Brazil*; [2] *Natura, Cajamar, Brazil*

Agroforestry-based oil palm production systems (oil palm AFS) may be a more sustainable option to produce palm oil compared to the conventional cultivation system (monoculture). However, little is known about the impacts of oil palm AFS on soil carbon (C), which is usually strongly related to soil sustainability and climate change mitigation potential of agricultural systems. We measured the soil C stock in an 11-yr-old organic, biodiverse oil palm AFS in eastern Amazon, Brazil. We also quantified soil C stocks in reference sites (~20-yr-old forest regrowth and 11-yr-old oil palm monoculture). In the AFS, oil palm seedlings were planted in double rows interspersed with strips consisting of five rows of palm and tree species. We collected soil samples (depth: 0-5, 5-10, and 10-20 cm) in three transects in each oil palm production system and forest regrowth. The soil C stock was significantly higher in the oil palm AFS than in the monoculture and forest regrowth (Figure 1). Increased soil C stock in the oil palm AFS very likely results from the input of organic matter through periodic pruning and organic fertilization. For both oil palm production systems, the soil C stocks was higher in the frond pile zone than close to the oil palm trunk. The cultivation of oil palm in organic, bio-diverse agroforestry systems has higher potential to accumulate soil C than the conventional cultivation of oil palm in monoculture.



Soil carbon stocks (0-20 cm) in oil palm agroforestry, oil palm monoculture, and forest regrowth in eastern Amazonia. Data are mean +/- standard error (n=3).

Keywords: Brazilian Amazonia, Elaeis guineensis.

L01.2_O.03

Soil carbon storage and aggregate-size fractions under agroforestry systems

Nair P.[1] (pknair@ufl.edu), Nair V.[2]

[1] *School of Forest Resources and Conservat, University of Florida, Gainesville, Florida, United States*;
[2] *Soil and Water Sciences, University of Florida, Gainesville, Florida, United States*

Rigorous research data are needed to support successful exploitation of the carbon (C) sequestration potential of agroforestry systems (AFS) as a viable strategy for climate-change mitigation. With that background, we studied the extent of soil organic carbon (SOC) storage under AFS in several locations across the world in association with various collaborators during the past two decades. The overarching hypothesis was that AFS, compared to tree-less systems, store more total SOC overall and more recalcitrant C (C in finer soil particles that is not easily decomposable) at lower soil depths.
The study included several AFS such as silvopasture (Florida, USA; North-Central Spain; and Minas-Gerais, Brazil); parklands (Ségue, Mali); homegardens (Kerala, India); and shaded perennials (Bahia, Brazil; Karnataka, India; and Turrialba, Costa Rica). At each location, C stocks in the whole soil and in three aggregate-size fractions were determined under AFS and other land-use systems (forestry, agriculture, pasture) at different soil layers up to 1.0 m depth. The fractions were macroaggregates (2000–250 μm), microaggregates (250–53 μm) and silt + clay (<53 μm), representing increasing levels of resistance to decomposition of their SOC: macroaggregates the least and silt + clay the most.
In general, upper levels of soils of tree-dominated and less disturbed (cultivated) systems contained relatively higher percentages of macroaggregates. Macroaggregates also harbored microaggregates and silt + clay fractions within, protecting their C from decomposition and thus leading to its sequestration. The overall SOC stock to 1.0 m depth under different land-use systems ranged widely from ca. 30 to 300 Mg ha-1, reflecting the dependence of SOC stock at a location on various site-specific factors. Within this wide range of conditions, some general trends of SOC storage were evident (ref 1–4): i) Tree-based systems, compared to treeless systems, had higher SOC stocks in deeper soil; ii) Systems with high tree-density had more SOC and macroaggregates in the upper 50 cm of soil; iii) Shaded perennial systems were comparable to forests in SOC storage; iv) Sparse tree-density systems had high SOC stocks near trees; and v) C3 plants (trees) contributed to more recalcitrant C than C4 plants in deeper soil profile. More studies are needed to understand the mechanisms involved in these observations.
These results, in conjunction with the output from a comprehensive meta-analysis of published results of soil C sequestration under AFS (ref 5), provide a robust dataset showing the important role of AFS in soil C storage and sequestration. The dataset is also valuable in the context of the UNFCC recognition of SOC as the most relevant variable for stringent MRV (measurement, reporting, and valuation schemes) scheme for certifying soil management practices as having a positive effect on SOC accumulation.

References:

1. 1. Nair PKR et al. 2010. Adv Agron 108: 237–307. Doi: 10.1016/S0065-2113(10)08005-3
2. 2. Haile SG et al. 2010. Global Ch Biol. 16: 427–438. Doi: 10.1111/j.1365-2486.2009.01981.x
3. 3. Saha SK et al. 2010. Plant and Soil 328: 433–446. DOI 10.1007/s11104-009-0123-x
4. 4. Tonucci RG et al. 2011. J Environ Qual 40: 825 – 832. DOI 10.1007/s11104-017-3347-1
5. 5. Chatterjee N et al. 2018. Agric Ecosyst Environ. 2018. doi.org/10.1016/j.agee.2018.07.014

L01.2_O.04

Diurnal and seasonal variations on soil CO_2 fluxes in tropical silvopastoral systems

Casanova-Lugo F.[1] (fkzanov@gmail.com), Adame-Castro D.[1], Díaz-Echeverría V. F.[1], Oros-Ortega I.[1], Aryal D. R.[2], Villanueva-López G.[3], Cetzal-Ix W. R.[4], Lara-Pérez L. A.[1]

[1] *Tecnológico Nacional de México, I.T. Zona Maya, Othón P. Blanco, Quintana Roo, Mexico*; [2] *CONACYT-UNACH, Facultad de Ciencias Agronómicas, Chiapas, Mexico*; [3] *El Colegio de la Frontera Sur, Agricultura, Sociedad y Ambiente, Villahermosa, Tabasco, Mexico*; [4] *Tecnológico Nacional de México, I.T. Chiná, Chiná, Campeche, Mexico*

Recent studies indicate that changes in the landscape promote significant variations in the dynamics of soil CO_2 fluxes under tropical conditions. An alternative that could reduce flows to the atmosphere is the incorporation of trees and shrubs to pastures and convert animal production systems based on pasture monocultures to silvopastoral systems (SPS). The aim of the present study was to evaluate the effect of the diurnal and seasonal variations on the soil CO_2 fluxes in two tropical SPS in Mexico. The climate of the study area is warm sub-humid and the soils are of the Gleysol type. Two silvopastoral arrangements were used, one consisting of *Leucaena leucocephala* cv. Cunningham associated with *Panicum maximum* cv. Mombaza, and another with *L. leucocephala* cv. Cunningham associated with *Cynodon plectostachyus*, established in 2014. The soil CO_2 fluxes, temperature and soil moisture were measured *in situ* with a LICOR-8100A infrared gas analyzer (LICOR Inc., Lincoln, NE) during the dry and rainy season at two sampling times (06:00-08:00 and 14:00-16:00 h), under a completely random design with four repetitions. The data were transformed to logarithm to comply with the normality assumptions (Kolmogorov-Smirnov) and analyzed with a two-way analysis of variance. Soil CO_2 fluxes, temperature, and soil moisture were similar ($P > 0.05$) in both SPS evaluated with average values of 6.1 μmol/m^2/s, 25.4 °C, and 33.5%, respectively. In both SPS it was observed that the soil CO_2 fluxes and the soil temperature were higher ($P < 0.05$) in afternoon (14:00-16:00 h), nevertheless; soil moisture was similar between sampling times ($P > 0.05$). Soil temperature was higher in the dry season compared to the rainy season for the SPS of *L. leucocephala* with *P. maximum* ($P < 0.05$). We concluded that the soil CO2 fluxes and the soil temperature were affected by the diurnal variations; however, in the dry season the SPS of *L. leucocephala* with *P. maximum* showed a higher soil temperature.

Keywords: Gleysol, shrub legume, soil respiration, tropical grasses.

L01.2_O.05

How do hedgerows influence soil organic carbon and carbon budgets in livestock-grazed pasture?

Ford H. (hilary.ford@bangor.ac.uk), Pagella T., Healey J., Webb B., Smith A.

Bangor University, Bangor, United Kingdom

Hedgerows have the potential to influence ecosystem function in livestock-grazed pasture. Despite this, they are often ignored when quantifying ecosystem service delivery. We assessed the contribution of hedgerows to C storage, with a particular emphasis on soil organic C (SOC), and annual C budgets. We measured SOC content at 0-0.15 m depth in pasture adjacent to hedgerows, stone walls or fences across ten farms in North Wales (UK). We also measured soil respiration in pasture adjacent to two hedgerows, and in the un-grazed zone directly under the hedgerow itself, in seasonally-wet and free-draining soils. SOC content was greatest under hedgerows (7-20%), with pasture within 2m of the hedgerow boundary fence greater (~7%) than farther into the pasture (~6%). The presence of hedgerows altered seasonal soil temperature and moisture dynamics which in turn influenced soil respiration. Pasture on free-draining soil was identified as an annual net source of C, with the un-grazed hedgerow zone a small net sink (Figure 1). The zone-of-influence of hedgerows in agricultural land in North Wales accounts for ~1% of land area, with potential to contribute to the 4 per 1000 initiative.

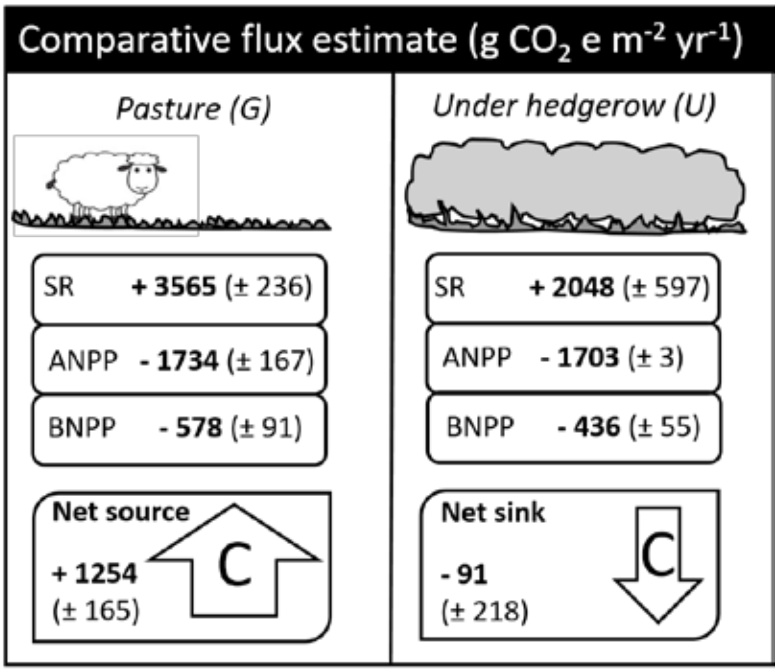


Figure 1. Annual carbon (C) budget of the effect of hedgerows on the C balance of livestock-grazed (G) pasture on free-draining soils. Annual soil respiration (SR) rates were calculated for pasture and un-grazed (U) zone directly under hedge. ANPP/BNPP = above/below-ground net primary productivity.

Keywords: carbon storage, soil respiration, carbon budget, grazed, hedgerows.

L01.2_O.06

Revisiting IPCC Tier 1 coefficients for soil organic and biomass carbon storage in agroforestry systems

Bernoux M.[1] (Martial.Bernoux@fao.org), Umulisa V.[2], Toudert A.[1], Olivier A.[3], Bockel L.[1], Cardinael R.[4]

[1] *Climate and Environment Division, FAO, Rome, Italy*; [2] *CIRAD, Bonn, Germany*; [3] *Université Laval, Québec, Canada*; [4] *CIRAD, Montpellier, France*

Agroforestry systems (AFS) have the capacity to sequester large quantities of carbon (C) in both soil and biomass. However, these systems have not yet been fully considered in the approach to C accounting developed by the Intergovernmental Panel on Climate Change (IPCC). Our literature review identified a total of 122 scientific, peer-reviewed articles associated with biomass C storage and with soil organic carbon (SOC), containing of total of 542 observations (324 and 218, respectively). Based on a synthesis of the reported observations, we are presenting a set of Tier 1 coefficients for biomass C storage for each of the 8 main AFS identified, including alley cropping, fallows, hedgerows, multistrata, parklands, shaded perennial-crop, silvoarable and silvopastoral systems, disaggregated by climate and region. Using the same agroforestry classification, we are presenting a set of stock change factors (FLU) and SOC accumulation/loss rates for three main land use changes: cropland to AFS; forest to AFS; and grassland to AFS. Globally, the mean SOC stock change factors (± confidence intervals) were estimated to be 1.25 ± 0.04, 0.89 ± 0.07, and 1.19 ± 0.10, for the three main land use changes, respectively. However, these average coefficients hide huge disparities across and within different climates, regions, and types of agroforestry systems, highlighting the necessity to adopt the more disaggregated coefficients provided herein.

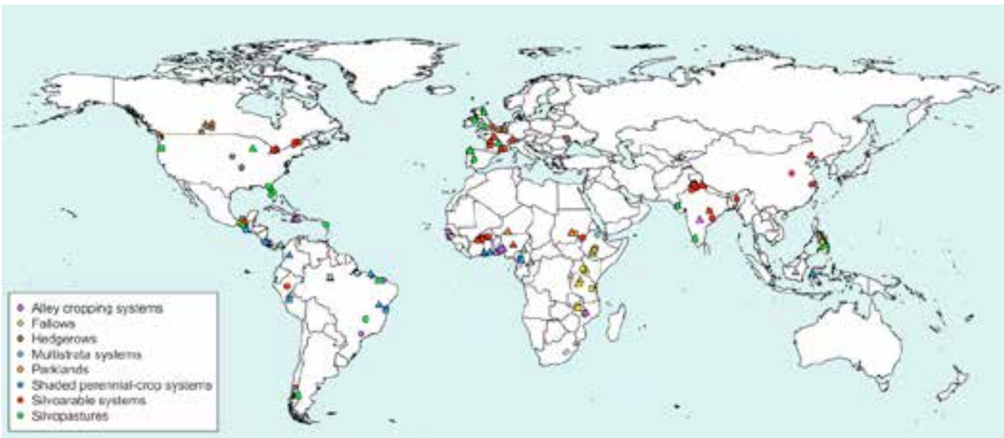


Figure: Sites of published studies on SOC (circles) and biomass (triangles) storage in various agroforestry systems. A few studies reported both SOC and biomass (squares).

Keywords: Carbone sequestration, emission factor, climate change mitigation, land use change.

References:

1. Cardinael R, Umulisa V, Toudert A, Olivier A, Bockel L, Bernoux M, 2018. Environ. Research Letters

L01.2_O.07

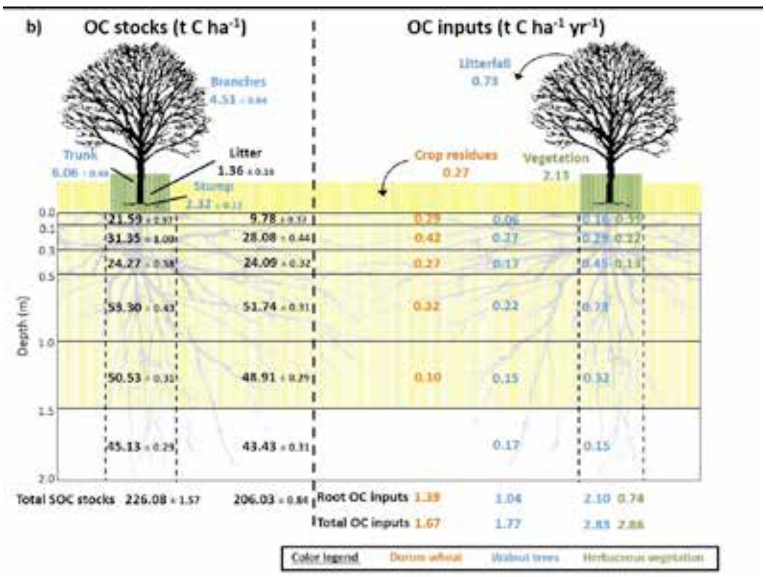
High organic inputs explain shallow and deep SOC storage in a long-term agroforestry system

Chenu C.[1] (claire.chenu@inra.fr), Guenet B.[2], Chevallier T.[3], Dupraz C.[4], Cozzi T.[1], Cardinael R.[5]

[1] *UMR Ecosys, AgroParisTech, Thiverval-Grignon, France*; [2] *LSCE, Gif-Sur-Yvette, France*; [3] *IRD, Montpellier, France*; [4] *UMR System, INRA, Montpellier, France*; [5] *CIRAD, Montpellier, France*

In agroforestry systems (AFS), soil organic carbon (SOC) stocks are generally increased, but it is difficult to disentangle the different factors responsible for this storage. We used an 18-year-old silvoarable system associating hybrid walnut trees and durum wheat and an adjacent agricultural control plot to quantify all OC inputs to the soil – leaf litter, tree fine root senescence, crop residues, and tree row herbaceous vegetation – and measured SOC stocks down to 2m of depth at varying distances from the trees. We then proposed a model that simulates SOC dynamics in AFS accounting for both the whole soil profile and the lateral spatial heterogeneity. The model was calibrated to the control plot only.

Measured OC inputs to soil were increased by about 40% (+1.11 tCha−1 yr−1) down to 2m of depth in the AFS plot compared to the control, resulting in an additional SOC stock of 6.3 tCha−1 down to 1m of depth. However, most of the SOC storage occurred in the first 30 cm of soil and in the tree rows. The model was strongly validated, properly describing the measured SOC stocks and distribution with depth in AFS tree rows and alleys. It showed that the increased inputs of fresh biomass to soil explained the observed additional SOC storage in the AFS plot. Moreover, only a priming effect variant of the model was able to capture the depth distribution of SOC stocks, suggesting the priming effect as a possible mechanism driving deep SOC dynamics.



Measured soil organic carbon stocks and organic carbon inputs to the soil in the 18-year- old agroforestry plot. Associated errors are standard errors. Values are expressed per hectare of land type (control, alley, tree row). To get the values per hectare of agroforestry, data from the alley and tree row have to be weighted by their respective surface area (i.e., 84 and 16 %, respectively) and then added up. OC: organic carbon; SOC: soil organic carbon. SOC stock data are from Cardinael et al. (2015b), and data for tree root OC inputs are combined from Cardinael et al. (2015a) and Germon et al. (2016).

Keywords: deep roots, deep SOC, SOC modeling, priming effect, C sequestration.

References:

1. Cardinael et al., 2018. Biogeosciences 15:297-317
2. Cardinael at., 2015a. Plant and Soil 391:219-235
3. Cardinael at., 2015b. Geoderma 259-260:288-299
4. Germon et al., 2016. Plant and Soil 401:409-426

L01.2_O.08

The net biome production of an alley-cropping system of sorghum and poplar SRC compared to an open field cultivation

Pecchioni G.[1] (g.pecchioni@santannapisa.it), Bosco S.[1], Volpi I.[1], Mantino A.[1], Dragoni F.[1], Giannini V.[1], Micci M.[2], Tozzini C.[1], Mele M.[3], Ragaglini G.[1]

[1] *Institute of Life Sciences, Sant'Anna School of Advanced Studies, Pisa, Italy*; [2] *Department of Agricultural Sciences, University of Perugia, Perugia, Italy*; [3] *DAFE, University of Pisa, Pisa, Italy*

Silvoarable systems are recognized to be able to stock higher amount of carbon (C) respect to conventional arable systems, both accumulating C in total biomass of trees and enhancing the soil organic carbon (SOC) sequestration potential (1). Several methods are available to assess agroecosystem C balance. Since changes in SOC become apparent in decades, soil sampling techniques do not allow to measure differences in short term. The flux approach is considered a good method for the full carbon balance accounting at annual scale. Indeed, it is an indirect method to estimate all carbon fluxes (2), suitable to quantify the net biome production (NBP), namely the net carbon gains/losses, calculated with the following equation (3):
NBP=CAGB+CBGB-CRh-Ch
The C inputs in the NBP calculation are the C in the aboveground biomass (CAGB) and in the belowground biomass of trees and crop (CBGB), while the C outputs are the C lost with the heterotrophic respiration (CRh) and with the harvested biomass (Ch).
The aim of this work was to assess the potential agroecosystem carbon storage through the NBP of three systems: open field (OF), agroforestry (AF) and poplar short rotation forestry (SRF). The experimental field, which includes the three systems, was located in Pisa (Italy) at 3 m a.s.l. in a loam to clay loam soil. Rows of short rotation coppice (2 years cut cycle) poplar are spaced 13.5 m. Poplar (*Populus spp.* clone AF2 and Monviso) was planted in 2009, sorghum (*Sorghum bicolor* L.) was sown in open field plots and in poplar alleys in June 2018.
In AF, the distance from trees was considered as a factor, sampling all the NBP components along a transect in the alley with 3 positions (AFW, westward; AFC, center; AFE, eastward). The experimental design included 4 replicates for each system and position.
In each system, initial soil characterization was carried out and microclimate conditions were monitored in continuum by meteorological stations recording air temperature, wind speed, soil temperature and soil water content (SWC).
The CAGB, CBGB and Ch were calculated multiplying the biomass dry weight per the biomass C concentration. The aboveground biomass was measured at harvest weighting all the crop aerial parts, weeds and litter. The belowground biomass was measured with soil coring at harvest. The harvested biomass was measured weighting sorghum grain and poplar biomass. The CRh was measured with the chamber method (portable CO2 analyser) in a soil CO2 flux partitioning experiment with the root exclusion method (trenching) (4), with weekly measurements. The method adopted in this study will allow to quantify the overall C sequestration potential of agroforestry in Mediterranean conditions considering the carbon accumulation at agroecosystem scale in short time in arable lands and to assess the effect of position along the transect on NBP due to different microclimate conditions.

Keywords: Carbon balance, CO2 flux, Sustainable intensification, Mitigation potential, Climate change adaptation.

References:

1. Cardinael et al., 2017, Agriculture, Ecosystems and Environment, 236: 243–255; doi: 10.1016/j.age
2. Hanson et al., 2000, Biogeochemistry 48: 115-46
3. Kutsch et al., 2010, Agriculture, Ecosystems and Environment, 139: 336-345; doi: 10.1016/j.agee.2
4. Heinemeyer et al., 2011, European Journal of Soil Science 62: 82–94; doi: 10.1111/j.1365-2389.201

L01.2_O.09

Soil Carbon Storage in Silvopasture in comparison with planted and native forests and pasture in a Brazilian Oxisol

Pinheiro F. M.[1] (felipinheirorj@gmail.com), Nair P.K.R.[2], Nair V. D.[3], Viana M. C. M.[4], Alvarenga R. C.[5]

[1] *School of Natural Resources and Envir., University of Florida, Gainesville, Florida, United States*; [2] *School of Forest Resources and Conserv., University of Florida, Gainesville, Florida, United States*; [3] *Soil and Water Sciences, University of Florida, Gainesville, Florida, United States*; [4] *EPAMIG Centro Oeste, Sete Lagoas, Minas Gerais, Brazil*; [5] *EMBRAPA Maize and Sorghum, Sete Lagoas, Minas Gerais, Brazil*

In Brazil, silvopastoral systems (SPS) are practiced in about 2 million hectares with Eucalyptus hybrids as the main tree species, and the area is increasing because of governmental incentives. To understand the influence of such systems on soil organic carbon (SOC) storage, we studied C content in three aggregate size classes in four land-use systems (LUS) on Oxisols in Prudente de Morais, Minas Gerais, Brazil. The LUS were 8-year-old SPS, planted forest (Eucalyptus hybrid), native (Cerrado) secondary forest, and managed pasture. The SPS had three tree-planting configurations: i) trees 3 m apart in double rows, 20 m between rows (SPS 20); ii) trees 2 m apart in double rows, 9 m spacing (SPS 9D); and iii) trees 2 m apart in single rows, 9 m spacing (SPS 9). The grass in SPS and pasture treatments was *Urochloa decumbens.* Cattle had been introduced 3 years after planting trees. The native forest was semi-deciduous degraded forest, with > 10 tree species, ~ 10 m height. From each treatment, composite soil samples were collected from each of the depth-classes (0–10, 10–30, 30–60, and 60–100 cm), three replications, and from two sites each in SPS: NT (near trees, 1.5 m from trees) and MR (middle of two rows). In the laboratory, each soil sample was manually fractionated (wet sieving) into three aggregate-size classes: macroaggregates, MA (2000 to 250 μm), microaggregates, MI (250 to 53 μm), and silt + clay, SC (<53 μm). The SOC contents in each fraction size class were determined and reported as stock (Mg ha^{-1} per cm) in various soil layers, and compared using *R* and ANOVA in a completely randomized design and Tukey's studentized range test (significant at $p < 0.05$). The results showed that pasture had higher SOC in the whole soil and MA fraction. The MI fraction had higher SOC under pasture than forest and SPS 20 (NT and AT). For the SC size fraction, no difference was found between the treatments. Comparing the depths, SOC in MA was higher in the top soil layers. For the MI and SC size fractions, the SOC decreased with depths and were similar at the depths of 30 – 60 and 60 – 100 cm. Down to 1 m, total SOC stock ranged from 260 Mg ha^{-1} under pasture to 167 Mg ha^{-1} under native secondary forest; 174 Mg ha^{-1} for Eucalyptus plantation; and the three SPS had values in the 190 to 200 Mg ha^{-1} range. The SPS had higher C stock than the native forest and Eucalyptus plantation, and the highest stock was under pasture. The lowest amount of SOC under forest was a reflection of the poor state of the degraded secondary forest. It will be worthwhile to study if incorporating the native nitrogen-fixing trees (NFT), several of which are available, in SPS would lead to better C storage in soils comparable to or exceeding that under pasture. The relative distribution of C in different soil fraction sizes under SPS with native NFTs is another important line of future investigation, especially considering the status of the Cerrado biome as a biodiversity hotspot.

Keywords: Agroforestry, Climate Change, Tree Management, Livestock, Soil Organic Matter.

L01.2_O.10

Soil-atmosphere CO2 fluxes in Central Africa humid tropics: comparative study among food crop and agroforest systems

Njine Bememba C. B.[1] (njine15@yahoo.com), Sonwa D. J.[1], Kwatcho Kengdo S.[2], Tejedor J.[2], Dannenmann M.[2], Rufino M.[3], Verchot L.[4]

[1] *Environment, CIFOR-Cameroon, Yaounde, Centre, Cameroon*; [2] *Institute of Meteorology and Climate R., Karlsruhe Institute of Technology, Garmisch, Germany*; [3] *University of Lancaster, Lancaster, England*; [4] *CIAT, Cali, Colombia*

The Congo Basin is the second largest forest reserve in the world and hold much of Africa's carbon. In Sub Saharan Africa region, AFOLU sector represents amongst 80% of GHG emission. In the case of Cameroon which commits to a 32% decrease of GHG emission compared to 2010, by 2035 and in the same time aiming to emerge on the same horizon, searching of balance for have a green economies is challenging. However, due to absence of analytical capacities in Central Africa, there is a severe lack of knowledge on GHG fluxes which introduces large uncertainties into regional GHG reporting.
The objectives of this study were to quantify and analyze seasonal variability and environmental controls of soil-atmosphere interface CO2 fluxes in secondary forests (as reference level), cocoa agroforests and unfertilized mixed crop fields in Cameroon, typical land uses of the Congo basin. We used manual static chamber techniques with approximately weekly temporal resolution over a full year and analyzed gas samples using a gas chromatographer. Soil temperature, moisture data were permanently recorded.
Our work indicates that cocoa agroforest contains 10 times more biomass than mixed crop field. We also notice a strong decrease of CO2 emissions after forest conversion to crop fields than agroforest (180.28 mgC.m-2.h-1 in forest towards respectively 141.06 mgC.m-2.h-1 and 102.56 mgC.m-2.h-1 for cocoa and crop field), showing that SOC is more important in agroforest system. And finally, variation in soil water content was the dominant driver of seasonal variations of the fluxes at all study sites.

Keywords: Congo bassin, soil-atmosphere, CO2 fluxes, Cocoa agroforest, mixed crop field.

L01.P.01

Long-term agroforestry systems options to recover degraded lands and to mitigate climate change in the Peruvian Amazon

Alegre J.[1] (jalegre@lamolina.edu.pe), Vega R.[1], Lao C.[2], Schrevens E.[3]

[1] *Soils, Universidad Nacional Agraria La Molina, Lima, Lima, Peru*; [2] *Soils, Universidad Agraria de la Selva, Tingo Maria, Huanuco, Peru*; [3] *Biosystems, Katholieke Universitie, Leuven, Flemish Brabant, Belgium*

Land degradation in the humid tropics of Peru by slash and burn agriculture is producing deforestation of around 113000 has per year. Some land use alternatives to reduce deforestation and land degradation by improving the physical and chemical soil properties were tested in the Peruvian amazon . Selective agroforestry systems (AFS) trials were established since 1987 in the Peruvian amazon . Main AFS was the multistrata system with crops, fruits and woody trees and a silvopatoral systems with cover crop.In 2016 new trials to recover degraded pastures was established and includes cover crop with centrosema and different mutistrata systems base in woody trees of fast, medium and long-term production. Results showed that with long-term agroforestry systems we had continuous food and fruit production and soft wood, firewood and at the end of 30 years the harvest of the hardwood of *Cedrelinga cateanaeformis*. Besides, these systems sequester an average of 10 t C ha-1 of carbon. The silvopastoral systems with adequate stocking rate and pasture maintenance and grazing rotation reduced the compaction and soil degradation . Recovering degraded pastures was reached at four months with centrosema cover crops followed by the establishment of multistrata systems. In conclusion long terms and short-term agroforestry systems with full soil cover offered and excellent option to recover degraded land, reduce the deforestation, and mitigate climate changes effects in the Peruvian amazon.

Multistrata Agroforestry System with cover crop in the peruvian amazon

Keywords: Multistrata system, cover crop, amazon, degradation.

References:

1. Alegre Julio, 2017, Peruvian Journal of Agronomy, 1-7
2. Alegre Julio 2015, LEISA,28-30
3. SERFOR, 2015, Global Green Growth Institute,DIE and German Development Institute ,1-40
4. Alegre Julio 2005, Agriculture, Ecosystems & Environment , 104-117
5. Arevalo Luis 1998, Agroforestry System, 109-114

L01.P.02

Growth and carbon sequestration in biomass of *Cordia alliodora* in coffee agroforestry systems in Tolima, Colombia

Andrade H. (hjandrade@ut.edu.co), Milena S., Escobar E.

Grupo de investigación PROECUT, Universidad del Tolima, Ibagué, Tolima, Colombia

Timber production and carbon sequestration (CS) of timber trees in agroforestry systems (AFS) are key for their productivity and climate change mitigation. Non-linear models of growth and CS of *Cordia alliodora* in coffee AFS with, a range of shade levels in Líbano, Tolima, Colombia were developed. A total of 98 trees with an age between 1 and 19 years were randomly selected in private farms and measured (diameter at breast height -dbh- and total height -th). Timber volume, biomass and carbon stock of these trees were estimated with volume and biomass alometric models and a carbon fraction of 0.47. The best-fit models were selected based on Information Criteria of Akaike (AIC) and Bayesian (BIC), the mean square error (MSE) and the biological adjustment. A residual analysis was also included in the selection. The greatest growth rate was reached at an age of 6 and 11 years (3.6 cm/year in dbh and 3.0 m/year in th, respectively); whereas the maximum carbon fixation was found between 13 and 17 years (60 kg C/tree/year) (Figure 1). The th reached the maximum value at 12 years, later that it was more or less contast. In a 20-years cycle in coffee AFS, *C. alliodora* could stock a total volume of timber of 148-495 m^3/ha and fix between 1.2 and 4.1 Mg C/ha/year with tree abundances of 30 and 100 trees/ha, respectively. These results show the importance of this species in AFS, mainly when timber production and carbon sequestration are priorities for their profitability.

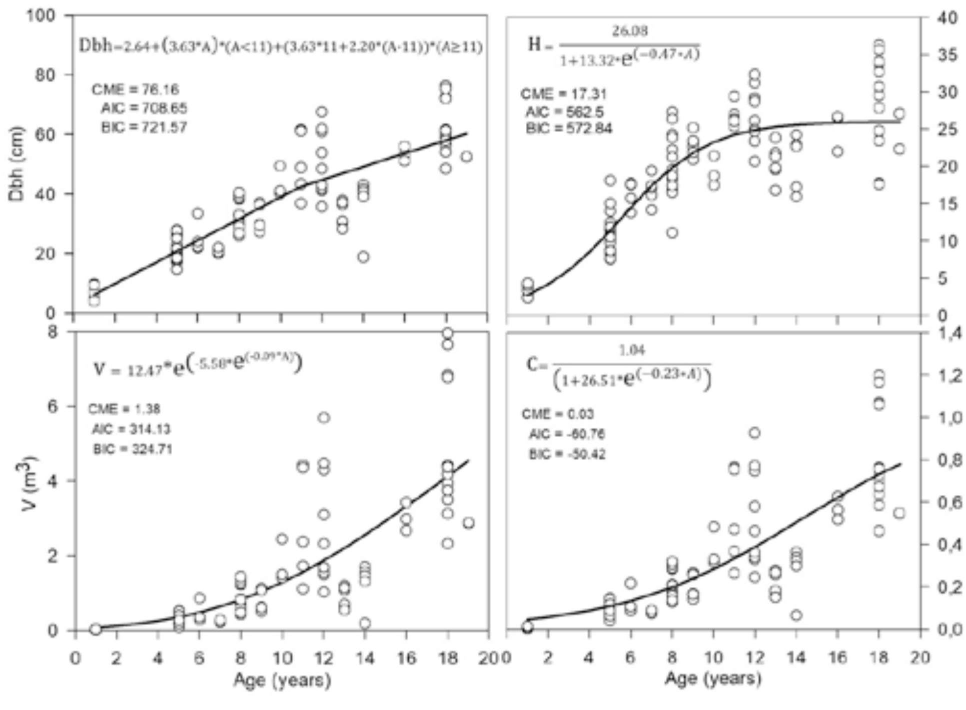


Figure 1. Growth and carbon sequestration of individual trees of Cordia alliodora in coffee agroforestry systems in Líbano, Tolima, Colombia. Dbh: diameter at breast height; H: total height; V: total timber volume; C: carbon stock in aboveground biomass.

Keywords: Abundance, Mitigation, Non-linear, Timber volume.

L01.P.03

Mitigation of climate change through carbon sequestration of coffee production systems in Cundinamarca, Colombia

Andrade H.[1] (hjandrade@ut.edu.co), Zapata P.[2]

[1] *Grupo de Investigación PROECUT, Universidad del Tolima, Ibagué, Tolima, Colombia*; [2] *U.D.C.A; The Nature Conservancy, Bogotá, Colombia*

Production systems with woody perennial plants, ideally timber trees, are technologies accepted in carbon projects to mitigate climate change through carbon sequestration. This research estimated C storage and fixation in coffee production systems in Cundinamarca, Colombia. Carbon in biomass, necromass and soil were estimated in systems with three different shade levels (low, medium and high) in three municipalities (Pacho, San Juan de Rioseco and Tibacuy) using IPCC´s recommendations (2006). Biomass was estimated with allometric equations, being some of them specific. Belowground biomass was estimated with a general model recommended by IPCC. Soil organic carbon was estimated at a 0-30 cm depth, considering the gross fragments. Variance analyses were carried out using the completely randomized design with three treatments (shade levels) and five repetitions per municipality. Soil stored 75% of the total C (93.9-137.7 Mg C ha-1), followed by trees (19%). Carbon increases with a rise in shade (55.8 *vs*42.0 *vs*23.0 Mg C ha-1for high, medium and low shade, respectively) (Figure 1a). Coffee bushes contributed just with 6% of total C in biomass and necromass; whereas necromass was the less important component (1-6%). These coffee plantations fixed a mean of 2.3 Mg C ha-1year-1, with a maximum value of ~7.1 Mg CO2 ha-1year-1 under a shade of 30-40% (Figure 1b). Coffee plantations, especially with high shade, have a high potential of C fixation and mitigate climate change.

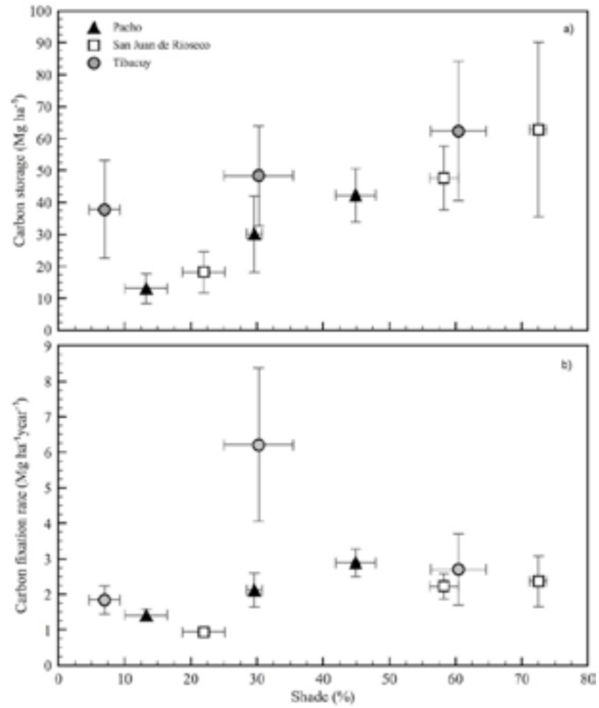


Figure 1.Impact of shade in carbon storage in total biomass and necromass (a) and fixation rate in total biomass (b) in coffee plantations in three municipalities of Cundinamarca, Colombia. Error bars correspond to standard error.

Keywords: Biomass, Fixation, Necromass, Roots, Soil organic carbon.

References:

1. Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC Guidelines for National Greenhouse Gas I

L01.P.04

Variation of soil microbial emissions in coffee agroforestry systems in Veracruz, México

Ayala D.[1] (diayalamontejo@gmail.com), Ramírez I.[2], Valdés E.[2], Alegre J.[3], Cruz J.[4], Pérez E.[4], Quispe G.[5]

[1] *Fitotecnia Department, Universidad Autónoma Chapingo, México, México*; [2] *Fitotecnia Department, Universidad Autónoma Chapingo, México, México*; [3] *Soil Science Department, Universidad Nacional Agraria La Molina, Lima, Perú*; [4] *Agroecology Department, Universidad Autónoma Chapingo, México, México*; [5] *DyG Solución Bio-organica S.A.C., Lima, Perú*

A high density of shade trees and varieties with high coffee cup quality characterizes the coffee agroforestry systems in Mexico. However, in the last decade it has been affected by leaf rust (*Hemileia vastatrix*), trade problems and low prices that lead producers to change their varieties, reduce shade density and apply inorganic inputs. These decisions affected the type and quality of organic matter and the microbial activity[2] that generated variations in CO_2 emissions. The objective of the study is to show the effects of the decisions adopted by producers to adapt to the problem of CO_2 emission generated by the soil microfauna (SM). The study was carried out in Tlaxopla, Veracruz, in three farms as follows: 1) One farms renovated using leaf rust tolerant varieties, 2) Management with application of pruning, and leaf rust control with application of inorganic fertilizers, 3) Traditional management. Three soil samples were taken per farm and per depths of 0-10; 10-20; 20-30 cm, and microbial activity was evaluated through the CO_2 content emitted by the SM. Results showed that on average the farm (1) emitted a higher concentration of CO_2 at the three depths (1.5; 1.4; 1.4 $mgCO_2.Kg^{-1}soil.day^{-1}$) and the adopted decisions to renew with tolerant varieties enriched the soil microfauna[3] with the generation of greater CO_2 emissions. However, concentrations of CO_2 were in the range (1.4; 1.4; 1.4 $mgCO_2.Kg^{-1}soil.day^{-1}$) of emissions generated by farms with traditional management[1] (3).

Figure 1: Renovated farm with varieties tolerant to rust

Keywords: Microbial activity, Farms renovated, CO2 emissions.

References:

1. Wuellins Durango, 2015, Agronomía costarricense, 37-46.
2. Noelia Chavarría, 2012, InterSedes de la Universidad de Costarica, 85-105
3. Veronica Acosta, 2010, Agriculture, ecosystems & environment, 231-240.

L01.P.05

Managing soil organic carbon in grazing lands and its potential role in climate change mitigation in Africa

Aynekulu E.[1] (e.betemariam@cgiar.org), Milne E.[2], Shepherd K.[1]

[1] *Land Health Decision, World Agroforestry Centre, Nairobi, Kenya*; [2] *Colorado State University, Fort Collins, United States*

Grazing lands contain large amount of soil organic carbon (SOC) making them important to mitigate climate change, improve water infiltration and storage, improve nutrient cycling, increase land productivity and increase below and potentially above ground biodiversity, hence improving livelihoods. The key determinants of SOC sequestration potential in grazing lands in SSA are climate (rainfall amount and regime) and soil type. In general, it can be said that i) mesic environments sustained grazing pressure is likely to lead to land degradation (and therefore may cause SOC to decrease) and 2) in dry areas with high rainfall variability, land degradation from sustained grazing may not be as apparent as grazing effects are overridden by rainfall effects. We found no significant differences in SOC following two decades of annual prescribed burning in Burkina Faso and three decades of avoiding livestock grazing management in Ethiopia. There may be instances in which there are large social costs to SOC sequestration and by making sequestration the primary goal, a situation could arise where the social or economic burdens of the project could be greater than the climate change mitigation benefits. Therefore, we recommend that SOC sequestration for climate change mitigation should be treated as a co-benefit rather than the target of a project/ activity. Projects also need to prioritize to avoid grazing land degradation and SOC losses in dry grazing lands which have less carbon sequestration potentials. Gaps in our understanding of the determinants of SOC sequestration potential were further discussed and general recommendations for future projects and other activities addressing SOC sequestration in grazing lands highlighted.

Keywords: land degradation, drylands, climate change, mitigation, restoration.

L01.P.07

Soil C stocks in the sylvopastoral zone of Senegal as influences by trees

Blanfort V.[1] (vincent.blanfort@cirad.fr), N'Goran A.-J. A.[2], Diouf A. A.[3], Diatta S.[4], Assouma M. H.[2], Djagoun A.[2], Cournac L.[5], Lardy-Chapuis L.[5], Taugourdeau S.[2]

[1] *UMR Selmet, Cirad, Montpellier, France*; [2] *UMR Selmet DP PPZS, Cirad, Dakar, Senegal*; [3] *Centre de Suivi Ecologique, Dakar, Senegal*; [4] *FST Departement Biologie Végétale, UCAD, Dakar, Senegal*; [5] *UMR Ecosol LMI IESOL, IRD, Dakar, Senegal*

Sahelian pastoral livestock systems are criticized for their high intensity of greenhouse gas emissions (CO2, N2O, CH4) per unit of product combined with their negative impact on soil and vegetation degradation caused by the trampling of animals, the overgrazing and the uncontrolled sampling. However, interactions between soil and plants could mitigate this environmental impact by an increase in the levels and stocks of organic carbon (C) in soils. In Senegal, some studies were conducted on the dynamics of C and C stocks in some areas of the pastoral zone (Ferlo). However, these studies did not cover the entire sylvopastoral zone of the Senegal. The main objective of this study is to determine the influence of the woody stratum on the soil C content and to identify the environmental factors influencing the variation of soil C stocks in the sylvopastoral zone of Senegal. Soil were collected in 15 of the soil control sites of the Senegalese Ecological Monitoring Center (CSE). Soil samples were taken outside and under tree crowns for the 0-10 and 10-30 cm soil layers. Sieved soil sample reflectance was measured in the near infra-red range (NIRS) to predict soil C and N contents. The soil bulk density was determined using the core method and soil C stocks calculated. Results showed that C stocks in the 0-30 cm surface layers of these sandy soils varied from 9.29 to 29.72/ 18.51 t.ha-1. Soil contents of C and N were higher under the crowns, and at 0-10 cm deep. In addition, the soil C-to-N ratio was significantly higher under than outside tree crowns. In the sylvopastoral zone of Senegal, the stocks of soil organic C increased along a North-South gradient and were positively influenced by rainfall and leaf biomass of trees. From this study, it appears that the tree impels the increase of the contents of C, N This content is also dependent on the rainfall variability and organic matter production of the vegetation cover in the Sahelian sylvopastoral zone.

Keywords: sahel, Soil Carbon, soil nitrogen, tree.

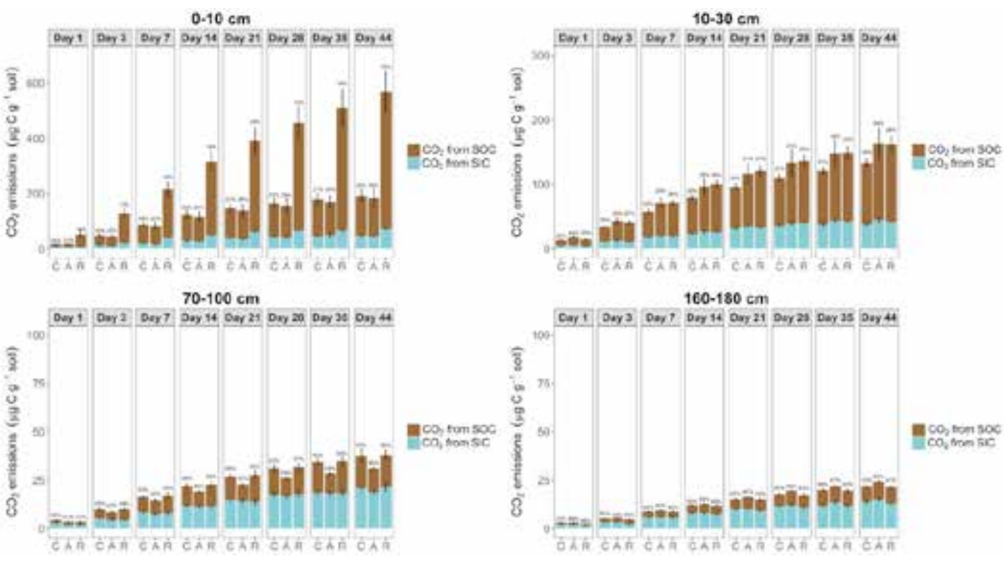
L01.P.08

Organic carbon decomposition rates with depth under an agroforestry system in a calcareous soil

Cardinael R.[1] (remi.cardinael@cirad.fr), Chevallier T.[2], Guenet B.[3], Cozzi T.[4], Girardin C.[5], Chenu C.[4]

[1] *UR AIDA, CIRAD, Montpellier, France*; [2] *UMR Eco&Sols, IRD, Montpellier, France*; [3] *LSCE, Gif-sur-Yvette, France*; [4] *UMR Ecosys, AgroParisTech, Thiverval-Grignon, France*; [5] *UMR Ecosys, INRA, Thiverval-Grignon, France*

The aims of this study were: (i) assess soil organic carbon (SOC) mineralisation potential as a function of soil depth in an agroforestry (AF) plot compared to an agricultural plot (ii) estimate the contribution of soil inorganic carbon (SIC) to CO2 emissions at different depths. Soils were collected in an 18-year-old AF (tree rows and alleys) and in an adjacent agricultural plot. The incubation comprised four soil replicates per location (control, tree row, alley) and per depth (0-10, 10-30, 70-100 and 160-180 cm). Soil samples were moistened to reach field capacity, at pF 2.5, and were then incubated at 20°C in the dark. The CO2 concentration and the δ13C of the CO2 were measured after 1, 3, 7, 14, 21, 28, 35 and 44 days. The microbial biomass was measured at the end of the incubation. Decomposition rates were calculated, as well as the metabolic quotient. The cumulated total CO2, SIC-derived CO2 and SOC-derived CO2 emissions were only significantly higher in tree row than in the alley or in the control plot at 0-10 cm. SOC decomposition rates decreased with increasing depth. Contributions of SIC to total CO2 emissions according were comprised between 0.15 and 0.30 in topsoil layers and between 0.50 and 0.70 in subsoil layers. The higher emission in the tree row at 0-10 cm was related to a large amount of labile particulate organic matter. SOC did not seem to be more stabilized in AF compared to the control. SIC-derived CO2 must be taken into account on calcareous soils.



Contribution of soil organic carbon (SOC) and soil inorganic carbon (SIC) derived CO2 to cumulated CO2 emissions (µg C-CO2 g-1 soil) during the incubation. C= control plot, A= cropped alley, R: tree row. Error bars are standard errors (N=4). The percentages represent the proportion of total CO2 emissions derived from soil inorganic carbon (SIC).

Keywords: alley cropping, silvoarable system, deep SOC, potential mineralization, metabolic quotient.

References:

1. Cardinael et al., 2015 Geoderma 259-260:288-299
2. Cardinael et al., 2018 Biogeosciences 15:297-317

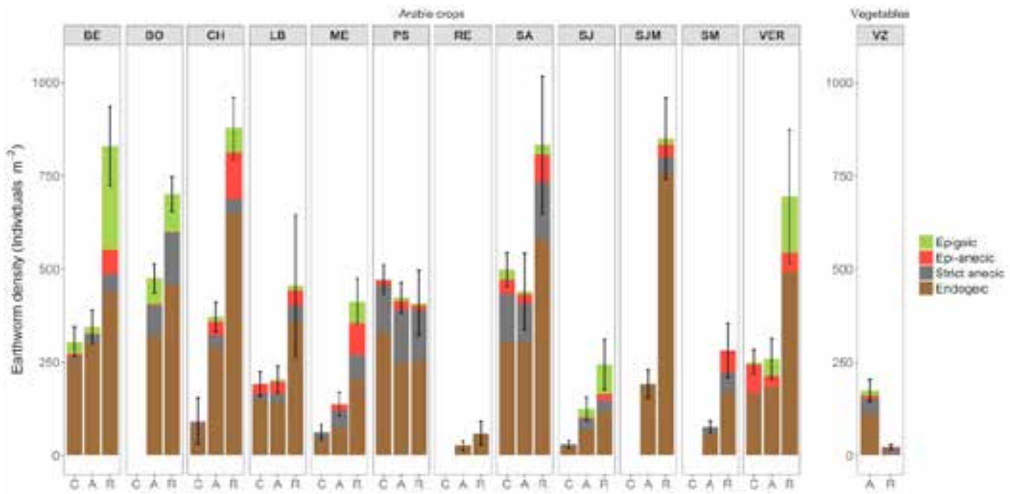
L01.P.09

Spatial variation of earthworm communities and soil organic carbon in temperate agroforestry

Cardinael R.[1] (remi.cardinael@cirad.fr), Hoeffner K.[2], Chenu C.[3], Chevallier T.[4], Béral C.[5], Dewisme A.[2], Cluzeau D.[2]

[1] *UR AIDA, CIRAD, Montpellier, France*; [2] *UMR Ecobio, Univ-Rennes, Rennes, France*; [3] *UMR Ecosys, AgroParisTech, Thiverval-Grignon, France*; [4] *UMR Eco&Sols, IRD, Montpellier, France*; [5] *Agroof, Anduze, France*

The aim of this study was to assess how soil organic C (SOC) stocks and earthworm communities were modified in agroforestry systems compared to treeless control plots, and within the agroforestry plots (tree rows vs alleys). We used a network of 13 silvoarable agroforestry sites in France along a North/South gradient. Total earthworm abundance and biomass were significantly higher in the tree rows than in the control plots, but were not modified in the alleys compared to the control plots. Earthworm species richness, Shannon index, and species evenness were significantly higher in the tree rows than in the alleys. Total abundance of epigeic, epi-anecic, strict anecic and endogeic was higher in the tree rows. Surprisingly, earthworm individual weight was significantly lower in the tree rows than in the alleys and in the control plots. SOC stocks were significantly higher in the tree rows compared to the control plots across all sites. Despite higher SOC stocks in the tree rows, the amount of available C per earthworm individual was lower compared to the control. The absence of disturbance (no tillage, no fertilizers, no pesticides) in the tree rows rather than increased SOC stocks therefore seems to be the main factor explaining the increased total abundance, biomass, and diversity of earthworms. The observed differences in earthworm communities between tree rows and alleys may lead to modified and spatially structured SOC dynamics within agroforestry plots.



Distribution of earthworm mean total abundance in the four ecological categories at the different agroforestry sites and modalities. C, Control; A, Alley; R, Tree row. Error bars represent standard errors for total earthworm abundance. For the sites BO, RE, SJM, SM and VZ, the control plots were not sampled for earthworms.

Keywords: silvoarable system, alley cropping, earthworm abundance, earthworm diversity, carbon sequestration.

References:

1. Cardinael et al., 2018 Biology and Fertility of Soils (in press)
2. Cardinael et al., 2017 Agriculture, Ecosystems & Environment 236:243-255

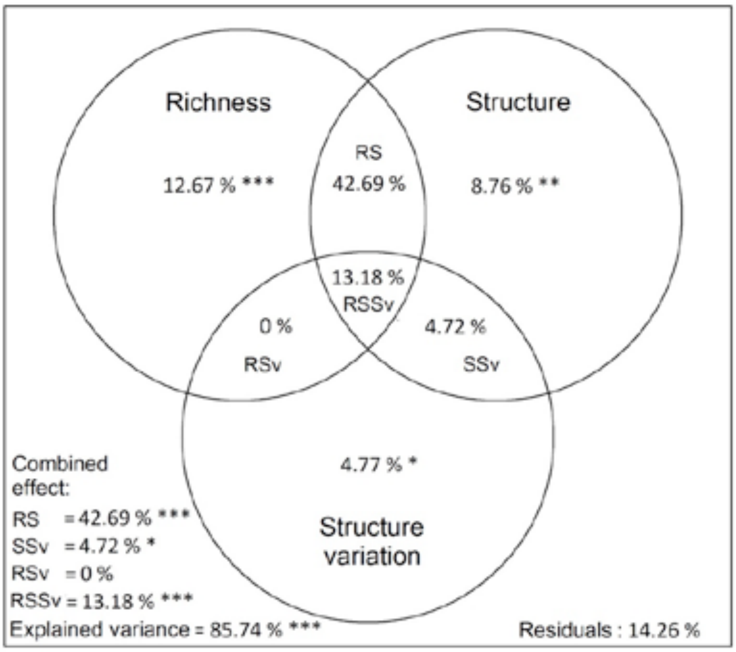
L01.P.10

More diverse and stratified agroforestry systems are more efficient to fix carbon

Celentano D. (danicelentano@yahoo.com.br), Rousseau G., Cardozo E., Gehring C.

Agroecology, Maranhão State University, São Luis, Maranhão, Brazil

Multistrata agroforestry systems (AFS) are known to provide goods, protect biodiversity and store carbon. Nonetheless, the role of tree diversification in the efficiency of the systems to store carbon is not well documented. We evaluated the effect of tree species richness and vegetation structure on aboveground biomass carbon in 25 AFS and 4 secondary forests from Southern Amazon of Bolivia. Vegetation (trees, shrubs and herbaceous) and necromass (leaf litter, branches and dead trees) were sampled in 1963 m2 circular plots. The relation between biomass carbon, tree species richness and vegetation structure was evaluated through linear and logarithmic functions. Variance partition by mean of partial redundancy analysis examined the pure and share effects of tree richness and vegetation structure on biomass carbon. Shaded coffee AFS had similar biomass carbon compared with old secondary forests. Overall AFS tree richness had a strong positive relation with biomass carbon ($r2 = 0.74$; $P < 0.001$) while, the partition analysis showed that tree richness, vegetation structure and variation of the structure explained 85.7% of biomass carbon variation. These results suggest that more diverse and stratified AFS use the resources more efficiently and therefore are able to fix more carbon.



Variance partition for carbon of the biomass aboveground (AGB) in agroforestry systems in the Southern Amazon of Bolivia.

Keywords: Mitigation, Aboveground biomass, Amazon, Bolivia, Variance partition.

References:

1. Albrecht, 2003, Agriculture Ecosystems and Environment, p.15
2. Poorter, 2016, Nature, 211
3. Cardozo, 2015, Agroforestry systems, 901

L01.P.11

Carbon sequestration in woody windbreaks and riparian buffers in eastern Quebec

Chauvette K.[1] (katja.chauvette@stud.uni-goettingen.de), Vézina A.[2], Boulfroy E.[3], Khasa D. P[4]

[1] *Georg-August-University, Göttingen, Germany*; [2] *Biopterre, La Pocatière, Canada*; [3] *Cerfo, Québec, Canada*; [4] *CEF, IBIS, Université Laval, Québec, Canada*

Since the 1980s, nearly 7 000 kilometers of woody windbreaks and riparian buffers have been established in the province of Quebec to protect agricultural soils, crops, waterways, livestock, roads and buildings. The establishment of hedgerows in agricultural areas is often perceived as a loss of arable land for the producer, which constitutes a major obstacle to the adoption of this practice. The demonstration that riparian woody buffers and windbreaks as agroforestry practices can provide a new source of revenue through the sale of carbon credits, which would offset the losses in arable land, could certainly be an important asset in convincing producers to implement trees and shrubs on farmlands.

The carbon market created in Quebec in 2013 could constitute a financial incentive thanks to emission rights. An adequate and rigorous assessment of the amounts of CO_2 sequestered by the various types of afforestation/reforestation (A/R) projects is fundamental, considering the imminent arrival of carbon offsets protocols for forest carbon sequestration.

The authors evaluated carbon sequestration potentials of indigenous tree and shrub species in windbreaks and riparian buffers planted in 2004 within a project aimed at studying opportunities for non-timber forest products of 10 shrub species. Three shrubs, *Aronia melanocarpa* (chokeberry), *Physocarpus opulifolius* (ninebark) and *Viburnum trilobum* (cranberry bush) were selected because they are commonly used in agroforestry systems in Quebec. Furthermore their vitality amongst the other shrub species seemed higher as their mortality rate of 10% was comparably low. In both systems, we chose 6 sites for every shrub with 10 replicates each. A nested sampling design was applied, where samples were equally collected from sandy soils and clay soils.

In Mai 2018, each shrub was cut individually near ground level and fresh biomass was weighted on site. After aboveground dry biomass was determined and carbon stocks at maturity were calculated. In addition, SOC at 15 cm depth in windbreaks, riparian buffers and their adjacent cultivated fields were estimated in September 2018.

There was a high variability of sequestered aboveground carbon, ranging from 0.1 kg C (chokeberry and cranberry bush) to 14.5 kg C (ninebark) with an average of 2.6 kg C of carbon per plant. Ninebark with 0.4 kg C to 14.5 kg C had the highest potential followed by chokeberry, 0.1 kg C to 5.3 kg C, and cranberry bush, 0.1 kg C to 5.4 kg C.

Windbreaks are more favourable than riparian buffer systems in terms of carbon sequestration ($p<0.001$). Moreover sandy soils were leading significantly ($p<0.01$) to higher carbon stocks. Considering only aboveground biomass, ninebark in a windbreak on sandy soils has the highest potential. Nevertheless samples of SOC at 15 cm soil depth still need to be analyzed and results will be presented during the oral presentation in Mai 2019.

Keywords: riparian buffer, windbreak, carbon sequestration, Quebec.

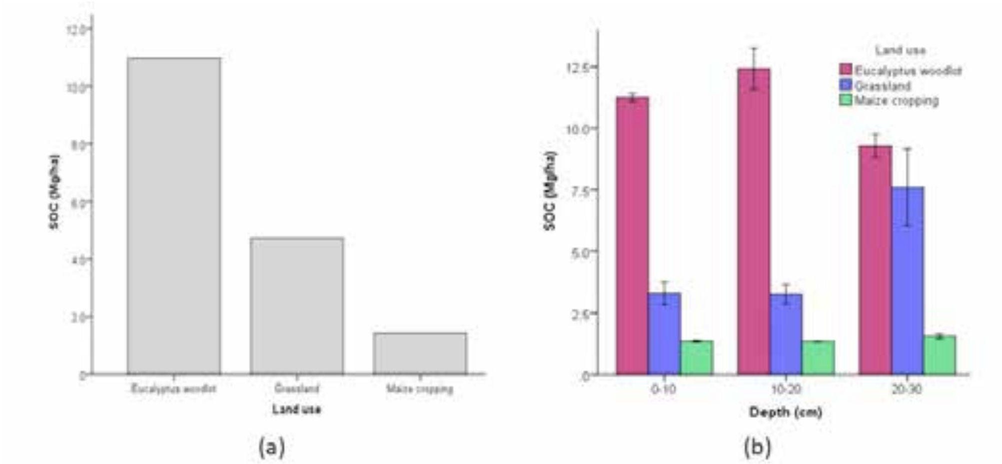
L01.P.12

Eucalyptus woodlots improve carbon sequestration in soils under small holder farming in Zimbabwe

Choruma D.[1] (dsrchoruma47@gmail.com), Mapurazi S.[2], Mujuru L.[2], Jimu L.[2]

[1] *Environmental Science, Bindura university of Science education, Bindura, Zimbabwe*; [2] *Natural Resources, Bindura university of Science education, Bindura, Zimbabwe*

The planting of woodlots in small holder farming communities has been upheld as key in supplying wood products while mitigating climate change in the face of widespread deforestation. A study was conducted in Wedza district of Zimbabwe to assess soil pH, bulk density and carbon storage potential of three land use systems; maize field, *Eucalyptus* woodlot and grassland 20 years after establishment of the woodlot. Soils samples were taken at 0-10, 10-20 and 20-30 cm, with replicates in each land use practice. Soil pH was not significantly different among the three land uses whereas bulk density in the *Eucalyptus* woodlot and the grassland were statistically similar. Soil organic carbon was significantly higher in the *Eucalyptus* woodlot (11 Mg/ha) than the grassland (5 Mg/ ha) and the maize field (1.4 Mg/ha). The carbon stocks were significantly higher at 0-10 cm than the 20-30 cm depths in the *Eucalyptus* woodlot whereas significantly higher carbon stocks were found at 20-30 cm in grassland. Croplands had similar carbon stocks at all depths. Results show that *Eucalyptus* woodlots increase the soil organic carbon and carbon dioxide storage than grassland and cropping land and has potential to reduce carbon emissions to the atmosphere thus helping to mitigate global warming. Inclusion of *Eucalyptus* woodlots in farmlands also contributes significantly to the reduction of land degradation whilst providing fuel wood, timber and income to the household.



Carbon storage in three land use practices (a) up to 30 cm (b) at three depth intervals over a 20 year period

Keywords: sequestration, Grassland, cropping system, agroforestry, carbon stocks.

References:

1. Bhavya VP et al,. 2014. International Journal of Chemical Studies. 5(4): 2019-2021
2. Duguma, L.A et al,. 2014. Environmental management 54(3) : 420-32.
3. Melenya et al,. 2015. Applied Research Journal. 1 (3):164-168
4. Prasad, J.V.N.S et al,. 2012. Current science. 103. 536-540
5. Sombroek, W.G. et al,. 1993. Ambio 22, 417–426.

L01.P.13

Plant Diversity, Ecological Services and Carbon Stock in Cocoa Agroforestry lands of Forest and Savannah in Cameroon

Choungo P. B.[1] (patrick_choungo@hotmail.fr), Jiofack R. B.[2], Temgoua L.[3], Mbouwe I. F.[2], Tchanou A. V.[2], Tchoundjeu Z.[4]

[1] *Global Environment Protects, Cameroon, Yaounde, west region, Cameroon*; [2] *Global Environment Protects, Cameroon, Yaounde, Cameroon*; [3] *University of Dschang, Dschang, Cameroon*; [4] *World Agroforestry Centre, (ICRAF), Yaounde, Cameroon*

T. conophorum is used for diversification in cocoa agroforestry plantations. This study was carried out in cocoa-based agroforestry systems in Mbam and Inoubou department, in Cameroon. The study aimed at assessing the plant species diversity, ecological services, and carbon sequestration potentials of diverse trees associated in cocoa agroforestry systems. Nine sampling plots of 100 × 20m were established in cocoa agroforestry systems in three villages. Our results registered the occurrence of 238 plant species grouped into 16 families in the sampled area. Sterculiaceae, Burseraceae, and Moraceae were the three dominant families. The species richness and diversity that were assessed using the Shannon index were 0.62, 0.66, and 0.68, respectively, while using the Simpson index, they were 1.421, 1.409, and 0.349, respectively, for Mouko, Rionong, and Nyamsong 3. Carbon stock sink was also estimated at 92.03, 55.18, and 46.83 Mg/ha. Carbon sink does not varies according to villages (p-value = 0.368 > 0.1), height and Dbh are correlated. These results indicate a high flora diversity in cocoa-based agroforests especially with respect to fruit trees where *T. conophorum* is introduced. The amount of CO2/ha per village plots is estimated at 337.46, 202.32, and 171.71 tCO2/ ha. Then, the ecological services that should be paid according to 10 US$ per ton of carbon are evaluated at 3374.6, 2023.2, and 1717.1 US$ to the owner of the selected farms.

One of the biggest stems of Tetracarpidium conophorum found in Rionong village in cocoa agroforests

Keywords: carbon sequestration, REDD+, agroforestry systems, climate change, mitigation.

References:

1. Amougou, J.A., Ebokona, B.L.D., Batha. R. A., Mala. A. W., Ngono. H. 2016. Regard suds, ISSN-2414-
2. Jiofack, T.; Guedje, N.M.; Tchoundjeu, Z.; Fokunang, C. ; Lejoly, J. and Kemeuze, V. 2013. Journal o
3. Sonwa D.J., Nkongmeneck B.A., Weise S.F., Tchatat M., Adesina A.A. & Janssens M.J.J., 2007. Biodiver
4. Tchoundjeu. Z., Mbile. P., Asaah. E., Degrande. A., Anegbeh. P., Facheux. C., Tsobeng. A., Sado. T.,
5. Termote C, Van-Damme P, Dhed'a Djailo B (2010). Ecology of Food and Nutrition 49(3): p 173-207

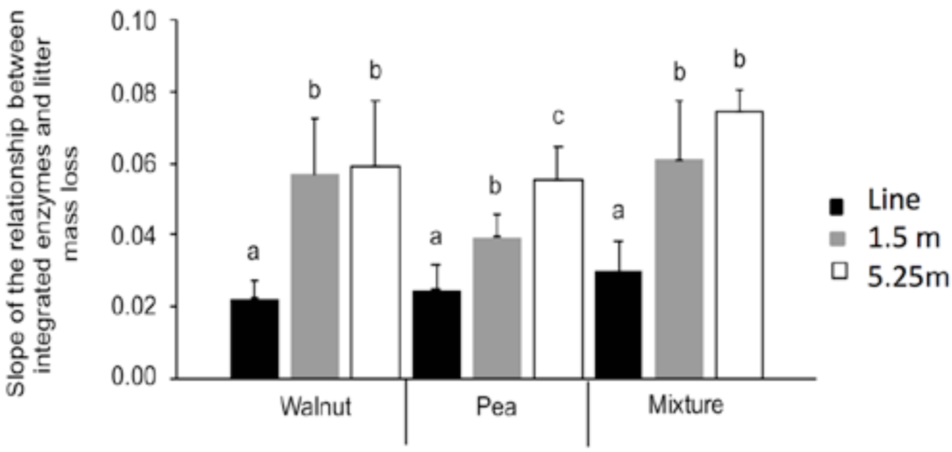
L01.P.14

Spatial gradient of soil decomposers' activities in a Mediterranean agroforestry system

Guillot E.[1] (esther.guillot@gmail.com), Hinsinger P.[1], Dufour L.[2], Bertrand I.[1]

[1] *INRA UMR Eco&Sols, Montpellier, France*; [2] *INRA UMR System, Montpellier, France*

In alley-cropping agroforestry systems, contrasted litters from the intercropped annual and perennial plants are more or less mixed in the field. Our aim was to unravel the drivers of C, N and P mineralization in such a heterogeneous agroecosystem. We hypothesized that there is a spatial gradient of functional capacity of decomposers perpendicular to the tree line and that litter would be the most decomposed under the tree row. We thus conducted an *in situ* experiment for 7 months at Restinclières (France) with walnut trees intercropped with peas/cereals. We placed litterbags made of a mixture of pea and walnut leaves, or each of the two separately, on the tree row, at 1.5 and 5.25 meters away from it. After 2, 4 and 7 months, we measured soil microbial activity, litter quality and mass loss. Our results showed a significant effect of litter quality on both decomposition rates and microbial biomass C, N, P contents. Soil decomposers on the tree row appeared to be less efficient for litter decomposition than those in the interrow, based on relationship between C-enzymes activities and litter mass loss. We assumed that these decomposers feed on other C-sources available under the tree row to maintain a high turnover and biomass, which could explain the higher absolute C-enzyme activities. The position in the agroforestry plot was the main driver of soil decomposers' activities, whatever the added litter type.



Enzymatic efficiency for C-enzymes corresponding to the slopes of the regression of litter mass loss as a function of cumulative C-enzymes produced between 52 and 188 days, for walnut leaves (walnut), pea and mixture of pea and walnut leaves (mixture). Data are means (n=5), bar represent standard deviation and different letters means significant difference between positions for one litter type.

Keywords: Agroforestry, Litter decomposition, Enzymatic activities, Spatial gradient.

L01.P.15

Phytoremediation and Agroforestry- mitigation of climate change, poverty reduction and cleaning of soils

Haller H. (henrik.haller@miun.se)

Department of Ecotechnology, Mid Sweden University, ÖSTERSUND, Jamtland, Sweden

Many edible crops grow well even on extremely contaminated soil and such plants can be used for soil remediation. Reclaiming sites that are traditionally rejected for food production such as urban sites, deserts and even contaminated land may be one way to increase food production, without expanding the agricultural frontier. If integrated in agroforestry systems and conducted in a controlled manner, cultivation of crops, that absorb contaminants in its tissue without translocation to the edible parts, can potentially enable farmers to obtain an income source at the same time as their soils are remediated. Numerous health risks are involved with growing food on contaminated land. A considerable amount of the world's food supply, especially in developing countries, however, is presently grown on contaminated land, often unsuspectingly and without measures to avoid health risks. With thorough knowledge about the planted crop´s bioaccumulation and translocation patterns, efficient remediation programs can be designed that give economic incentives to landowners and avoid that consumers are exposed to toxic levels of contaminants. This study shows that such systems may be lucrative and can clean the soil at the same time as carbon is sequestered. Calculations with the modelling software CO2FIX with a runtime of 100 years showed that agroforesrety systems with bioremediation capacity based on *Tectona grandis* and *Pogostemon cablin (S1) Erythrina poeppigiana* and *Ricinus communis (S2)* may sequester as much as 217 MgC/ha (S1) and 71 MgC/ha (S2).

Keywords: Agroforestry, Phytoremediation, Carbon Sequestration, Bioremediation, Poverty reduction.

L01.P.16

New agroforestry on European ecosystem service deficit farmland can compensate up to 43% of agricultural GHG emissions

Herzog F.[1] (felix.herzog@agroscope.admin.ch), Kay S.[1], Roces-Diaz J.[1], Crous-Durán J.[2], Giannitsopoulos M.[3], Graves A.[3], den Herder M.[4], Moreno G.[5], Mosquera-Losada R.[6], Pantera A.[7], Palma J. H.[2], Paracchini M.-L.[8], Rega C.[8], Rolo V.[5], Rosati A.[9], Smith J.[10], Szerencsits E.[1]

[1] *Agroscope, Zurich, Switzerland*; [2] *University of Lisbon, Lisbon, Portugal*; [3] *Cranfield University, Cranfield, United Kingdom*; [4] *European Forest Institute, Helsinki, Finland*; [5] *Universidad de Extremadura, Plasencia, Spain*; [6] *Universidad de Santiago de Compostela, Lugo, Spain*; [7] *Forestry and Natural Environment Manag, TEI Stereas Elladas, Greece*; [8] *European Commission Joint Research Cen, Ispra, Italy*; [9] *CREA OLI, Spoleto, Italy*; [10] *Organic Research Centre, Newbury, United Kingdom*

Landscapes with a high share of agroforestry provide more regulating ecosystem services than landscapes dominated by conventional agriculture (Kay et al. 2018). Yet, which type of agroforestry to recommend depends on local and regional conditions and there may be regions where there is a higher need for agroforestry than others.

We identified European farmlands where several ecosystem service (ES) deficits occur at the same time (soil erosion, low soil organic carbon and biodiversity, nitrate surplus, irrigation, low pest control and pollination potential). Almost ten percent of arable and grassland had more than five and four stacked deficits, respectively (Figure 1). In those areas, the introduction of agroforestry can help to reduce ES deficits. We propose 64 candidate agroforestry systems, which are locally adapted and attractive for farmers. They range from lines of trees around arable plots to relatively densely planted silvo-arable and silvo-pastoral systems.

As an example for the reduction of ES deficits, we modelled the potential carbon sequestration of each candidate agroforestry system. The conversion of the 140,000 sqkm of priority farmland to agroforestry would sequester - depending mainly on the tree species and density - between 2 and 64 10^6 t of carbon per year in above and below ground biomass. This would correspond to up to 43 percent of the European greenhouse gas emissions attributed to the agricultural sector.

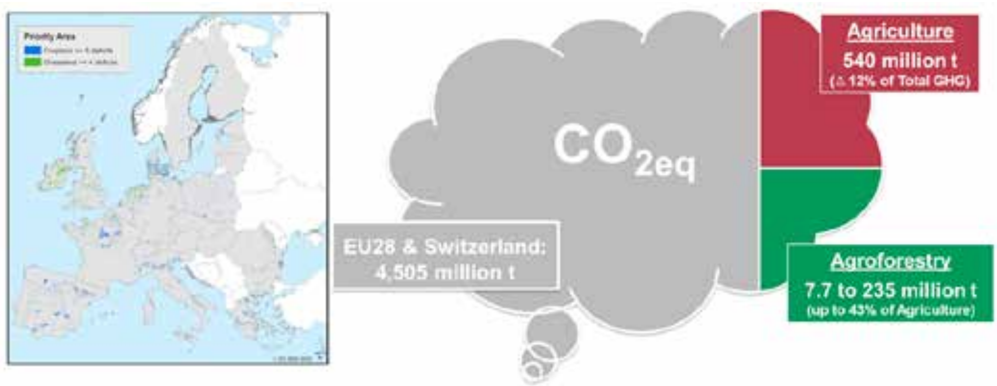


Figure 1. Implementing agroforestry on the 8.9 percent of European farmland with the highest deficit in ecosystem services would compensate up to 43 percent of European agricultural GHG emissions.

Keywords: Carbon mitigation, Greenhouse gas, Arable farmland, European grassland.

References:

1. Kay S., 2018, Agroforestry Systems 92(4), 1075-1089

L01.P.17

Soil Carbon fractioning in Chestnut tree forests

Mosquera-Losada M. R. (mrosa.mosquera.losada@usc.es)

Crop production and Project Engineering, Univ. Santiago Compostela, Lugo, Lugo, Spain

Soil Carbon fractioning in Chestnut tree forests
Mosquera-Losada MR1, Ferreiro-Domínguez N1, Silva-Pando FJ 2, Rodriguez-Rigueiro J1, Arias-Martínez D1, Santiago-Freijanes JJ, Rigueiro-Rodríguez A1,
1University of Santiago de Compostela, Spain; 2 Centro de Investigaciones Forestales de Lourizán, Spain; 3 SERIDA, Spain; 4NEIKER
Nowadays, the lack of profitability of some chestnut stands linked to the high amount of man power needed to harvest the chestnut fruits in high step mountain areas. A good option to increase profitability of these areas is to rare animals to use fruit as feeds. Most of the mountain chestnut stands are associated to less favored areas where autochthonous breeds are able to survive and even procreate due to the adaptation they have to these difficult environments. An INIA National Project was funded by the Spanish Ministry of Agriculture to evaluate two stocking rates in four different scenarios located in the Galicia, Asturias and Vasque Country. An initial sampling was done to evaluate the soil capacity of storing Carbon in the different conditions. Carbon fractioning was conducted in order to evaluate the persistence of carbon in the soil linked to macro and micro (lime plus silt) fractions. A good relationship between the C stored in soil and the C in each fraction was highly correlated with the exception to that linked to microagregates, which can indicate the difficulty of C to be stored in long term stock particles (Figure 1).

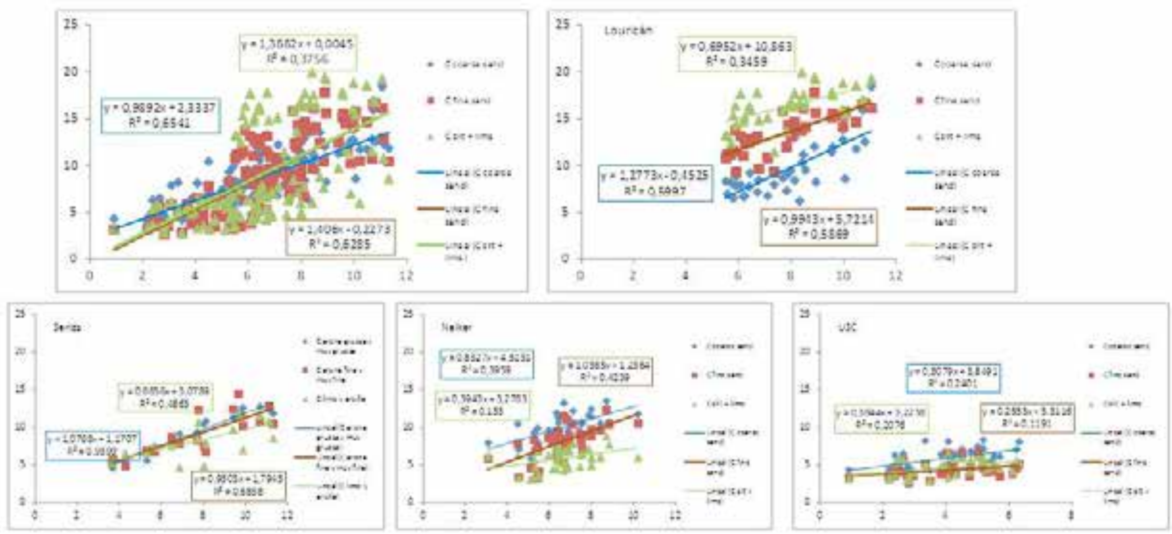


Figure 1. Total and Fraction C relationship in four chestnut stands of North Spain.

Keywords: C fractioning, macroagregates, microagregates.

L01.P.19

The CENTURY Model as a tool to study the Soil Carbon dynamics in Agroforestry and Teak plantations of Kerala, India

Munishamappa M.[1] (manjumunsar@gmail.com), A.V S.[2], T.K K.[3], S S.[4], K.M S. K.[3], P S. K.[5]

[1] *Center for Climate Change, EMPRI, Bangalore, Karnataka, India*; [2] *Tree Physiology and Breeding, College of Forestry, KAU, Thrissur, Kerala, India*; [3] *College of Forestry, KAU, Thrissur, Kerala, India*; [4] *Kerala Forest Research Institute, Thrissur, Kerala, India*; [5] *Horticulture College, KAU, Thrissur, Kerala, India*

The objective of the study is to evaluate the suitability of CENTURY model to depict *Teak* plantations with silvicultural practices that are being converted to an agroforestry practices (*Teak* trees and Ginger Cultivation) in the Western Ghats of Kerala. The existing *Teak* plantations of different age classes were selected for studying the soil carbon dynamics of teak monoculture in the forest divisions (Fig1). The validation was conducted by comparing the simulation results to analyzed statistical data from the field measurements of carbon stocks in *Tectona grandis* stands 0–5, 06–10, 11–20, 21–30 and above 30 years old.The CENTURY model simulated the total Soil Organic Carbon in conversion of *Tectona grandis* plantation to agroforestry system was observed to decline from 2864.40 to 2577.63 g C m-2at a period of 7 years. Then the values increased and stabilized at 2546.43 g C m-2at the age of 30 years. The active carbon pool declined from 11.86 to 2.07 g C m-2at a 5 year period, and then slowly increased to 11.05 g C m-2at the 32nd year of simulation. The slow carbon decreased from 931.94 to 695.10 g C m-2at the age of 8 years, after which it proceeded to increase slowly to 780.97 g C m-2at the end of 30 years. However the passive carbon pool exhibited a decrease from 1907.30 to 1743.92 g C m-2at the end of the simulated period. It can be concluded that SOC data from soil monitoring database can, as a part of SOC modeling, also serve for predicting of future SOC stock.

Figure.1 Location map of experimental sites

Keywords: CENTURY Model, Soil Carbon Dynamics, Agro-forestry, Tectona grandis, Western Ghats.

L01.P.20

Carbon stock potential of smallholder agroforestry parklands in Burkina Faso: Way forward for REDD+ implementation

Neya T.[1] (neyatiga@gmail.com), Neya O.[2], A. Abungyewa A.[3], Callo-Concha D.[4]

[1] *Department Civil Engineering, Kwame Nkrumah University of Sciences, Ouagadougou, Kadiogo, Burkina Faso*; [2] *Ecosystem Servicies, WASCAL competence Center, Ouagadougou, Burkina Faso*; [3] *Agroforestry, Kwame Nkrumah University of Sciences, Kumasi, Ghana*; [4] *ZEF, University of Bonn, Bonn, Germany*

Agroforestry play an important role in climate mitigation trough atmospheric carbon removal by trees photosynthesis activities but the carbon sequestration potential of smallholders agroforestry parkland are not well documented in Burkina Faso. Therefore, agroforestry parkland of smallholders' farmers in three climatic zones of Burkina Faso was studied. Thirty (30) household farmlands in each climatic zone representing about 35 ha were selected on which systematic woody species inventory and dendrometry data collections were undertaken. Non-destructive method using fitted allomectrics equations were used to compute carbon stock and to estimate equivalent dioxide carbon. Sustainability analysis of carbon sequestration potential was done using [0-10],] 10-40] and]40-110 cm] diameter classes respectively as long term , medium term and short term capability of agroforestry parklands to sequester the carbon. The balance between marketable carbon value and the trade-off resulting from tree conservation and major crop (millet, red sorghum and white sorghum) value was also analysed. The results revealed 24.71± 5.84 tCO2ha-1, 28.35± 5.84 tCO2ha-1 and 33.86±5.84 tCO2ha-1 respectively in Ouahigouya, Sapouy and Bouroum-Bouroum. Ouahigouya earned the first place for long term carbon sequestration potential with 1.82% of total amount of carbon. The medium term analysis give the first place to Sapouy with 71.71% of total amount of carbon and the short term analysis give the first place to Ouahigouya with 68.03%. The marketable carbon value was less than the trade-off value resulting from trees keeping and crop production value. The balance analysis revealed that carbon payment system promoted by REDD+ initiative will be profitable and compensable to smallholder farmers effort to keep tree when the tCO2 /ha price will be around 4 US$. By taking into account farmers, interests, profitability on carbon market will be the most relevant incentive method to enhance carbon stock in agroforestry parkland in order to meet Paris agreement.

Keywords: trade-offs, corbon dioxide, smallholders, Agroforestry parland, REDD+.

L01.P.21

Carbon assessment for Robusta coffee systems across an intensification gradient

Nguyen N.[1] (d.n.nguyen@cgiar.org), Tiffany T.[1], Läderach P.[1], Vaast P.[2], Ortiz D.[3]

[1] *Decision and Policy Analysis, CIAT, Hanoi, Vietnam*; [2] *UMR Eco&Sols, CIRAD, Montpellier, France*; [3] *Plant and Environmental Sciences, University of Copenhagen, Copenhagen, Denmark*

Introduction

The objective of this study was to compare the carbon trade-offs of different coffee systems via quantification of carbon stock and greenhouse gas (GHG) emissions.

Materials and methods

Six coffee systems of shaded and unshaded (highly intensive, in terms of input use), shaded with exotic and native native trees (moderately intensive), and low and high shade tree density (least intensive) from Vietnam, Uganda and India, respectively, were compared. Carbon (C) stock was calculated from tree height, diameter, and wood density extracted from ICRAF database (http://db.worldagroforestry.org/wd) using allometric equations partly developed by Chave *et al.* (2014). GHG emissions were calculated from data on soils, fertilizer use, crop residues, energy use, and transportation of inputs and outputs using CoolFarmTool, an online GHG calculator (Hillier *et al.*, 2011).

Results and discussion

The study showed that, higher carbon stock systems , did not significantly reduce Robusta coffee green bean yield (2.4 vs 2.6 tons ha^{-1} in shaded and unshaded coffee systems, Vietnam; 1.06 vs 1.04 tons ha^{-1} in shaded systems with exotic and native shade trees, India) while helped increase significantly carbon stock compared to unshaded systems (e.g., 15.2 tons carbon ha^{-1}, Vietnam). The additional carbon was achieved by growing primarily with fruit trees in Vietnam (85 trees ha^{-1}, contributing 15.2 tons C) and in India by maintenance of an agroforestry system with native shade trees (up to 245 trees ha^{-1}, contributing 77.6 tons C) or exotic (*Grevillea robusta*) shade tree species (397 trees ha^{-1}, contributing 47.5 tons C).

The study also revealed that the GHG emission per unit product of systems in Vietnam (3.46 – 3.98 kg CO_2e kg^{-1}) are not significantly higher than those in India (3.09 – 3.13 kg CO_2e kg^{-1}), despite a much higher GHG emission per ha (7.5 vs 2.4 tons CO_2e ha^{-1}, respectively) resulted from a significantly (3-fold) higher application of inorganic fertilizers, the main GHG contributor, in the former systems than the latter ones (around 2 tons ha^{-1} vs 0.7 tons ha^{-1}, respectively). This results from the higher yield of coffee systems in Vietnam, which compensates for the effect of GHG emission when measured per unit product. That coffee systems of Uganda had low GHG emissions (0.72 kg CO_2e kg^{-1}) in spite of negligible inorganic fertilizer use (on average 5kg ha^{-1}) is explained by extremely low yields (0.86 tons ha^{-1}). This may imply a trade-off effect in that a higher application of inorganic fertilizers increases coffee yield but simultaneously creates a negative environmental effect via higher GHG emissions.

Conclusion

The introduction of shade trees to coffee systems of different input intensification helps provide significant carbon sequestration service while not significantly reducing coffee bean yield. Application of more inorganic fertilizers help increase coffee yield but must be optimized against the trade-off of causing higher GHG emissions.

Keywords: GHG emissions, Carbon stock, Robusta coffee, Input intensification.

References:

1. Chave et al. 2014. Global Change Biology. 14.
2. Hillier et al. 2011. Environmental Modelling & Software. 9.
3. ICRAF.http://db.worldagroforestry.org/wd.Accessed 15 June 2017.

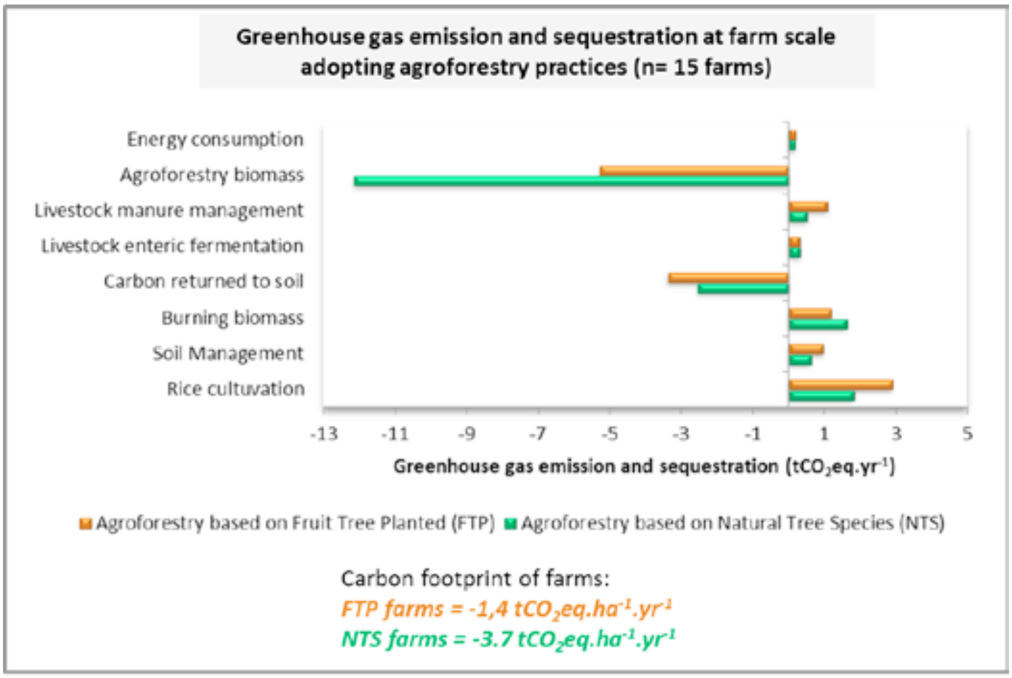
L01.P.23

Farmers' greenhouse gas balances in diverse agroforestry systems in Madagascar targeting climate change mitigation

Rakotovao H. N.[1] (nanaharisoa2@yahoo.fr), Chevallier T.[2], Chapuis-Lardy L.[3], Rasoarinaivo A. R.[1], Razafimbelo T. M.[1]

[1] *Laboratoire des Radio Isotopes, Antananarivo, Madagascar*; [2] *UMR Eco&Sols, IRD, Cirad, Inra, SupAgro, Montpellier, France*; [3] *LMI IESOL, Dakar, Senegal*

Agroforestry is one of the most important options suggested to smallholder farmers living around protected forest area to reduce deforestation and soil erosion. The objective of this study was to make an impact assessment of agroforestry systems on greenhouse gas (GHG) balances. In order to assess the GHG balance of the farming system, using a carbon footprint approach, we considered all agricultural activities existing at each farm scale including agroforestry plots, rice plots, livestock, fertilizations and energy consumptions. In 2018, a survey was carried out on 15 households of about 2.7 ha each to collect information characterizing each farming system. The results showed two main agroforestry practices. The first system is an agroforestry based on Naturally occurring Tree Species (NTS), i.e. annual crops were planted in a forest dominated by native trees species. The second system is an agroforestry based on actual annual crop fields where Fruit Trees have been Planted (FTP). The results showed that the average carbon footprint of the farmers adopting NTS was about -3.7 $tCO_2eq.ha^{-1}.yr^{-1}$ while it was estimated to -1.4 $tCO_2eq.ha^{-1}.yr^{-1}$ for those adopting FTP. The agroforestry system based on NTS sequestered more GHG (-15.36 tCO_2eq) at farm scale compared to FTP (-1.47 tCO_2eq) due to tree species diversity and density plantation. This study highlighted the important contribution of agroforestry to improve GHG balance of smallholder farmers.



Greenhouse gas balances of farms adopting agroforestry practices in Moramanga, Madagascar

Keywords: carbon footprint, carbon, forest, soil, biomass.

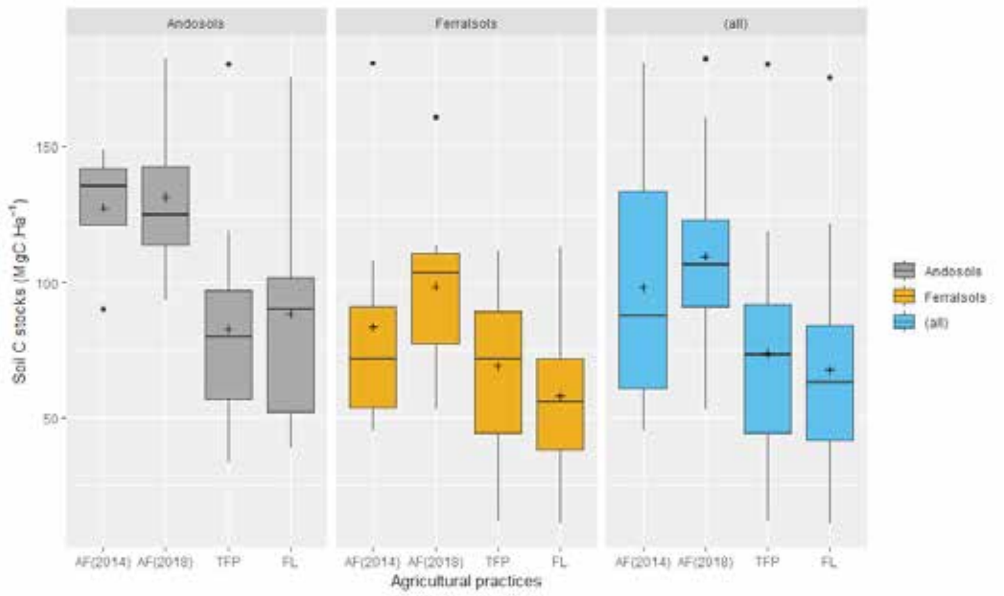
L01.P.24

Impact of agroforestry on soil organic carbon sequestration in Madagascar using synchronic and diachronic approaches

Ramifehiarivo N.[1] (ranandrianina@hotmail.fr), Rakotovao N.[1], Razakamanarivo H.[1], Grinand C.[2], Razafimbelo T.[1]

[1] *Laboratoire des RadioIsotopes, University of Antananarivo, 101, Antananarivo, Madagascar*; [2] *Nitidae, Maison de la télédétection,34000,Montpellier, France*

Agroforestry is known to be an opportunity to sequester carbon in soil and biomass leading to climate change mitigation. It provides also multiple benefits for farmers (additional incomes and sustainable land management). However, agroforestry impacts on soil organic carbon (SOC) sequestration rate are rarely documented in tropical regions due to the lack of long-term field experiments. This study aimed to quantify (i) SOC storage in agroforestry systems (AF, fruit trees inside staple crop plot) compared to traditional farming practices (TFP, staple crop only) and fallow land (FL, grass land) for synchronic approach (year 2018), and (ii) SOC accumulation rate under AF over 4 years (2014 to 2018) for diachronic approach. Soil sampling was conducted over 36 farmers' plot, at 3 soil depth (0-10, 10-20 and 20-30 cm) and over the 2 dominant soil types, ferralsols and andosols. Results showed that SOC stocks in AF was significantly higher (109 MgC.ha^{-1}) than TFP (61 %) and FL (61%). The diachronic method showed an effective SOC accumulation rate up to 3 MgC.ha^{-1}.yr^{-1} for AF, with a slightly less accumulation rate in andosols, reflecting SOC saturation effect. High value of SOC sequestration on AF was due to an important organic fertilization supply (12 tons.ha^{-1}.yr^{-1} of manure) and trees density (500 feet.ha^{-1}) feeding the soil biomass. This study confirmed the important role of AF to sequester carbon in the soil at farmer scale meeting widely the objectives of the 4 ‰ Initiative.



Soil carbon stock comparison (0-30 cm) under agroforestry system (AF), traditional farming practices (TFP) and fallow land (FL)

Keywords: Accumulation rate, farmer, fertilization, soil types, system.

L01.P.25

Making trees count: MRV of agroforestry under the UNFCCC

Rosenstock T.[1] (t.rosenstock@cgiar.org), Wilkes A.[2], Jallo C.[3], Namoi N.[4], Belusu M.[5], Suber M.[6]

[1] *World Agroforestry Centre, Kinshasa, Congo - Kinshasa*; [2] *Values for Development, London, United Kingdom*; [3] *Private Consultant, Davis, United States*; [4] *World Agroforestry Centre, Nairobi, Kenya*; [5] *Private Consultant, Stuttgart, Germany*; [6] *World Agroforestry Centre, Lima, Peru*

Agroforestry—the integration of trees with crops and livestock—is not mentioned explicitly in the UNFCCC's Koronivia Joint Work on Agriculture. However, agroforestry generates many benefits directly relevant to the topics addressed, including: (i) building resilience, (ii) increasing soil carbon and improving soil health, (iii) providing fodder and shade for sustainable livestock production and (iv) diversifying human diets and economic opportunities. Despite its significance, agroforestry may not be included in measurement, reporting and verification (MRV) systems under the UNFCCC. Here we report on a first appraisal of how agroforestry is treated in national MRV systems under the UNFCCC. We examined national communications (NCs) and Nationally Determined Contributions (NDCs) of 147 countries, 73 countries' REDD+ strategies and plans, and 283 Nationally Appropriate Mitigation Actions (NAMAs) and conducted interviews with representative of 17 countries in Africa, Asia and Latin America. Our assessment found that there is a significant gap between national ambition and national ability to measure and report on agroforestry. Forty percent of the countries assessed explicitly propose agroforestry as a solution in their NDCs, with agroforestry being embraced most widely in Africa (71%) and less broadly in the Americas (34%), Asia (21%) and Oceania (7%). Seven countries have proposed 10 agroforestry-based NAMAs. Of 73 developing countries that have REDD+ strategies, about 50% identify agroforestry as a way to combat drivers of forest decline. Despite intentions, however, agroforestry is still not visible in many MRV systems. For example, though 66% of the countries reported non-forest trees in national inventory, only 11% gave a quantitative estimate of number of trees or areal extent. Interviews revealed a suite of definitional, institutional, technical and financial challenges preventing more comprehensive and transparent inclusion of agroforestry in MRV system. This absence has serious implications. If such trees are not counted in inventories or climate change programs, then in many ways they don't count. Only if agroforestry resources are measured, reported and verified will they gain access to finance and other support. The paper will discuss finding of the assessment, successes and specific Investments needed to help ability match ambition.

Keywords: agroforestry, MRV, mitigation, adapation.

L01.P.26

"*Faidherbia-Flux*", an open observatory for GHG balance and C stocks in a semi-arid agro-sylvo-pastoral system (Senegal)

Roupsard O.[1] (olivier.roupsard@cirad.fr), Cournac L.[2], Jourdan C.[1], Tall L.[3], Duthoit M.[4], Kergoat L.[5], Timouk F.[6], Grippa M.[7], Ly A.[8], Lardy L.[2], Masse D.[9], Vezy R.[4], le Maire G.[4], Chotte J.-L.[10]

[1] *CIRAD, Dakar, Senegal*; [2] *IRD, Dakar, Senegal*; [3] *ISRA, Dakar, Senegal*; [4] *CIRAD, Montpellier, France*; [5] *CNRS, Toulouse, France*; [6] *IRD, Toulouse, France*; [7] *UPS, Toulouse, France*; [8] *LMI IESOL, Dakar, Senegal*; [9] *IRD, Abidjan, Côte d'Ivoire*; [10] *IRD, Montpellier, France*

The mitigation of climate change by agro-sylvo-pastoral systems is complex to assess or model, owing to high spatial and temporal heterogeneities.
We set a new long-term observatory up for the monitoring and modelling of microclimate, GHG and deep SOC in a semi-arid agro-sylvo-pastoral system (Niakhar, Sénégal), dominated by the multipurpose *Faidherbia albida* tree. Crops were mainly millet and peanut, under annual rotation. Transhumant livestock contributed largely to manure, SOM and soil fertility.
Early 2018, we installed 3 eddy-covariance towers above (i) the whole mosaic, (ii) millet and (iii) peanut and monitored energy, CO2 balance and evapotranspiration for one full year. The mosaic ecosystem displayed low but significant CO2 and H2O fluxes during the dry season, owing to *Faidherbia* in leaf (Fig. 1). When rains resumed, the soil bursted a large amount of CO2. Just after the raising of millet, CO2 uptake by photosynthesis increased dramatically, then stabilized before harvest. However, this was compensated by large ecosystem respiration. The annual ecosystem CO2 balance was close to nil.
This observatory is currently installing soil chambers for GHG fluxes, studying the horizontal variability of SOC by Vis-NIR and of deep soil roots and C using wells. Microclimate (land surface temperature, energy balance and gas exchanges) and light-use-efficiency will be mapped through 3D modelling (Charbonnier et al., 2017; Vezy et al., 2018).
This observatory is open for collaboration.

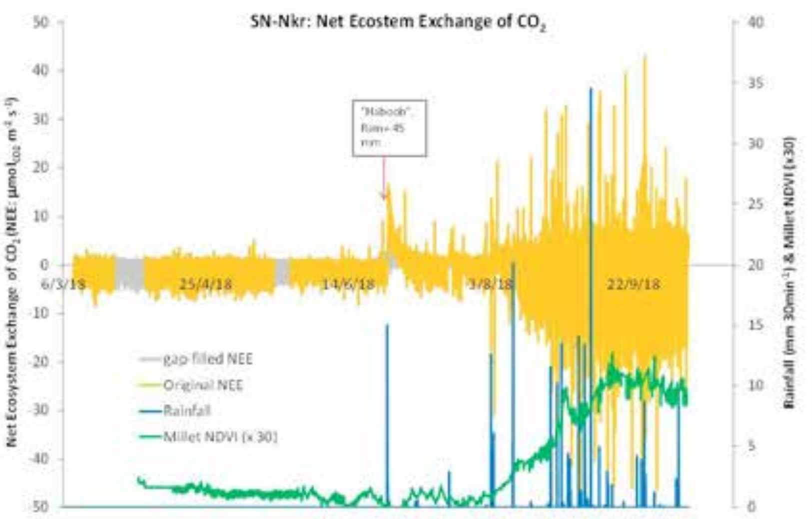


Fig. 1: The Net Ecosystem Exchange (NEE) of CO2 (or CO2 flux, negative = uptake during the day; positive = release at night) was very weak during the dry season, maximum photosynthesis (GPP) around 10 mmolCO2 m-2 s-1 and maximum ecosystem respiration (Re) around 1.5 mmolCO2 m-2 s-1. GPP was from Faidherbia trees only at that time. Just after the "Haboob", a large CO2 burst was recorded with slow decay during more than one week or so. Other CO2 peaks in July correspond to smaller rain events. Early August, millet NDVI took off, followed by a large CO2 uptake, but also ecosystem respiration. [Fluxes filtered out for wet sensor, Planar-fitted, WPL and spectral corrected, quality checked. Gaps are due to power failure. Grey dots are from gap-filling according to Lasslop et al. (2010)]

Keywords: Eddy Covariance, Faidherbia albida, Millet, GHG balance, SOM.

References:

1. Charbonnier, F., et al., 2017. Plant Cell and Environment, 40(8), 1592-1608. doi:10.1111/pce.12964
2. Vezy, R., et al., 2018. AFM, 253, 203-217. doi:10.1016/j.agrformet.2018.02.005

L01.P.27

Modeling the effects of climate change and management on carbon sequestration in agroforestry systems in Kerala, India

Russell A.[1] (arussell@iastate.edu), Kumar B. M.[2]

[1] *Natural Resource Ecology & Management, Iowa State University, Ames, IA, United States*; [2] *Forestry, Kerala Agricultural University, Mannuthy, Kerala, India*

Agroforestry systems in the humid tropics have the potential for high rates of production and large accumulations of carbon (C) in plant biomass and soils, and thus may play an important role in the global carbon cycle. Many factors, including crop species composition, management, and climate change could influence the extent to which agroforestry systems sequester C, but the relationships among the factors are complex. The objective of this study was to evaluate the relative effects of individual factors on C stocks in soil and plant mass in agroforestry systems in Kerala, India. We used CENTURY, a general model of plant-soil nutrient cycling, parameterizing the model for this region. We then conducted simulations to investigate the effects on C stocks in aboveground biomass and soil under four experimental scenarios: 1) Change in crop system; 2) Differences in soil types; 3) Increase in temperature above 20-yr means; and 4) Change in tree species. All of the factors influenced the simulated soil C stocks, whereas C in aboveground biomass was relatively little influenced by increasing temperatures and soil type under these scenarios. The significance of these findings is that if carbon trading schemes were to be initiated in Kerala, it is apparent that a variety of factors can potentially influence the actual amount of C sequestered in Kerala agroecosystems.

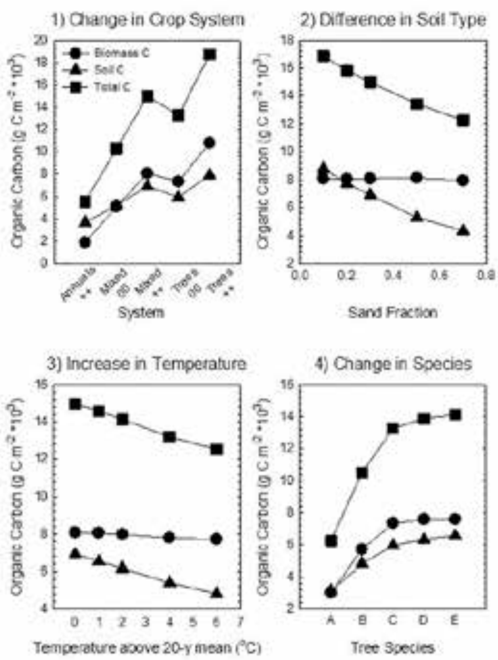


Fig. 1. Predicted organic carbon in aboveground biomass and soil (0-20 cm) in Kerala agroecosystems under four scenarios modeled with CENTURY, a process-based model. 1) Under the 'Change in Crop System' scenario, both diversity and management were varied. 'Mixed' systems contain annuals and trees. A '++' indicates additions of manure and irrigation water and '00' indicates no additions. 2) Under the 'Difference in Soil Type' scenario, the sand fraction was varied from 0.1 to 0.7 in the 'Mixed, ++' system. 3) Under 'Increase in Temperature', minimum and maximum temperatures were increased above the current 20-y means, as indicated, also in the 'Mixed ++' system. 4) The effect of 'Change in Species' of trees was simulated by increasing the production capacity and tissue lignin contents in the 'Trees 00' system. Species 'C' is the default tree (LUQD) in CENTURY.

Keywords: Carbon sequestration, CENTURY model, Soil carbon, Tree species, Climate change.

L01.P.28

From the old agroforestry systems of the modern high-density olive groves: which Carbon sequestration?

Sala G.[1] (giovanna.sala@yahoo.it), Brunori A.[2], Caruso T.[3], Dini F.[2], Marra F. P.[3], Proietti P.[4], Regni L.[4], La Mantia T.[3]

[1] *Agrarian-Technological Institute RUDN, Russian University of Peoples Friendship, Moscow, Russia*; [2] *PEFC Italy, Perugia, Italy*; [3] *SAAF, University of Palermo, Palermo, Italy*; [4] *DSA, University of Perugia, Perugia, Italy*

Olive tree (Olea europaea L) represents one of the most important evergreen tree species. In Sicily agroforestry systems based on the olive tree, named tTraditional olive orchard, are common and often are grown together to other tree crops, such as vineyards, or with cereals or forages. This last are usually grown in the interspace between rows and particularly in olive groves were planting density is rather low (less than 200 trees/ha). To increase crop efficiency and to reduce costs of harvesting, by using proper machines, in the last 20 years in the olive industry have been developed new planting systems: Intensive (up to 400 trees/ha), and the Superintensive (up to 2000 trees/ha). Within the project LIFE15 OLIVE4CLIMATE has been evaluated the balance, in terms of biomass and of carbon sequestration, for the above olive orchards systems. The biomass of orchard was evaluated both in the above- and in the below-ground tree components. The dry matter of the vegetation removed by pruning was evaluated as well. The enlargement of trunk cross sectional area, the dry matter accumulated in the cover crop and the root biomass were measured as well. By the data currently collected resulted that carbon sequestration efficiency in the Traditional olive orchards is greater than in the Superintensive ones and this, affects the carbon sequestration efficiency in the two orchard systems studied.

Keywords: carbon balance, carbon sequestration, olive biomass, Traditional olive grove, Intensive and Superintensive olive grove.

References:

1. Rühl et al., 2011, Plant Biosystems, 120-130; Doi: 10.1080/11263504.2010.540383
2. Brunori et al., 2017, Trees, 1859-1874; Doi: 10.1007/s00468-017-1592-9

L01.P.29

The problem of phased changes in the humus status of soils under shelterbelts in agroforestry landscapes

Sauer T.[1] (tom.sauer@ars.usda.gov), Chendev Y.[2], Gennadiev A.[3], Abdelrahman H.[4]

[1] *Natl Lab for Agric. and the Environ., USDA, AMES, IA, United States*; [2] *Natural Resources Man. and Land Cadastre, Belgorod State University, Belgorod, Russia*; [3] *Landscape Geochemistry & Soil Geography, Lomonosov Moscow State University, Moscow, Russia*; [4] *Soil Science, Cairo University, Giza, Egypt*

The study of shelterbelts in agroforestry landscapes includes a range of issues and tasks, solutions of which are aimed at a deeper knowledge of patterns for environmental changes. Changes in soil properties as a result of planting and long-term functioning of artificial forest plantations are of great interest. One of the most important aspects of this research is the assessment of shelterbelt contributions to carbon sequestration by soils. Our studies on the Great Plains (USA) and Central Russian Upland of Russia (6 key sites were studied) show the high probability of the accumulation of soil organic matter or humus in the surface meter of soil under the shelterbelts, which ranged from 21 to 70 years old (Chendev et al., 2015). However, we have reason to believe that this process has a stage character, i.e. accumulation of humus in soils under shelterbelts does not occur indefinitely. Sauer et al. (2012) observed an increase in soil organic carbon (SOC) accumulation in the surface 30 cm of soil at 4 locations in Iowa under artificial forest plantations up to tree age of 30 years. At tree age of 50 years the rate of SOC accumulation decreased to a lower rate similar to the early years of tree growth. Study of young shelterbelts aged 20-30 years at the Kamennaya Steppe in Russia in the 1920s confirmed the accumulation of organic matter in soils under the shelterbelts (Tumin, 1930). However, research in the same areas conducted in the 1990s - 2010s showed no differences in organic matter stocks in the soils of old-growth (~100 years) shelterbelts and in the adjacent background steppe areas (Kaganov, 2012; Prikhod'ko et al., 2013). Researchers noted that as a result of the Late Holocene forest expansion on grasslands in Europe (due to natural changes of climate), fertile Chernozem soils (in the US - Mollisols) transformed into less fertile Luvisols (according to the American Soil Classification - Alfisols) (Chendev et al., 2018). Thus, the accumulation of humus in soils under shelterbelts can occur during the first decades after planting and then may be followed by a change in soil evolution including potential degradation. Our working hypothesis requires further research that can solve an important fundamental soil-geographic problem, which consists in developing the concept of "soil formation factors — soil formation processes — soil properties". Additional SOC characterization including permanganate oxidizable carbon (POXC) was used to further interpret SOC distribution. Soil cover type had an insignificant effect on POXC at two sites in Russia but at a third (Yamskaya) it had a very significant effect. Depth had a significant effect on POXC at all sites ($P = 0.026$; <0.001 and 0.03 for Streletskaya, Yamskaya, Kamennaya, respectively). The system of "shelterbelt-soil" can act as a controlled model of interaction of soils and factors of their formation, the parameters of which are specified in a space-time dimension.

Keywords: soil organic carbon, humus, shelterbelt, carbon sequestration, POXC.

References:

1. Chendev et al. 2015. Eurasian Soil Sci. 48(1):43–53.
2. Chendev et al. 2018. Radiocarbon 60(4):1185-1198.
3. Kaganov 2012. Regional Environmental Issues. 4:7–12 [in Russian]
4. Prikhod'ko et al. 2013. Eurasian Soil Sci. 46(12)1230–1240.
5. Sauer et al. 2012. Plant Soil 360(1-2):375-390.

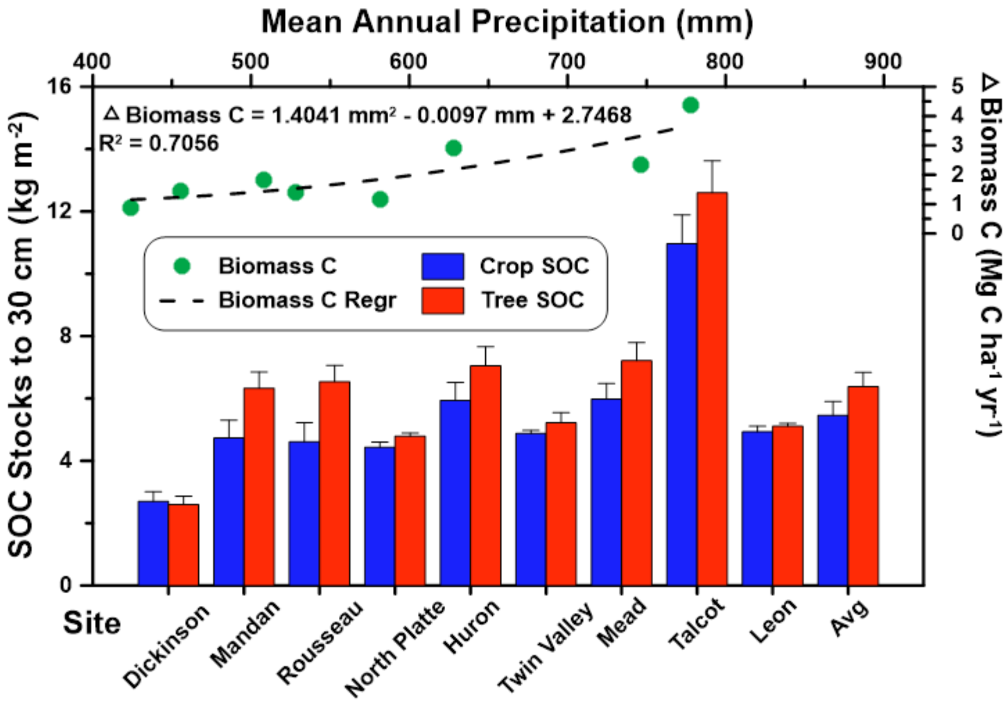
L01.P.30

Effect of red cedar windbreaks on soil carbon and quality in the U.S. Great Plains

Sauer T.[1] (tom.sauer@ars.usda.gov), Brevik E.[2], Zamora D.[3], Tyndall J.[4], Zhu J.Y.[5], Wyatt G.[3]

[1] *Nat. Lab for Agric. and the Environ., USDA, Ames, Iowa, United States*; [2] *Natural Sciences, Dickinson State University, Dickinson, North Dakota, United States*; [3] *Forest Resources, University of Minnesota Extension, St. Paul, Minnesota, United States*; [4] *Nat. Res., Ecology and Management, Iowa State University, Ames, Iowa, United States*; [5] *Forest Products Laboratory, USDA, Madison, Wisconsin, United States*

Targeting marginal lands for woody bioenergy production avoids some of the competition for food production and may improve soil health, the local microclimate and provide other ecosystem services. The objective of this study was to evaluate the effect of eastern red cedar (*Juniperus virginiana* L.) windbreaks on soil quality in the U.S. Great Plains. Eastern red cedar has great potential for bioenergy production due to its adaptability to a wide range of soil and climate conditions and the physical and chemical characteristics of its biomass. Nine sites were selected from latitudes 41-47 deg N and longitudes 94-103 deg W with MAP from 425 to 970 mm and MAT from 4.9 to 9.9 deg C. Tree age varied from 22 to 59 years. Ponded infiltration (twin ring technique) and penetration resistance at 2.5 cm increments to 30 cm (digital static cone penetrometer) were measured at 9 locations under the trees and in adjacent fields (crop, pasture, or hay). Soil samples were collected for carbon, bulk density, pH, and nutrient analyses. Infiltration rate was greater and penetration resistance lower under tree cover at most sites. Soil organic carbon (SOC) to 30 cm depth averaged 0.92 kg m^{-2} (16.8%) greater under trees as compared to adjacent land use. Improvements in soil quality following tree planting for bioenergy feedstock production may allow some marginal lands to be converted back to crop or forage production at a higher level of productivity.



Soil organic carbon (SOC) stocks under red cedar and adjacent crop fields and tree biomass growth with changing mean annual precipitation (MAP).

Keywords: soil organic carbon, infiltration, root penetration resistance, aboveground biomass growth.

L01.P.32

Dynamic agroforestry: food, fertile soil and mitigation of climate change

Stadler-Kaulich N.[1] (nstadlerkaulich@gmail.com), Azero A. M.[2], Kuonen L.[3], Ungar B.[4], Vögerl J.[5], Sandoval S.[2]

[1] *Mollesnejta-Center of AndeanAgroforestry, Combuyo, Cochabamba, Bolivia*; [2] *UCB- Universidad Boliviana Catolica, Cochabamba, Bolivia*; [3] *HAFL, Bern University of Applied Sciences, Zollikofen, Switzerland*; [4] *Technische Universität München, München, Germany*; [5] *U of Applied Sciences Rhine-Waal, Kleve, Germany*

The loss of soil fertility at the global scale is alarming, as are the impacts of climate change. Conventional agriculture practices are reducing the organic matter content of soil as well as the soil´s capacity to regenerate nutrients to a minimum. In order to ensure food security in the future, sustainable agriculture techniques have to be promoted. These techniques should not only be productive, but also build soil fertility in the long term. At *Mollesnejta- Centro de Agroforestería Andina,* we apply dynamic agroforestry measures in combination with two agroecological techniques, with the goal of improving soil quality: (a) Activated Biochar and (b) Ramial Chipped Wood (RCW). Pruning material sourced from pruning in agroforestry systems was used as a soil amendment through both techniques. The presentation will describe the benefits of Activated Biochar and RCW and discusses their preparation and application to the soil, where both act as long-term carbon sink. Also, are provided the results of the experiences obtained at *Mollesnejta- Centro de Agroforestería Andina* after using these techniques. Both techniques proved to be effective at improving soil fertility and the capacity of rainwater storage. In combination with their impact as carbon sink it would be reasonable to intensify the practice of dynamic agroforestry

Organic material of pruning is transferred to biochar, which activated with manure and urine of compost/dry-toilets becomes TerraPreta; this is applied into the soil to increase the fertility and the capacity to store the rainwater and at the same time act like a carbon sink during several hundreds of years.

Keywords: dynamic agroforestry, biochar, terra preta, chipped wood, mitigation of climate change.

References:

1. 2018 “Más allá de la Agroforestería: el Biocarbón activado y la Madera Ramal Fragmentada”, editado

L01.P.34

Do agroforestry practices on peatlands in Indonesia support climate smart agriculture?

Tata H.[1] (hl.tata@gmail.com), Adinugroho W.[2]

[1] *Silviculture, Forest Research & Development Center, Bogor, Indonesia*; [2] *Biometrics, Forest Research & Development Center, Bogor, Indonesia*

Climate Smart Agriculture (CSA) is defined as an approach for transforming and reorienting agricultural development under the new realities of climate change. CSA is an agriculture practice that sustainably increase productivity, enhances resilience (adaptation), reduce Green House Gasses (GHGs) emission and enhance achievement on national food security and Sustainable Development Goals. Agroforestry on peatlands may challenge two factors of mitigation and improve productivity. Higher productivity on peatlands may lead to increase GHGs. On the other hand, reduce GHGs may not improve productivity. Agroforestry on peatlands in several places in Indonesia provides economic benefit for the community. Various agriculture commodities, such as pineapple, aloe vera, vegetables, corns, and others, have been planted on peatlands, which give cash income for farmers. However, farming practice on peatlands is quite different with farming practice on minral soils. Farmers has to do trenching in order to reduce water level, which increase GHGs emission. This manuscript will show review results from several published and unpublished papers based on the studies that have been conducted in Indonesia. Agroforestry practices on peatlands supported local livelihood, however, it may not suitable for mitigating the climate change. Appropriate technology on managing peatland is necessary to improve climate smart agriculture on peatlands.

Keywords: climate change, mitigation, GHGs.

References:

1. Lipper L, Thornton P, Campbell BM, Baedeker T, ... 2014, Nature Climate Change, 1068-1072.
2. FAO, 2013, Climate-Smart Agriculture: Sourcebook, 557p.

L01.P.35

Carbon dynamics within four black walnut alley cropping sites across Missouri and Arkansas, USA

Thomas A.[1] (thomasal@missouri.edu), Kallenbach R.[2], Sauer T.[3], Brauer D.[4], Burner D.[5], Coggeshall M.[6], Dold C.[3], Rogers W.[6], Bardhan S.[6], Jose S.[7]

[1] *Division of Plant Science, University of Missouri, Mt. Vernon, Missouri, USA*; [2] *Division of Plant Science, University of Missouri, Columbia, MO, USA*; [3] *NLAE, USDA-ARS, Ames, IA, USA*; [4] *CPRL, USDA-ARS, Bushland, TX, USA*; [5] *DBSFRC, USDA-ARS, Booneville, AR, USA*; [6] *Center for Agroforestry, University of Missouri, Columbia, MO, USA*; [7] *The School of Natural Resources, University of Missouri, Columbia, MO, USA*

Agroforestry and alley-cropping systems that integrate useful long-lived trees with crops or livestock have been proposed to help mitigate the accumulation of fossil fuel-derived carbon in Earth's atmosphere. Black walnut (*Juglans nigra*) is frequently planted and cultivated in North America both for its valuable lumber and its unique edible nuts, and is highly amenable to the introduction of understory crops or livestock in well-managed agroforestry systems. However, little is known about carbon assimilation in black walnut trees, including the amounts and locations of carbon assimilated into lignocellulosic tissues. Forty black walnut trees from four sites across the midwestern USA were destructively harvested, and biomass, % carbon (C), and % nitrogen (N) quantified. Soils surrounding the harvested trees were also sampled and analyzed for C and N. A growth model for C assimilation into black walnut trees across diverse locations was developed. Total tree biomass (dry weight) for the ≈ 10-year-old trees ranged from 27 to 54 kg, and woody tissues contained an average of 46.4 % C and 0.44 % N (Table 1). Percent C differed among various woody tissues, with trunk sections containing more assimilated C compared with root tissues. While soil C and N varied consistently at increasing depths, they did not vary in distance from the trees, likely because the trees were not yet old enough to have impacted the C and N dynamics in the surrounding soils in a significant manner.

Table 1. Black walnut tree tissue C and N concentration at four sites in Missouri and Arkansas, USA, and among above- and below-ground woody tissues.

Factor	Sub-factor	C (% DW) [a]	N (% DW)
Site [b]	NF	45.72 c	0.563 a
	MV	46.63 ab	0.557 a
	FV	46.39 b	0.364 b
	BN	46.85 a	0.282 c
	p value	< 0.0001	0.0006
Tree Tissue [c]	30 cm trunk section	46.87 bc	0.148 d
	60 cm trunk section	46.91 bc	0.154 d
	120 cm trunk section	47.08 ab	0.169 d
	180 cm trunk section	46.99 abc	0.165 d
	large branches	47.48 a	0.203 cd
	small branches	46.97 abc	0.611 b
	root bole section	44.94 d	0.260 c
	large roots	46.50 c	0.662 b
	small roots	43.97 e	1.335 a
	p value	< 0.0001	< 0.0001
Site × Tissue	*p* value	0.6028	< 0.0001
Overall Mean		46.42	0.438

[a] Means within sub-columns with the same letters are not different according to Fisher's Least Significant Difference (LSD) test ($p < 0.05$). DW = dry weight.

[b] Site abbreviations: NF = New Franklin, MO; MV = Mt. Vernon, MO; FV = Fayetteville, AR; BN = Booneville, AR.

[c] Tree tissue definitions: large branches ≥12 cm diameter, small branches <12 cm diameter, large roots ≥ 1.6 cm diameter, small roots < 1.6 cm diameter.

Keywords: Juglans nigra, agroforestry, carbon, sequestration.

L01.P.36

Organic carbon sequestered by coffee plantations in Veracruz (Mexico)

Valdes-Velarde E.[1] (valdevela@gmail.com), Ordaz-Chaparro V. M.[2], Sanchez-Hernandez R.[3], Gallardo-Lancho J. F.[4], Ayala-Montejo D.[5], Khalil Gardezi A.[2]

[1] *Fitotecnia, Universidad Autonoma Chapingo, Texcoco, Mexico, Mexico*; [2] *Edaphology Programe, Postgraduate College, Texcoco, Mexico, Mexico*; [3] *Academic Division of Agricultural Scienc, Juarez Autonomous University of Tabasco, Villahermosa, Tabasco, Mexico*; [4] *Retired Investigator, CSIC-IR-NASa, Salamanca, Castilla y Leon, España*; [5] *Fitotecnia, Chapingo Autonomous University, Texcoco, Mexico, Mexico*

Coffee agroforestry systems (AFS) have a high potential for carbon sequestration, due to the large diversity of woody species used as shade. The objective of the present study was to evaluate the potential of carbon sequestration in aerial biomass and soil organic matter at different depths in the coffee SAF in the coffee region of Huatusco, Veracruz, Mexico. The AFS studied were a Mesophilic Mountain Forest (BMM) that served as a reference, and three shade coffee plantations (specialized systems: BRE, BCC, and BIP) and two in full sun (CGB, CCR) which were compared to each other; also, in contrast of a not AFS, a conventional pasture (PTC). Harvesting of herbaceous and mulch, vegetal samples was done in plots of 4x25 m2 (UM); it was also measured shrub and tree biomass. The soil was sampled at four depths (0-10, 10-20, 20-30 and 30-60 cm). Tree biomass was estimated by allometric equations. The system that showed the highest C content in aerial biomass was BMM (457 Mg C ha-1), followed by BRE (374 Mg C ha-1), BIP (232 Mg C ha-1), CGB C ha-1), CCR (61.1 Mg C ha-1), BCC (46.0 Mg C ha-1) and PTC (3.1 Mg C ha-1). Regarding the total organic C captured, the poorly intervened forest ecosystem (BMM) reached the maximum value (565 Mg C ha-1), of the coffee systems the BRE obtained the highest value (478 Mg C ha-1) and the BCC the lowest (108 Mg C ha-1. In contrast, pasture only stores 99.0 Mg C ha-1. It is concluded that the coffee systems sequestering an average of 246 Mg C ha-1 of C sequestered, depending on the management, being significantly separated those from the shade of the full sun.

Keywords: Cloud Tropical Mountains forests, Coffee management systems, Mixed forest system, Agroforestry systems.

References:

1. CONAFOR. 2008. Catálogo de contenido de carbono en especies forestales de tipo arbóreo del norest
2. Etchevers J.D., C.M. Monreal, C. Hidalgo, M. Acosta, J. Padilla, R.M. López. 2005. Manual para la
3. Masuhara A., E. Valdés, J. Pérez, D. Gutiérrez, J. C. Vázquez, E. Salcedo, M. J. Juárez, A. Merin
4. Rügnitz M.T., M.L. Chacón, R. Porro. 2009. Guía para la Determinación de Carbono en Pequeñas Prop

L01.P.37

Carbon sequestration in riparian buffer systems; influenced by soil texture, vegetation type and age in Ontario, Canada

Vijayakumar S. (sowthini@uoguelph.ca), Coleman B., Gordon A., Voroney P., Thevathasan N.

School of Environmental Sciences, University of Guelph, Guelph, Ontario, Canada

Riparian buffer systems (RBS) have the potential to sequester atmospheric carbon dioxide into stable pools like biomass and soil. In this context, a study was conducted in the Grand River watershed, southern Ontario, Canada, to find the influence of two soil textures (clay, loam), two vegetation types (coniferous, deciduous) and age [<15 years (young), > 15 years (mature)] on soil organic carbon (SOC) sequestration. In all treatment combinations, soil from 0-30 cm depth were collected from eight RBS sites [Mature deciduous clay (MDC), Mature coniferous clay (MCC), Mature deciduous loam (MDL), Mature coniferous loam (MCL), Young deciduous clay (YDC), Young coniferous clay (YCC), Young deciduous loam (YDL) and Young coniferous loam (YCL). Soil samples were also collected from adjacent agricultural fields (control). SOC were determined using the dry combustion procedure as outlined in the Leco CR-412 manual (Wang and Anderson 1998). Results indicate that RBS with mature trees, irrespective of soil texture and vegetation type, sequestered significantly higher ($p<0.05$) SOC (MDC =177.6 ±5.48, MDL=159.2 ±3.39, MCL= 143.5 ±4.56, and MCC =134.4 ±4.10 Mg C ha^{-1}) compared to adjacent agricultural fields whereas, RBS with young trees did not show significant difference (Figure 1). Overall, MDC had more positive impact on SOC sequestration whereas YCL had least impact among the RBS. However, all RBS showed numerically higher mean SOC content compared to its adjacent agricultural fields.

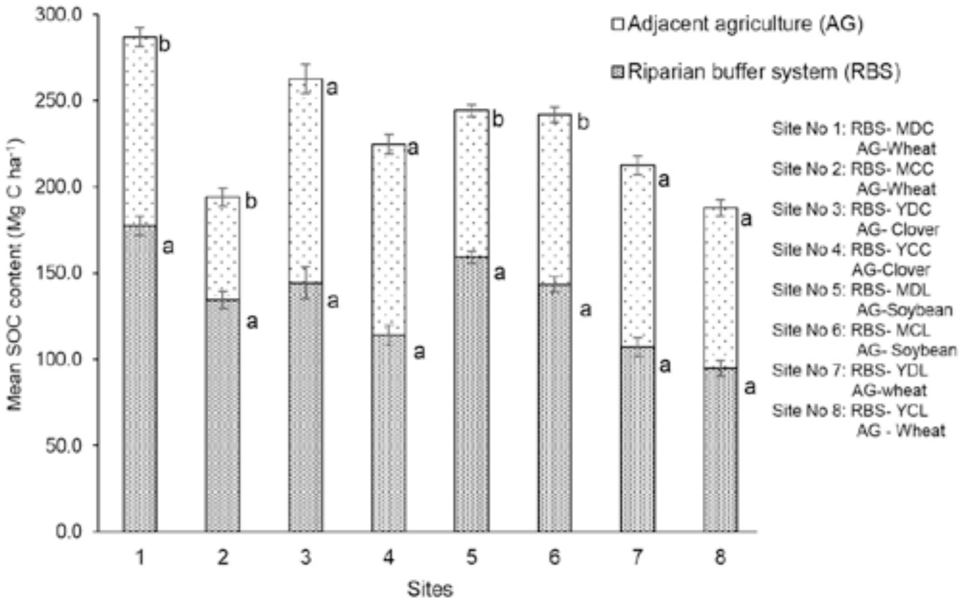


Figure 1: Comparison of mean SOC content (Mg C ha -1) between riparian buffer systems (RBS) and respective adjacent agricultural fields in each site sampled at 0 – 30 cm depth in Grand River watershed, waterloo region, Ontario in 2017-2018. (MDC – Mature deciduous clay, MCC- Mature coniferous clay, YDC- Young deciduous clay, YCC- Young coniferous clay, MDL- Mature deciduous loam, MCL- Mature coniferous loam, YDL- Young deciduous loam and YCL- Young coniferous loam). With in a site, means followed by the same letter are not significantly different according to a Tukey's multiple range test ($P \geq 0.05$). Error bars indicate the standard error of the mean (n=5).

Keywords: Agroforestry, climate change mitigation, soil organic carbon, dry combustion.

References:

1. Wang and Anderson, 1998, Commun Soil Sci Plant Anal, 29(1-2), 15-21; DOI: 10.1080/00103629809369925

L01.P.38

Evalution of aboveground biomass of *Piliostigma reticulatum* (DC) Hochst. Planted in north soudanian zone of Burkina Faso

Yélémou B.[1] (yelbart@hotmail.com), Tyano A.[2], Koala J.[3]

[1] *Gestion des Ressources Naturelles, INERA/CNRST, Koudougou, Burkina Faso*; [2] *Foresterie, Université Nazi Boni, Bobo Dioulasso, Burkina Faso*; [3] *Environnement et Forêt, INERA/CNRST, Koudougou, Burkina Faso*

Developing forest Clean Development Mechanism projects necessarily involves estimating quantities of carbon stored. Carbon stock has been studied for many trees species, but there are few data relating to shrubs. However shrubs are more and more important in agrarian system in sahelian zone. In Burkina Faso *Piliostigma reticulatum* is one the important shrubs in farms. This study aims to measure aboveground biomass of *P. reticulatum* after 3, 5 and 15 years after planting. We used destructive method for biomass assessment. Before tree cutting, morphological parameters have been measured. A total of thirty (30) trees of *P. reticulatum* were cut at the base. Then fresh weight has been weighted in the field, and sample was taken for dry weight determination. Results show that *P. reticulatum* tree with 15 years old measure 3.06 ± 0.43 m of height, 34.90 ± 11.98 cm of circumference of the trunk to the basis. Best annual growth in height is gotten for tree of 05 years old (0.32 ± 0.07). In 05 years, *P. reticulatum* with 1111 trees/ha stocks 3.65± 1.34 tMS ha1 of aboveground biomass. That means 30 ± 6.49 tMS ha1 in 15 years. Regression made show that that there is allometric relation between crown size and aboveground biomass of *P. reticulatum*. These results contribute to understand impact plantation of shrubs and/ or their conservation in farms on the climatic change mitigation.

Keywords: Piliostigma reticulatum, allometric relations, biomass, Burkina faso.

References:

1. Koala J., Sawadogo L., Savadogo P., Aynekulu E., Heiskanen J., Saïd M., 2017. Silva Fennica. 51 (3)
2. Lufafa A., Diedhiou N. A. S., Séné M., Kizito F., Dick R. P. et Noller J. S., 2009. Journal of Arid
3. Peltier R., Forkong C. N., Ntoupka M., Manlay R., Henry M., Morillon V., 2007. Bois et forêts des tr
4. Saint André L., 2005. Forest Ecology and Management 205:199-214.

ABSTRACTS

Agroforestry and world challenges

Agroforestry: riding to the world's rescue

- L2 -
Agroforestry and adaptation to climate change

Singing in the rain: adapting to the erratic new normal

Shade trees are often used to protect crops from excess heat and light in the tropics, where agroforestry (AF) is clearly seen as a way to adapt to climate change (CC). It could be interesting to grow crops under shade trees in temperate climates also, to adapt agriculture to CC by buffering temperature both at the annual scale and at the daily scale, thus reducing yield loss due to extreme temperatures (frost, heat wave), by reducing soil evaporation through a reduction in radiation, wind speed, temperature and increase in air humidity and by reducing flood risk. However, the competition for water between trees and crops might be exacerbated in the context of CC due to reduced rainfall and increased risk of drought. Tree productivity in AF conditions could thus be reduced, although the deeper rooting pattern in AF compared to forest conditions, might give the trees access to more water resources. This session welcomes modelling and experimental studies relevant to the assessment of the resilience of AF systems to CC as well as to the design of AF systems more adapted to CC and their adoption by stakeholders.

L02.1_O.01

A framework for resilience to climate shocks in agroforestry systems

Morel A.[1] (alexandra.morel@gmail.com), Hirons M.[2], Ashley Asare R.[3], Adu Sasu M.[4], Quaye M.[3], Mason J.[3], Adu-Bredu S.[5], Woldemariam Gole T.[6], Gonfa T.[6], Mc C.[7], Robinson E.[8], Boyd E.[9], Malhi Y.[2], Norris K.[1]

[1] *Institute of Zoology, Zoological Society of London, London, United Kingdom*; [2] *Environmental Change Institute, University of Oxford, Oxford, United Kingdom*; [3] *Nature Conservation Research Centre, Accra, Ghana*; [4] *Environmental Change Institute, Nature Conservation Research Centre, Accra, Ghana*; [5] *Forestry Research Institute of Ghana, Kumasi, Ghana*; [6] *ECCCFF, Addis Ababa, Ethiopia*; [7] *University of Oxford, Oxford, United Kingdom*; [8] *School of Agriculture, University of Reading, Reading, United Kingdom*; [9] *Centre for Sustainability, Lund University, Lund, Sweden*

This framework was developed by monitoring two contrasting agroforestry systems over three years, before, during and following the 2015/16 El Niño. We hypothesize that during a climate shock there will be factors outside of a farmer's control (e.g. farm 's location in the landscape) and management options within the control of the farmer that may either positively or negatively interact (e.g. be complementary or trade-off) with climatic conditions to impact yields. To explore this, we present the results of ecological and socio-economic data from 56 low-input (*Coffea arabica* in Ethiopia) and 36 medium-input (*Theobroma cacao* in Ghana) farms, along landscape and management gradients. Both systems were severely impacted by the El Niño shock; however, monitored coffee shrubs showed a dramatic collapse in yields while the most stressed cocoa trees showed increased pod production. In Ethiopia, we found location in the landscape (e.g. elevation and forest patch size) and diversity of shade trees had trade-off effects and the presence of leguminous shade trees had complementary effects on yield variability. Whereas in Ghana, both shade management and distance from forest had trade-off effects, while only soil nutrient management was complementary throughout the study period. We discuss the implications of monitored yield variability on household resilience and poverty outcomes using insights gleaned from household surveys and community focus groups.

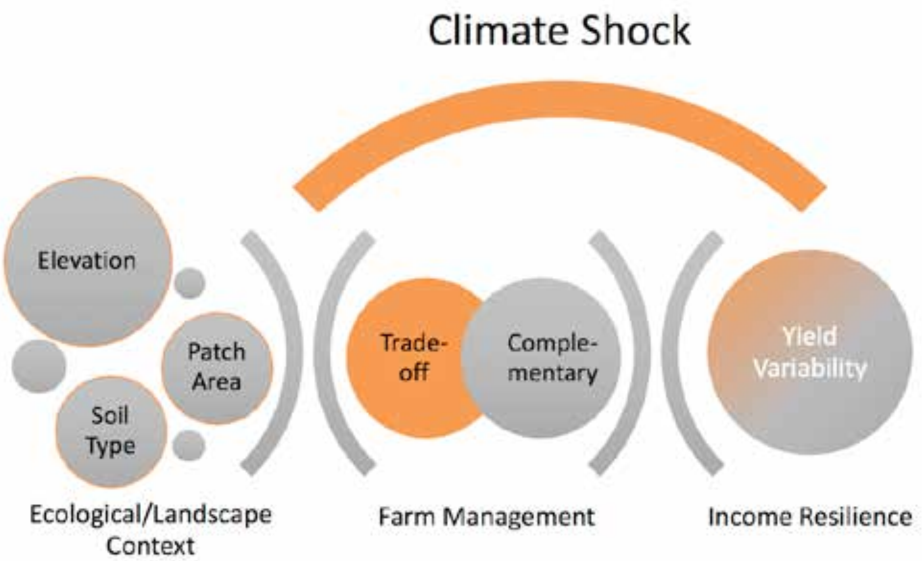


Figure 1 Depiction of proposed framework describing the prevailing attributes of a farm beyond the control of the farmer (e.g. its location in the landscape) and the management decisions available to the farmer. Resilience, in this model, is described by the interaction of farm attributes and farm management with a climate shock to influence inter-annual yield variability.

Keywords: Coffea arabica, Theobroma cacao, Resilience, El Nino, Yield Variability.

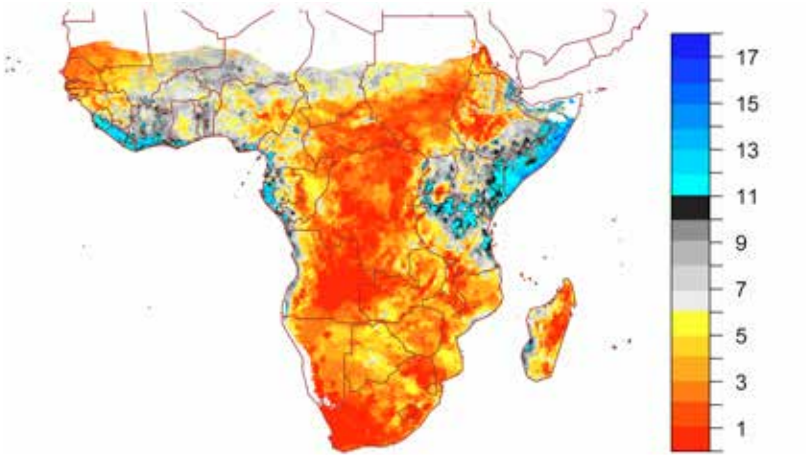
L02.1_O.02

Towards a climate change atlas for Africa: results of ensemble suitability modelling for 150+ native tree species

Kindt R.[1] (r.kindt@CGIAR.org), Dawson I.[2], McMullin S.[1], Jamnadass R.[1], Graudal L.[3]

[1] *Tree Productivity and Diversity, World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [2] *Crop & Soil Systems Research Group, Scotland's Rural College, Edinburgh, United Kingdom*; [3] *Department of Geosciences and Natural Re, University of Copenhagen, Frederiksberg, Denmark*

The World Agroforestry Centre, in collaboration with Bioversity International, CATIE and Hivos, recently published habitat suitability maps for 54 tree species that are widely used in Central America for shade in coffee or cocoa agroforestry systems[1] (www.worldagroforestry.org/atlas-central-america). Using similar methods of species distribution modelling, including ensemble methods whereby consensus habitat suitabilities are weighted average probabilities from different algorithms[2] and a likelihood scale recommended by the IPCC[3], habit change maps were prepared for 150 tree species native to Africa. The Central American atlas calibration methods were augmented using filtering approaches of species occurrence datasets in geographical and environmental space and spatial blocking techniques to reduce spatial correlation during model evaluations[4]. These methods were also integrated in the newer versions of the *BiodiversityR* package. Models were calibrated with a subset of bioclimatic and topographic variables obtained from AFRICLIM[5] and ENVIREM. To reduce potential overestimation of the effects of climate change, species distribution data were obtained across Africa. Selected species were priorities in different projects and countries, including for a large forest landscape restoration project in Ethiopia, the African Orphan Crops Consortium, an ecosystem-based adaptation project for Gambia and cover priority food tree species identified in Burkina Faso, Ethiopia and Kenya.



Most of sub-Saharan Africa is expected to experience drier climates by the middle of the 21st century. Shown here are the number of 18 downscaled General Circulation Models that project increases in the moisture index (P/PET) compared to the 20th century baseline (hyperarid areas were masked from the baseline; future grid layers from AFRICLIM for RCP 4.5). The major changes in the colour schemes correspond to the likelihood scale recommended for the fifth Assessment Report of the IPCC (red - orange : likely decreases in moisture index; light blue – dark blue: likely increases in moisture index).

Keywords: species distribution modelling, priority tree species, restoration, habitat change, AFRICLIM.

References:

1. De Sousa et al. 2017. ICRAF Occasional paper No. 26, World Agroforestry Centre
2. Kindt. 2018. Env. Modell. Softw.100: 136-145. https://doi.org/10.1016/j.envsoft.2017.11.009
3. Mastrandea et al. 2011. Climatic Change. 108:675. https://doi.org/10.1007/s10584-011-0178-6
4. Valavi et al. 2018. Methods Ecol. Evol. 1-8. https://doi.org/10.1111/2041-210X.13107
5. Platts et al. 2015. Afr. J. Ecol., 53: 103–108

L02.1_O.03

Diachronic study of the effect of growing trees on grapevine yield: 24 years of experience in the South of France

Gosme M.[1] (marie.gosme@supagro.inra.fr), Grimaldi J.[2], Trambouze W.[3]

[1] *UMR SYSTEM, INRA, Montpellier, France*; [2] *CESBIO, Toulouse, France*; [3] *Chambre d'agriculture de l'Hérault, Montblanc, France*

Grapevine growers are fearful of the potential effects of climate change on yield and wine quality: the continuing trend for earlier harvest date leads to a decrease in wine organoleptic quality, and increased temperatures lead to heat stress and reduced yield. Thanks to its microclimatic effect, agroforestry could mitigate these risks. In 1995, trees (mainly *Pinus pinea* and *Sorbus domestica*) were planted with 4 or 5 rows of grapevine between each row of trees, on the Restinclières Agroforestry Platform, in the South of France. Twenty-four years later, the accumulated experience allows us to draw conclusions on the beneficial effects of the agroforestry microclimate, with up to 6 degrees lower in agroforestry compared to the pure grapevine control in the hottest summer days, but also on the negative effects of agroforestry, such as nitrogen competition between the trees and the vine, which is significant only on the grapevine row nearest to the tree line.

Grapevine associated with Sorbus domestica and Pinus pinea

Keywords: grapevine, microclimate, yield, grape juice quality.

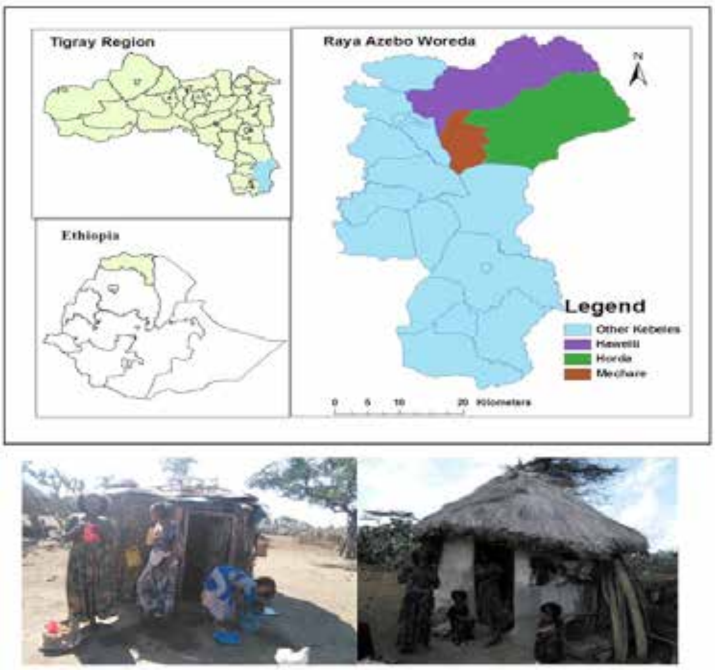
L02.1_O.04

Gender based impacts of climate change and adaptation strategies

Asheber M. N. (merrynegasi@gmail.com)

Rural Dev›t and Agricultural Extension, Mekelle University, Mekelle City, Tigray, Ethiopia

Climate change is a global phenomenon; its negative impacts are more severely felt by poor people in developing countries who rely heavily on the natural resource base for their livelihoods.[1] The objective of this study was to analyze the impact of climate change on gender assets and adaptation strategies in Ethiopia. Results show that climate change affects both households' types, but poses more threat to female-headed households. The choice of adaptation strategies was also different between female and male-headed households. As compared to female-headed households, male-headed households adopted multiple adaptation strategies. Those strategies include planting trees that are droughts resistant like acacia and cactus, crop diversification, and use of drought resistant and short growing crop varieties, adjusting and shifting of planting dates. In addition, a probit model result shows that age, sex, education, family size, farm size, access to extension service, participation in social organization, participation in off-farm activity, livestock holding, farming experience and distance to the nearest market are major determinant factors that significantly affect farmers' choice of adaptation of different strategies to climate change. As a recommendation, Government and non-government organization should create more awareness on the role of agroforestry practices as an adaptation strategy to reduce the impact of climate change.



Map of the study area and pictures of female-headed households during interview

Keywords: Gender, Asset, Climate Change, Adaptation strategies.

References:

1. Hoffmann, I. (2009). Livestock and climate change. IFAD.

L02.1_O.05

Farmers' perception of vulnerability and resilience of agroforestry systems to climate change in Benin, West Africa

Gnonlonfoun I.[1] (isidoregnonlonfoun@gmail.com), Assogbadjo A. E.[1], Gnanglè C. P.[2], Glèlè Kakaï R. L.[1]

[1] *Management of Naturals Resources, Faculty of Agronomic Sciences, Cotonou, Abomey-Calavi, Benin*; [2] *INRAB, Cotonou, Abomey-Calavi, Benin*

Climate change leads to serious threats to ecosystems including traditional agroforestry parklands. Assessing the level of susceptibility and resilience of any ecosystem to climate change is important for sustainable adaptation. We assessed farmers' perceptions of the vulnerability of agroforestry systems to climate change in Benin. The objectives of the study were to (i) assess the effect of changes in climatic conditions on agroforestry systems (ii) assess the main indicators of vulnerability of agroforestry systems to climate change and (ii) analyze agroforestry and cropping systems' resilience to climate change. We hypothesized that some agroforestry systems are more resilient to climate change than others. A total of 233 household heads and seven agroforestry systems were studied. Data collected were components, indicators of vulnerability and the level of resilience of agroforestry systems. Descriptive statistics based on the percentage of arborescent population and density of tree were used to characterize the agroforestry systems. A canonical factorial discriminant analysis with heplots for pairs of discriminant variables was performed to differentiate agroforestry systems with regard to vulnerability indicators. The resilience of agroforestry and cropping systems was evaluated through four levels of resilience. Results showed that the vulnerability to climate change of *Anacardium occidentale* and *Citrus sensis* parks was especially determined by the number of components damaged in the system. Age and density of *Vitellaria paradoxa* parks and mixed parks (*Vitellaria paradoxa-Parkia biglobosa)* were indicators that determined their sensibility to climate damage according to local people. All agroforestry systems were perceived to be resilient to climate change but at different degrees. *Manihot esculenta* was reported as the most resilient crop to climate damage. Our results support calls for considering indicators of the vulnerability of agroforestry systems, as well as their resilience when developing agroforestry adaptation strategies.

Keywords: Agroforestry systems, climate change, traditional ecological knowledge, ecosystem services, food security.

References:

1. Assogbadjo et al. 2012. For. Policy Econ. 14: 41-49. doi: 10.1016/j.forpol.2011.07.013
2. Coulibaly et al. 2014. Agroforest syst 88: 3-28. doi: 10.1007/s10457-013-9651-8
3. Collier et al. 2008. Oxf. Rev. Econ. Policy. 24 (2), 337–353
4. Luedeling et al. 2014. Curr. Opin. Environ. Sustain. 6: 1-7. doi: 10.1016/j.cosust.2013.07.013
5. Palsaniya DR and Ghosh PK 2016. In Conservation Agriculture: pp 203-223. doi: 10.1007/978-981-10-255

L02.1_O.06

Sustainability and vulnerability to climate change of smallholding agroforestry systems in tropical highlands, Ecuador

Córdova R. (raul_cordova@hotmail.com), Kanninen M., Hogarth N.

Forest Sciences, University of Helsinki, Helsinki, Uusimaa, Finland

An estimated 570 million farms throughout the world are considered to be small or family operated, responsible for most of the world's agricultural production (1,2), and probably the most vulnerable sector to the impact of climate change and variability (CCV), especially in mountain regions of developing countries (3). Considering that small holder farmers have a significant influence on the land use/cover change process and agrobiodiversity conservation (2), the maintenance of sustainable and resilient smallholder farming systems represents a key condition for sustainable land management and to safeguard the livelihoods of millions of rural households. This study uses a combination of biophysical and socioeconomic data based on household interviews to compare 30 highland agroforestry systems (AFS) and 30 conventional agriculture systems (CAS), in order to determine which system provides better conditions to support sustainable livelihoods, and reduce vulnerability to CCV. The interview data is based mainly on the perceptions of Kayambi indigenous farmers who rely on these farming systems to support their livelihoods. The analysis of vulnerability is based on data from a modified Climate Change Questionnaire Version 2 of the World Overview of Conservation Approaches and Technologies (WOCAT). Independent Samples *t* Test and descriptive statistics were applied to analyse the data from 60 farms. The main findings indicate that AFS compared to CAS contain greater agrobiodiversity; more diversified livelihoods; better land tenure security and household income; more diversified irrigation sources and less dependency on rainfall. In addition AFS are less vulnerable to CCV, showing less exposition and sensitivity to climate and non-climate stressors, and having better adaptive capacity conditions than CAS. These findings highlight the role of agroforestry systems in supporting sustainable livelihoods and reducing the socioeconomic and environmental vulnerability of smallholder farmers in mountainous areas (4,5).

Keywords: Smallholder farmers' perceptions, Highland agroforestry systems, Climate change vulnerability, Socioeconomic and environmental sustainability, Indigenous people and traditional knowledge.

References:

1. Vadjunec et al., 2016, Land, 34, doi: 10.3390/land50400
2. Lowder et al., 2016, World Development, 16-29, doi: http://dx.doi.org/10.1016/j.worlddev.2015.10.041
3. Easterling.,in:Climate Change 2007, 2007, Parry, 273-313
4. van Noordwijk,in:Climate Change Impact and Adaptation in Agricultural Systems,2014, Fuhrer, 216-232
5. Córdova et al., 2017, Land, 45, doi: 10.3390/land7020045

L02.1_O.07

Impact of past climate change and socio-economic drivers on different crops in agroforestry systems of Wayanad, India

George A. (angelgeo93@gmail.com), Joseph S., Sebastian A., Sajeev T.V

GIS and Remote Sensing Department, Kerala Forest Research Institute, Thrissur, Kerala, India

Agroforestry systems are conventionally treated as a mitigation tool to reduce the impact of climate change. However, climate change is threatening the very existence of every ecosystem, and there is no reason to believe that agroforestry systems will be spared. Hence we have addressed whether climate change has an impact on agri and agroforestry systems of Western Ghats biodiversity hotspot.The objective of the study was to identify and measure the impact of climate change on patterns, productions and processes in agroforestry systems of Western Ghats region of Kerala, India in particular Wayanad.The shift in area and production of major crops were analyzed using the data available from Agricultural Statistics records of the Government of Kerala. The daily temperature and rainfall data were collected from different agencies and ordinary least square regression equations were fitted in order to analyze the changes in trends. A house-hold survey was conducted to understand how agricultural practices have changed over the period, and what drove the changes in practices. Factor analysis based on principal components was conducted to identify the most important factors that drove the shift in agroforestry practices.The result showed that Wayanad has undergone major changes in agroforestry practices over the last couple of decades. The area and production of crops such as arecanut, coconut, rubber and banana increased considerably whereas that of rice, ginger and pepper has declined. Climate variables showed that monsoon rainfall is found to be decreasing over the years, while there is an increase in temperature during the same period. Also, there is a delay in the onset of monsoon and an advance in the offset of monsoon. Factor analysis indicated that 71% of the changes in cropping pattern of the area is driven by four principal components which were found to be, market driven shift in agricultural practices (25%), adaptive agriculture management strategy adopted by the stakeholders (18%), impact of climate change (15%) and booming expansion of tourism industry (13%). The study concludes that there are changes in pattern, production and processes of agroforestry systems in Wayanad, and climate change contributes 15% of the shift in agricultural practices. The present study contributes to our existing knowledge on the effect of climate change on crop production and agricultural dynamics, and sheds light into the programs related to the agroforestry based climate change mitigation where climate variability and other factors need to be accounted before making policy decisions that aimed to mitigate the impact of climate change by means of agroforestry systems.

Keywords: Agroforestry systems, Climate change, Wayanad, Kerala, India.

L02.1_O.08

Shade trees affect soil resource acquisition strategies of cocoa in suboptimal climates

Borden K.[1] (kira.borden@utoronto.ca), Martin A.[1], Anglaaere L.[2], Buchanan S.[1], Addo-Danso S.[2], Owusu S.[2], Isaac M.[1]

[1] *Physical & Environmental Sciences, University of Toronto Scarborough, Toronto, Canada*; [2] *Forestry Research Institute of Ghana, Kumasi, Ghana*

Shade trees have a complex role in adapting agroecosystems to a changing climate. Disentangling these complexities is central for climate change adaptation strategies for cocoa production in West Africa. In this study, we adopted a trait-based approach to investigate the effects of a common shade tree species (*Terminalia ivorensis*) on the resource acquisition strategies of cocoa (Fig. 1), as characterized by variation and covariation in fine root traits. We assessed these shade tree effects across optimal and suboptimal precipitation regimes, and in contrasting edaphic conditions (sandy vs. loam) in Ghana. We found that absorptive fine roots of cocoa are more acquisitive in drier sites, expressing trait values associated with higher acquisition but lower lifespan, suggesting roots are more responsive to soil moisture. Shade trees play a key role in controlling resource strategies of cocoa, and dictate the position of individual cocoa trees along on a singular axis of trait covariation, or the 'root economics spectrum', although this effect is specific to climate and edaphic conditions (Fig. 1). Shade tree management that accounts for soil physical properties may be critical in suboptimal climatic conditions, conditions which are expected to become more prevalent in West Africa. Context-specific agroforestry arrangements designed in ways that optimize resource acquisition strategies of cocoa represent a viable means to sustain productivity in the coming decades.

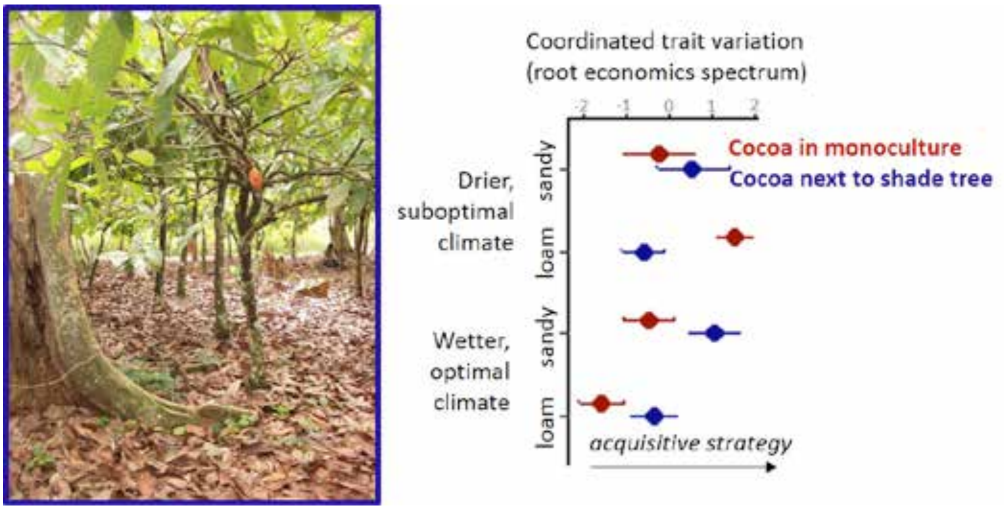


Figure 1: Cocoa next to shade tree (left panel) and coordinated trait variation in cocoa roots described by principal component axis scores (right panel).

Keywords: competition, functional traits, phenotypic plasticity, roots, Theobroma cacao.

L02.1_O.09

Using Yield-SAFE model to assess impacts of climate change on yield of Coffee under agroforestry and monoculture systems

Gidey Bezabeh T.[1] (tglove.gidey@gmail.com), Palma J.[2], Oliveira T.[3], Crous-Duran J.[2]

[1] *Plant science, Adigrat University, Adigrat, - Tigrai, Ethiopia*; [2] *School of Agriculture, University of Lisbon, Lisbon, Portugal*; [3] *Department of Informatics, University of Lisbon, Lisbon, Portugal*

Ethiopian economy strongly depends on coffee production. Coffee is sensitive to climate change and recent studies have suggested that future changes in climate will have a negative impact on its yield. One of the strategies that ensuring coffee production under future climate change is agroforestry-based production, as combination of trees in the system buffers extreme conditions. The objective of this study was to assess coffee production under: 1) monoculture and 2) coffee grown under trees using: a) current climate and b) two climate change scenarios. The study focused on two coffee growing regions of Ethiopia. A process-based growth model (Yield-SAFE) was used to simulate coffee production for a time horizon of 40 years. Climate change scenarios considered were: Representative Concentration Pathways (RCP) 4.5 and 8.5. Results suggest that in monoculture systems, the current coffee yields are between 1200-1250 kg ha^{-1}yr^{-1}, with expected decrease of between 4-38% and 20-60% in scenarios RCP 4.5 and 8.5, respectively. However, in agroforestry systems, the current yields are between 1600-2200 kg ha^{-1} yr^{-1}, the decrease was lower, ranging between 4-13% and 16-25% in RCP 4.5 and 8.5 scenarios, respectively (Figure 1). These results evidenced that agroforestry systems for coffee production have a higher level of resilience when facing future climate change and reinforce the idea of using this type of management to mitigate negative impacts of climate change on coffee production.

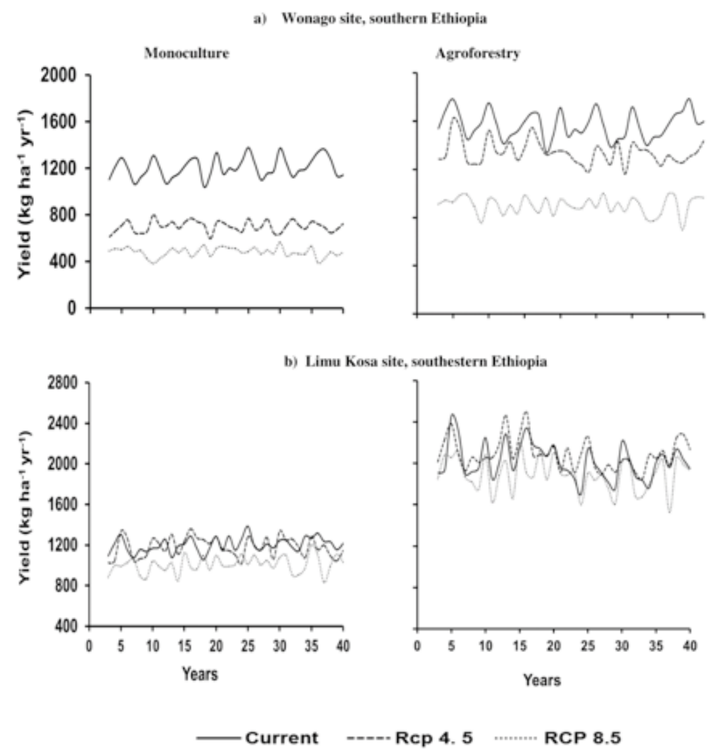


Figure 1. Coffee yields under monoculture and agroforestry systems in current and future climate change scenarios at: a) Wonago b) Limu Kosa sites in Ethiopia

Keywords: CORDEX, HADCM3 model, process-based model, system resilience, Albizia gummifera.

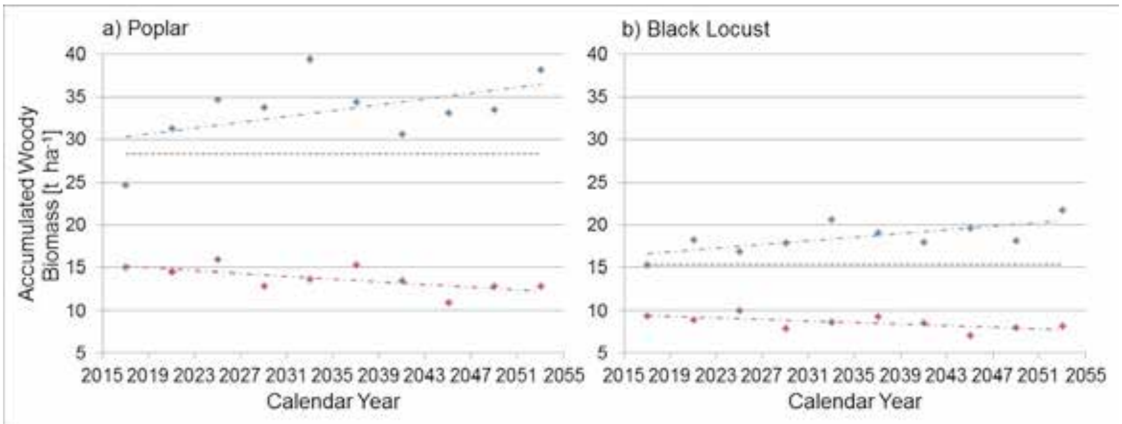
L02.1_O.10

Growth vulnerability of hybrid-poplar and black locust to prospective climatic changes

Seserman D.-M.[1] (seserman@b-tu.de), Pohle I.[2], Veste M.[3], Freese D.[1]

[1] *Soil Protection and Recultivation, BTU Cottbus–Senftenberg, Cottbus, Brandenburg, Germany*; [2] *Environmental and Biochemical Sciences, The James Hutton Institute, Aberdeen, Scotland, United Kingdom*; [3] *Centre for Energy Technology Brandenburg, CEBra e.V., Cottbus, Brandenburg, Germany*

In Brandenburg, eastern Germany, prospective climate changes imply extreme weather events[1], increasing annual temperature, and decreasing summer precipitation[2]. Since alley-cropping systems (ACS) have a broad planning horizon, appraising their sustainability and efficiency under changing climate conditions is crucial for forthcoming risk assessments and adaptation scenarios. Consequently, this combined experimental and simulation study investigated the growth vulnerability of poplar clone "Max I" (*Populus nigra* L. x *P. maximowiczii* Henry) and black locust (*Robinia pseudoacacia* L.) short rotation coppices in an ACS established in Brandenburg to a considerable spectrum of weather conditions and long-term climate change, from 2015 to the end of 2054[3]. The investigation employed (i) Yield-SAFE[4], a biophysical, process-based model to simulate the above-ground tree woody biomass and (ii) 100 realisations of the statistical regional climate model STAR 2K[5]. In the most optimistic sequence of events pertaining to air temperature, precipitation, and global radiation, 35% more woody biomass would be achieved by poplar and 43% by black locust in the last period compared to the base period (Fig. 1). Alternatively, in the most pessimistic circumstances, 54% less woody biomass would be rendered by poplar and 47% by black locust (Fig. 1). Our findings corroborated the tree growth vulnerability to prospective climatic changes, particularly to changes in water availability.



A bandwidth of potential woody biomass accumulated in a 4-year rotation cycle from 2015 to the end of 2054 shown by maximum (blue) and minimum (red) values for (a) poplar and (b) black locust (after Seserman et al., 2018). The dash-dotted lines describe trend lines for the woody biomass. The dashed lines represent the woody biomass, as per reference period.

Keywords: Climate scenario, Tree growth, Woody biomass, Short rotation coppice, Modelling.

References:

1. Jacob, et al., 2014, Reg. Environ. Change, 563–578. doi: 10.1007/s10113-013-0499-2.
2. Gädeke, et al., 2017, Reg. Environ. Change, 1751–1762. doi: 10.1007/s10113-017-1138-0.
3. Seserman, et al., 2018, Forests, 419; doi: 10.3390/f9070419.
4. van der Werf, et al., 2007, Ecol. Eng., 419–433. doi: 10.1016/j.ecoleng.2006.09.017.
5. Orlowsky, et al., 2008, Theor. Appl. Climatol., 209–223. doi: 10.1007/s00704-007-0352-y.

L02.2_O.01

Assessing the role of agroforestry in adapting to climate change in the United States

Bentrup G.[1] (gbentrup@fs.fed.us), Patel-Weynand T.[2], Stein S.[3]

[1] *USDA National Agroforestry Center, U.S. Forest Service, Lincoln, NE, United States*; [2] *Sustainable Forest Management Research, U.S. Forest Service, Washington, DC, United States*; [3] *USDA National Agroforestry Center, U.S. Forest Service, Washington, DC, United States*

A scientific assessment was conducted on the role of agroforestry in helping adapt agriculture and agricultural lands to threats from climate change in the United States. This recently released report entitled *Agroforestry: Enhancing Resiliency in U.S. Agricultural Landscapes under Changing Conditions* was led by USDA Forest Service scientists and included participation from more than 50 scientific experts from the Forest Service, other federal agencies, research institutes, tribal lands, and universities across the U.S., as well as input by scientists from Canada and Mexico. Based on expert input and information gleaned from over 1000 citations, this document represents a comprehensive synthesis on agroforestry as a mechanism to meet integrated climate change adaptation and mitigation objectives in the U.S. The report also evaluates the social, cultural, and economic aspects of agroforestry and the capacity of agroforestry systems to provide multipurpose solutions. For instance, indigenous agroforestry systems of the United States and U.S.-affiliated islands offer time-tested models that can inform current agroforestry systems. In addition, the report presents U.S. regional overviews as well as international overviews from Canada and Mexico to provide a North American perspective and understanding of agroforestry's strengths and limitations. This presentation summarizes key points from the assessment and presents brief case studies to illustrate real world impacts.

Climate change activity	Major climate change functions	Agroforestry functions that support climate change mitigation and adaptation
Adaptation Actions that reduce or eliminate the negative effects of climate change or take advantage of the positive effects	Reduce threats and enhance resilience.	• Alter microclimate to reduce impact of extreme weather events on crop production. • Alter microclimate to maintain quality and quantity of forage production. • Alter microclimate to reduce livestock stress. • Provide greater habitat diversity to support organisms (e.g., native pollinators, beneficial insects). • Provide greater structural and functional diversity to maintain and protect natural resource services. • Create diversified production opportunities to reduce risk under fluctuating climate.
	Facilitate species movement to more favorable conditions.	• Assist in plant species movement through planting decisions. • Provide travel corridors for species migration.
Mitigation Activities that reduce GHGs in the atmosphere or enhance the storage of GHGs stored in ecosystems	Sequester C.	• Accumulate C in woody biomass. • Accumulate C in soil.
	Reduce GHG emissions.	• Reduce fossil fuel consumption: ◊ With reduced equipment runs in areas with trees. ◊ With reduced farmstead heating and cooling. • Reduce N_2O emissions: ◊ By greater nutrient uptake through plant diversity. ◊ By reduced N fertilizer application in tree component. • Enhance forage quality, thereby reducing CH_4.

C = carbon. CH_4 = methane. GHG = greenhouse gas. N = nitrogen. N_2O = nitrous oxide.

Source: Modified from Schoeneberger et al. (2012).

Keywords: climate change, adaptation, mitigation, resiliency.

References:

1. Schoeneberger et al., 2012, Journal of Soil and Water Conservation 67(5),128a-136a.

L02.2_O.02

Agroforestry in National Adaptation Plans: preliminary insights

Meybeck A.[1] (a.meybeck@cgiar.org), Gitz V.[2], Wolf J.[3]

[1] *FTA, CIFOR, Maccarese (Fiumicino), Italy*; [2] *FTA, CIFOR, Bogor, Indonesia*; [3] *CBC, FAO, Rome, Italy*

The national adaptation plan (NAP) process was established under the UNFCCC in 2010. Least developed and other developing countries prepare national adaptation plans (NAPs) that identify and address medium- and long-term adaptation needs. The objective of this presentation is to show some preliminary insights on how agroforestry is considered in the NAPs prepared by developing countries[1] and also in some comparable documents prepared by developed countries[2]. It is the result of a preliminary analysis conducted as part of the preparation of a joint publication of FAO and the Forests, Trees and Agroforestry research program of the CGIAR (FTA) to support countries in the integration of forests, trees and agroforestry in their national adaptation processes. The form, length and structure of national adaptation plans vary by country. The analysis thus does not attempt to strictly compare NAPs but rather to identify in them features and measures that are relevant for agroforestry. The NAPs contain, in various sections, numerous mentions of the benefits of planting trees as an adaptation mean, for a great variety of purposes related to natural resources management, to restore degraded land, reduce soil erosion, restore water catchments, protect water tanks and rivers, protect against wind and storms or provide shade. In some cases, agroforestry is mentioned or broad measures like planting 10% of agricultural land with forest trees. However, these recommendations generally focus on a single biophysical benefit to mitigate a negative impact of climate change, without specificities (species, management practices) to achieve these adaptation objectives and without integrating the trees in a proper agroforestry system. As a result, they often neglect integration of the trees with other crops as well as potential socio-economic potential benefits. Measures related to the enabling environment needed for planting trees, like on tenure, on seed and seedlings systems, are often lacking, especially for countries with no established tradition of planted forests. Moreover, the constraints to the insertion of trees in farming systems, and more generally in the landscapes, are generally not mentioned, nor are measures to overcome them. When considering how the NAP process is generally conducted, these gaps may be due to a lack of consultation between agriculture and tree specialists as well as to a lack of engagement with the scientific community. As the NAP process is evidence based there is a need for the scientific community to be better engaged and provide to decision makers the options and enabling conditions that would enable agroforestry to play its role to support the adaptation of agriculture. There is also a need to facilitate the integration of forests and trees in the NAP process itself.

Keywords: National Adaptation Plan, adaptation, agroforestry, climate change, policies.

References:

1. http://www4.unfccc.int/nap/Pages/national-adaptation-plans.aspx
2. https://www4.unfccc.int/sites/NAPC/Pages/adaptation-plans-and-strategies.aspx

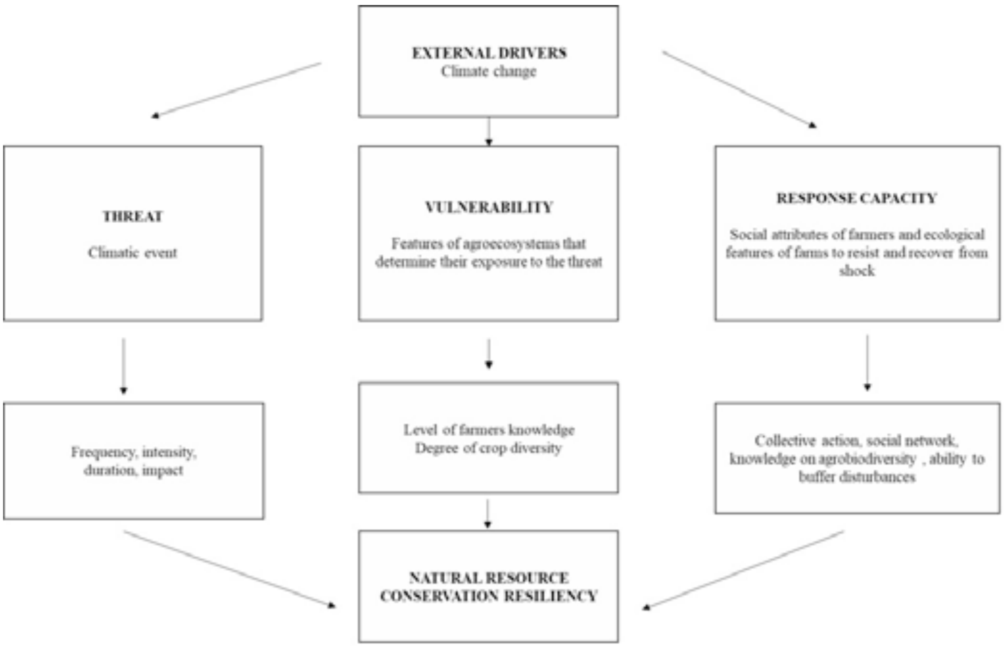
L02.2_O.03

Assessment of resilience capacity in coffee agroforestry systems in Nicaragua

Mugica M. (marta.mugica@hotmail.com)

Copenhagen University, Copenhagen, Hovedstaden, Denmark

Coffee production is going to be highly affected by climate change[3]. In Nicaragua, where the coffee sector employs 54% of the agricultural work force, climate change is predicted to cause a 40% reduction in the area suitable for coffee by 2050[3]. This study investigates the resilience to climate change of six different agroforestry coffee communities in Nicaragua by assessing the vulnerability and the response capacity of farmers and their farms, and through exploring farmers' perception of climate change. Data was collected through a survey and biophysical measurements on the farms, following a protocol developed by the Latin America Society of Agroecology[1,2]. The study found that farmers' perception of climate change is highly affected by the types of crops they grow, with the exception of coffee. Notably, farmers who grow grains perceive higher temperature increases and changes in rainfall patterns. Farmers' response capacities are determined by their management practices, and socio-economic factors[2]. The presence of organisations influence farmers' awareness of climate change as well as their management adaptation to the new climatic conditions. The resilience of the farms was determined, the results from this calculation indicate that cooperatives show a higher number of resilient farmers (low vulnerability, high response capacity). This study can contribute to the design of adaptation measures, such as soil management techniques and farmers knowledge of climate change.



Diversity, landscape, and soil and water characteristics that increase the ecological resilience of an agroecosystem affected by an extreme climatic event. Source: Nicholls and Altieri 2013.

Keywords: Agroforestry, Coffee, Resilience, Nicaragua, Climate change.

References:

1. Altieri et al., 2015, INRA and Springer-Verlag France , 869–890
2. Nichols and Altieri, 2013, Agoecology 8, 7-20
3. Läderach et al., 2015, Springer, Climatic Change (2017) 141:47–62

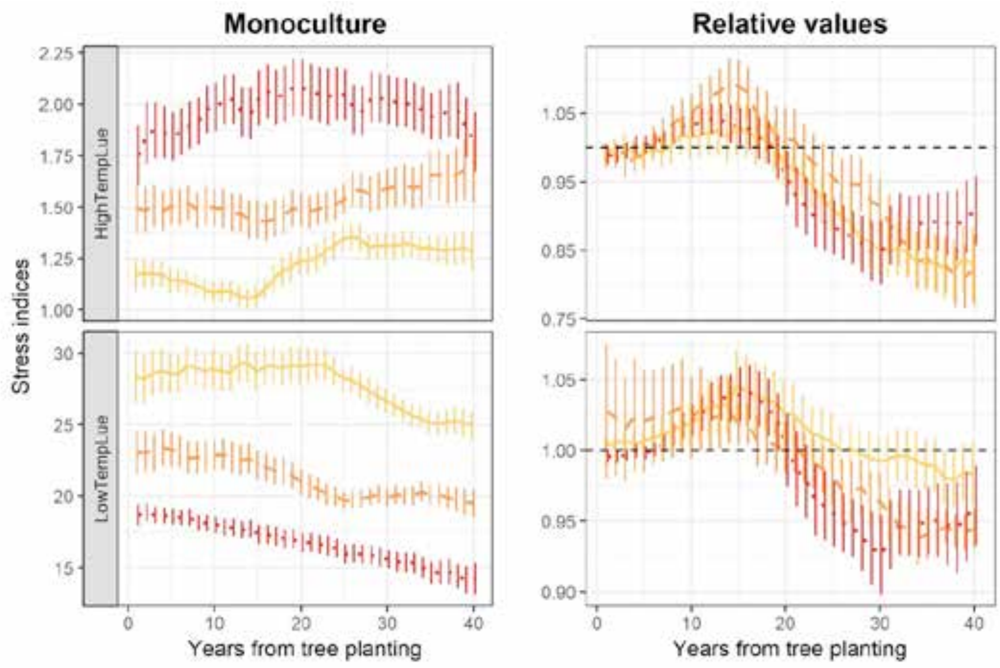
L02.2_O.04

Crop microclimate: can alleycropping alleviate climate change effects on durum wheat?

Reyes F.[1] (freyes@unitus.it), Gosme M.[2], Wolz K.[2], Lecomte I.[2], Dupraz C.[2]

[1] *DAFNE, University of Tuscia, Viterbo, Italy*; [2] *UMR System, INRA, University of Montpellier, Montpellier, France*

Climate Change (CC) is expected to lead to both improvements and worsening of the crop growing conditions, depending on site-specific conditions. Agroforestry (AF) systems have significant effects on the climate experienced by the understory crop. The complex crop-tree-soil-microclimate dynamics make it challenging to predict crop yields in AF systems with too simple/empirical models. We explore the use of a process-based bio-physical AF model (Hi-sAFe) for the prediction of the drivers of crop growth and yields in AF under CC.
Hi-sAFe is a 3D model representing tree-crop interactions for the capture of light, water and nitrogen, as well as the effect of tree shading on crop temperature and crop water use efficiency. The model was used to compare a monocrop of winter wheat and an alley cropping plot combining wheat and hybrid walnut tree lines. Each plot was simulated over cycles of forty years, in a location in southern France, as driven by climatic projections from IPCC, representing Past, Present, and Future climates.
Trends in intercepted PAR radiation by the crop and thermal comfort indices were interpreted for the different agricultural systems and climate scenarios, taking into account the effect of the tree size in agroforestry. By this approach the positive and negative impacts of trees on crop growth temperatures for the different climate scenarios were discriminated.



Thermal stresses on photosynthesis due to sub-optimal high (above) and low (below) temperatures across climatic scenarios (solid yellow line: Past; dashed orange line: Present; red dotted line: Future). Stress values are calculated as the product of the number of days of stress annually experienced, multiplied by one minus the mean annual value of the stress index. Stresses are represented after the application of a moving average with a window of eleven years. Vertical lines represent confidence intervals. The horizontal dashed lines correspond to relative stresses equal to one.

Keywords: Stress, Modeling, Growth, Optimal temperature, Agroforestry.

L02.2_O.05

Adaptation to climate change: the impact of olive trees on the microclimate of the understorey durum wheat crop

Panozzo A.[1] (nn.panozzo@gmail.com), Desclaux D.[2], Bernazeau B.[2], Meunier F.[2]

[1] *Department of DAFNAE, University of Padova, Legnaro (PD), Italy*; [2] *INRA - DiaScope unit, Mauguio - Domaine de Melgueil, France*

The Mediterranean region has been identified as one of the most prominent *Hot-Spot* in climate change projections. We investigated an olive tree - durum wheat AF system and we wondered what is the potential role of these trees on the vulnerability of d. wheat to shifting environments.
The experiments were conducted at INRA Mauguio (South of France) for 3 years. D. wheat was sown each year just after olive harvesting in 3 experimental conditions: AF: yearly pruned olive orchard, AF+: never pruned olive orchard (both 6 m between rows), C: open field.
A national weather station and temporary sensors placed in the treatments provided air temperature and humidity, global radiation, PAR, wind velocity and water in the soil (Figure 1).
PAR reaching d. wheat was reduced by averagely 30% in AF and 55 % in AF+, compared to C.
A “**buffer effect**” was clearly noticed: air temperature in AF was lower (-4 °C) from 5am to 3pm and higher (+2°C) from 3pm to 12pm. Daily average **wind velocity** was significantly reduced by AF treatments: 2.0 (C), 0.25 (AF) and 0.01 m.s-1 (AF+). These effects allowed a reduction of water evaporation and an increasing of **soil moisture** conservation in AF treatments, with the greatest difference, compared to C, recorded from 30 to 60 cm depth in the soil, all years.
The presence of evergreen tree species, with the PAR reduction observed, might be responsible for the decresed wheat yield in agroforestry (-43% in AF; -83% in AF+), while olive yield even slightly increased.

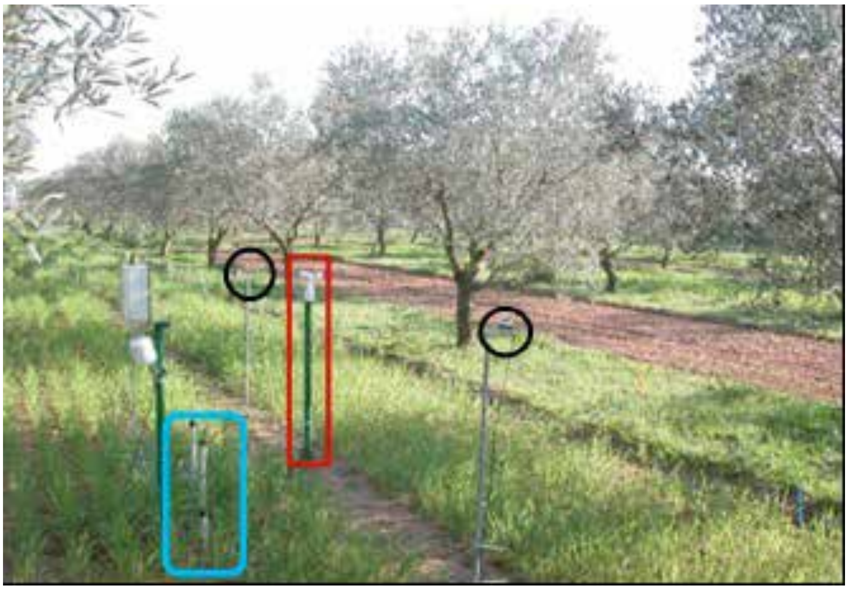


Figure 1. Photo taken in the AF treatment showing the position of two PAR (Photosynthetically active radiation) sensors (black circle), of the anemometer (red) and of the four tensiometers (blue).

Keywords: climate change, PAR reduction, daily temperature cycle, water availability.

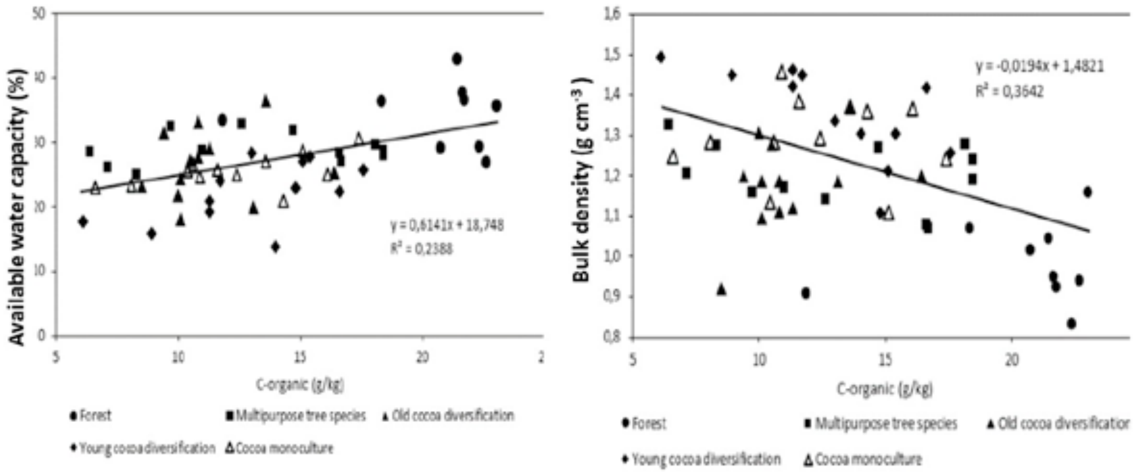
L02.2_O.06

Soil organic matter connecting mitigation of/and adaptation to climate change in cocoa-based agroforestry systems

Gusli S. (sikstusgusli@gmail.com), Sumeni S., Sabodin R., Muqfi I. H., Nur M., Hairiah K. van Noordwijk M., Useng D.

[1] *Soil Science, Hasanuddin University, Makassar, South Sulawesi, Indonesia*; [2] *Hasanuddin University, Makassar, Indonesia*

Large areas of tropical forests in Sulawesi have been converted to smallholder cocoa-based agroforestry (AF), with consequences for C-stocks, soil water balance, and implications for global climate change (CC) mitigation. We characterized land use (LU) systems with remnant primary forests (NFS), multi-purpose agroforestry (MPTS-AF), multistrata cocoa-based agroforestry (AFM) (young and mature stages, 5 and 34 years respectively), simple cocoa-based agroforestry (AFS), and cocoa monoculture (MONO). With 4 reps per LU (but only 2 reps in NFS due to acreage limit), we measured 5 C-pools, soil's total and macro porosity, hydraulic conductivity and water availability. Converting tropical forest to MPTS-AF system reduced the total C-stock to 58 % of that under NFS (290 Mg ha^{-1}) or to 30-33 % under MONO and young AFS, with partial recovery to 41 % under old cocoa AFM. Changes in soil C-stock in top 30 cm of soil were relatively small, but soil compaction was evident. Surface soil had 60 % total porosity (f) and 20-30 % macro (>60 mm) pores (fa) under forest and 50-55 % f and 15-20 % fa under cocoa AF. This compaction reduced water conductivity and availability. With current rainfall pattern cocoa production is unaffected, but with predicted lower rainfall reliability, loss of soil macro porosity exacerbates risks. CC adaptation concerns primarily focus on the belowground part in relation to water, while differences in C stock, relevant for CC mitigation, are mostly aboveground.



Available water capacity (left) and soil bulk density (right) as influenced by soil C-organic

Keywords: Cocoa Agroforestry Systems, remnant primary forest, total carbon stocks, soil macroporosity, water availability.

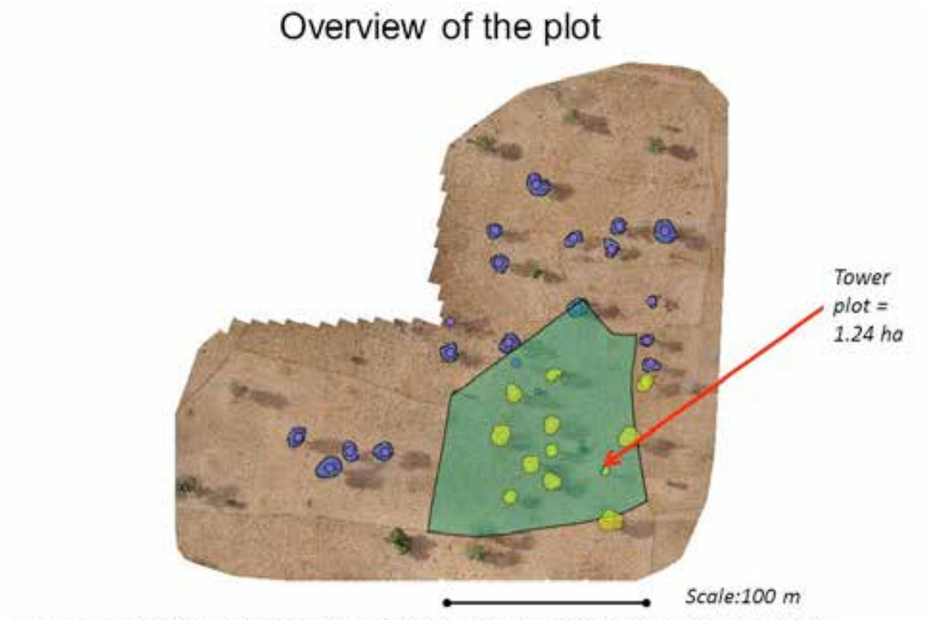
L02.2_O.07

"*Faidherbia-Flux*": adapting crops to climate changes in a semi-arid agro-sylvo-pastoral open observatory (Senegal)

Roupsard O.[1] (olivier.roupsard@cirad.fr), Clermont-Dauphin C.[2], Audebert A.[3], Sanou J.[4], Koala J.[4], Jourdan C.[1], Orange D.[5], Do F. C.[5], Rocheteau A.[5], Bertrand I.[6], Faye E.[1], Tall L.[7], Gaglo E.[7], Tounkara A.[7], Demarchi G.[8], Brévault T.[1], Vezy R.[8], le Maire G.[8], Seghieri J.[5], Cournac L.[2]

[1] *CIRAD, Dakar, Senegal*; [2] *IRD, Dakar, Senegal*; [3] *CIRAD, Thiès, Senegal*; [4] *INERA, Ouagadougou, Burkina Faso*; [5] *IRD, Montpellier, France*; [6] *INRA, Montpellier, France*; [7] *ISRA, Dakar, Senegal*; [8] *CIRAD, Montpellier, France*

The adaptation of semi-arid crops to climate changes is theoretically possible through agroforestry, provided that the trees exert little competition, or even increase the multifunctional LER (LER_M).
We monitored microclimate, net primary productivity (NPP), CO2 and H2O fluxes in a semi-arid agro-sylvo-pastoral system (Niakhar, Senegal), dominated by the multipurpose *Faidherbia albida* (FA) tree. Undercrops were mainly millet and peanut, under annual rotation.
We scanned a 1.24 ha millet under FA plot with UAV photogrammetry in RGB, thermal infrared and multispectral bands. At harvest, we collected 12 subplots of 15 millet holes each, distributed either below the crown of *FA*, or at 2.5 x crown radius, or at 5 x crown radius. We separated all organs. The whole millet root system (0-200 cm) was sampled also in 2 m trenches, totalizing 4 millet holes, where all roots were sorted by layer. The whole plot harvest will allow extrapolating yield from subplots, through UAV images.
Millet yield per unit ground area was about 3 times higher below *FA*, with still a positive influence at 2.5 x crown radius and less impacts of pests close to FA. In the trenches, we noted higher soil humidity and SOC close to the *FA* trunks.
This observatory is open for collaboration.



Orthomosaic of the 1.24 ha experimental plot, with the position of the Faidherbia (FA) trees (gree and blue shapes). Mosaic image from UAV (drone) flight in May 2018 (A. Audebert and E. Faye). GIS from Demarchi G.

Keywords: Faidherbia effect, LER_M, Drone, yield, pests.

L02.2_O.08

Building climate resilient communities through package-based integrated agroforestry practices

Aryal K.[1] (syangjali999@gmail.com), Thapa P. S.[2], Lamichhane D.[2]

[1] *Provincial Forest Directorate, Dhangadhi, Far-western Province, Nepal*; [2] *Ministry of Forests and Environment, Kathmandu, Nepal*

Agriculture based livelihoods in the developing countries are bearing significant negative impacts due to climate change. In this scenario, agroforestry is one of the best alternatives to cope with climate change and disaster risks. However, the agroforestry approaches adopted in the past were sectoral and partial, and were insufficient to contribute to socio-economic wellbeing and resilient communities. Nepal has been implementing package-based integrated agroforestry since 2016. It is a project approach to advance agroforestry practices by including disaster mitigation, land and water management, and community development activities. This paper reflects on the process and outcomes of the agroforestry practices, implemented by the government in seven super zones of Nepal. The programs have shown fairly satisfactory output in building adaptive capacity to climate change, awareness and ctive participation in agroforestry development activities. This paper reveals that the agroforestry alone cannot be sustained, and hence, it has to be integrated with land productivity enhancement, natural resource management, climate change adaptation, and livelihood support in addition to tree plantation in agricultural lands. This paper is crucial in understanding the scope of package-based integrated agroforestry approach to build climate resilient communities.

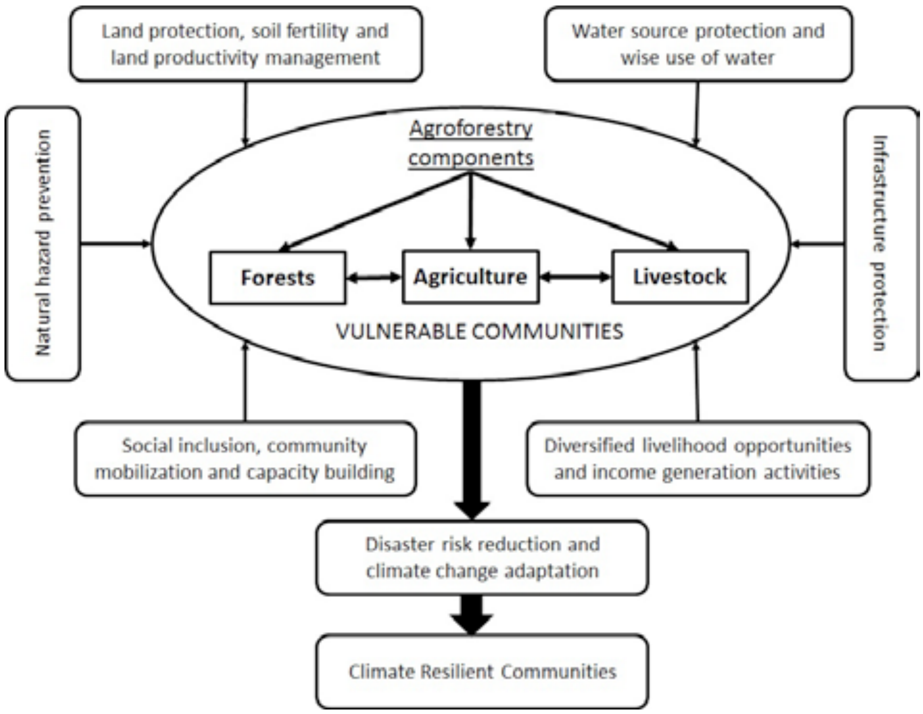


Figure: Package-based integrated agroforestry

Keywords: resilient communities, agroforestry systems, climate change adaptation, super zone development program, water and land management.

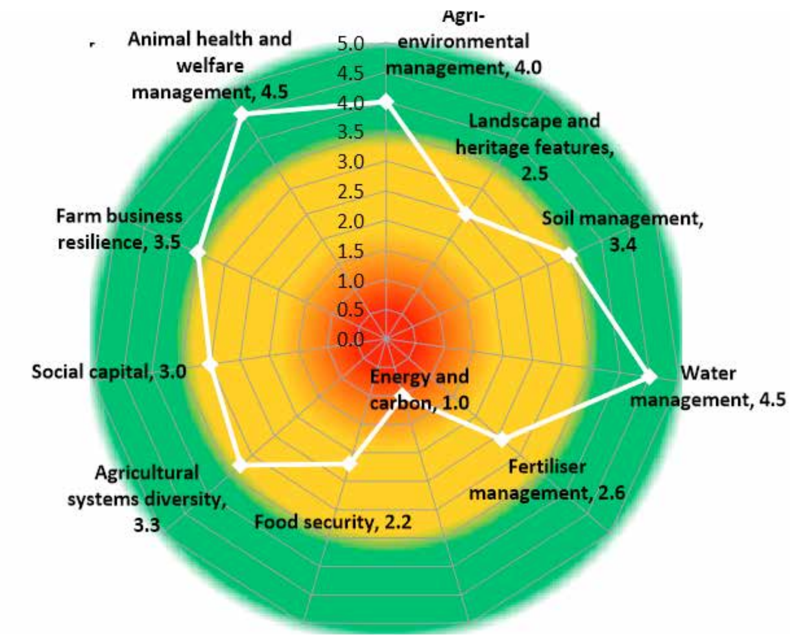
L02.2_O.10

Implementation of the Public Goods Tool to Assess Sustainable Agricultural Practices

Alexander S.[1] (stephenalex123@gmail.com), Ghaley B. B.[1], Smith L.[2]

[1] *Plants and environmental science, University of Copenhagen, Copenhagen, Denmark*; [2] *Organic Research Centre, Newbury, United Kingdom*

Climate change effects are increasing the need for a switch to sustainable agricultural practices including agroforestry (AF) systems[1]. Compensations for direct and indirect effects of climate change are required. To confront the challenges posed by climate change, an agricultural system that shows high levels of diversity, productivity and efficiency needs to be developed[2]. The Public Goods tool (PG tool) measures the performance of a combined food and energy (CFE) system through the parameters of eleven different spurs, with the aim of providing rapid sustainability assessment that allows for easy data collection and quick calculation of results, to allow the farmer immediate access to the desired information[3]. By using the land equivalent ratio (LER), the benefits of a CFE in terms of yield can be calculated against the already measured monoculture numbers[4]. This study used the PG tool to measure a CFE system in Denmark and compared the results from two other study sites associated with the SustainFarm project. The systems in place at these sites include alley cropping, intercropping and a mixture of these and other techniques. The LER results of all three sites showed that these three CFE systems produced higher yields than those seen in a monoculture system. The PG tool is not without its faults but it could be very useful in contributing to the necessary adaptation to sustainable agricultural practices in response to the effects of climate change.



Example of the radar graph produced by the PG tool.

Keywords: Agroforestry, Sustainability, Climate Change, Combined food and energy, Public Goods.

References:

1. BOGDANSKI, A., et al. 2010. Making Integrated Food-Energy Systems Work, FAO
2. ALTIERI, M. et al. 2011. Agronomical Sustainable Development, 1-13, DOI: 10.1007/s13593-011-0065-6
3. SMITH, L. 2018. RE: Milestone 3.3: Pilot-testing of improved PG tool, SustainFarm
4. KANTOR, S. 1999. Agroecology: E. P. in S. A.,Washington State University

L02.P.01

Climate Change Impacts And Adaption On Agroforestry systems and Biodiversity conservation in West-African Sahel

Akande S.[1] (soakande@futa.edu.ng), Jejelola O.[2]

[1] *Meteorology and Climate Sciences, Federal University of Technology Akure, Akure, Ondo, Nigeria*;
[2] *School of Environmental Technology, Federal University of Technology Akure, Akure, Ondo, Nigeria*

Recent findings explained climate change as one of the most urgent environmental threats with widespread implications on the earth's ecosystems and livelihoods. The study examined vegetation patterns and changes with respect to climatic trends as they affect the ecosystem structure and biodiversity conservation in West Africa Sahel. The vegetation indices (such as EVI2, NDVI, IFI etc) were obtained from the Landsat and MODIS satellite images to detect the vast degradation of the vegetation patterns. The sixty (1957-2017) years climatic data were obtained from the NCEP-NCAR, Climate Research Unit Time Series (CRU-TS) to assess the devastating droughts and famines and their consequent damages. Results of rainfall and temperature data analysis also indicate significant changes in the seasonal and annual distribution, including longer dry periods within rainy seasons, which may contribute to the perceived decrease in rainfall, thereby affecting agroforestry systems. The vegetation indices derived from the MODIS and Landsat images were used and analyzed to quantify the changes in forest vegetation. A measure of climate changes, statistical correlations were established between the peak values of average seasonal and annual temperatures across the region. Results showed that the average temperature had increased significantly over the 45-year period. Normalized Difference Vegetation Index (NDVI), Integrated Forest Index (IFI), and Enhanced Vegetation Index (EVI), were calculated from Landsat at-sensor-reflectance data. It was observed that the vegetation covers had shown a considerably low radiant temperature in all the years considered, areas of dense vegetation recorded less temperature amount of heat and surface structures through transpiration. Results however proposes climate smart agricultural technologies and policies to support recuperation of degraded lands, soil and water management, and sustainable agriculture and pastoralism in the West-African Sahel. The study concluded that climate change is reducing the natural ability of the forests to provide ecosystem services in the study area. From the obtained results, changes in vegetation growth were observed during the short wet season (June-September), across the different zones within the Sahel. The prolong dry season (October-May) had led to far-reaching damaging effects on the livelihood such as crop failures, wind erosion, decreased in organic soil and natural vegetation, and depleting water supplies. Finally, future improvements in the application of Earth-Observation and time series analysis of extreme weather/climate events would improve the knowledge on vegetation changes and its drivers across the West Africa Sahel region.The results from these analyses would be used to policy making and to ensure eco-friendly environment by growing massive tree commodity crops of different tree species, which would be well managed and propagated and used for herbal treatments.

Keywords: Vegetation, Agroforestry, Ecosystem, Climate.

L02.P.02

Shade implications of upper canopy tree crown architecture in cocoa agroforestry systems in the Western region of Ghana

Asante W.[1] (winstonasante@gmail.com), Kyereh B.[1], Ahoma G.[1], Gyampoh B.[1], Asare R.[2]

[1] *Silviculture and Forest Management, Kwame Nkrumah University of Sci & Tech, Kumasi, Ghana*; [2] *Cocoa, International Institute of Tropical Agri, Accra, Ghana*

Several studies have been conducted on shaded cocoa systems, very few of these have examined species-specific crown architecture and its influence on shade provision in cocoa agroforestry systems. In view of the fact that cocoa agroforestry is the recommended practice to drive cocoa production onto a climate-smart pathway, and given the role of upper canopy trees in the moderation of shade and light to the cocoa system, there is the need to understand the characteristics of crown parameters of upper canopy trees and the associated implication for shade provision for the cocoa system. This will provide useful guide to the selection of upper canopy tree species for the provision of shade to cocoa systems. The aim of the research was to investigate the crown architecture and dendrometric parameters of upper canopy trees and their implications for shade provision in two age classes of cocoa agroforestry systems. Employing a replicated transect method, quantitative data on upper canopy trees in cocoa agroforestry systems were collected from twelve (12) 1 ha plots established on a 5 km long transects at the Bonsu Nkwanta cocoa growing district in the Western region of Ghana. Information on the following crown parameters were generated, crown height, crown area, crown volume, uncompacted live crown ratio, and crown spread index. Given that there was no existing information on various crown forms of upper canopy trees in cocoa systems in Ghana, the crown forms generated by Frank (2010) was adopted for this study. These were "*spreading to cylindrical", "elongate to rounded to oval", "upswept and vase shaped", "conical to pyramidal" and "spade shaped" crown forms*. Results from the study showed that one hundred and sixty (160) upper canopy trees belonging to 44 species, distributed in 21 families were recorded in the cocoa agroforestry systems surveyed in the study area. *Newbouldia laevis*was the most abundant species recorded and constituted (11.88%) of all the trees. The study showed that crown and dendrometric characteristics of the upper canopy trees did not differ in cocoa agroforestry systems of different ages. Also, the highest values of crown volume, crown area and shade area were recorded for the "*spreading to cylindrical"* crown forms followed by the "*elongate"* crown form. Furthermore, results from the study showed that crown area, crown volume, crown diameter, tree DBH and crown height were the parameters that strongly affected the ability of a particular crown form of a tree to provide higher shade. Based on the results, we conclude that in selecting upper canopy trees for the provision of shade to cocoa systems, "*spreading to cylindrical"* and "*elongate"* crown forms are the most suitable crown forms to incorporate in the cocoa agroforestry system. The results of this study hold implications for promotion of climate – smart and sustainable cocoa agroforestry in Ghana and the West African cocoa belt.

Keywords: Cocoa, Shaded cocoa, climate change adaptation, Crown architecture, Ghana.

References:

1. Anim-Kwapong G J, Frimpong EB (2008). Vulnerability and adaptation assessment under the Netherlands
2. Asare, R., and Anders, R. (2016). https://doi.org/10.1007/s11056-015-9515-3.
3. Frank, E. F. (2010). Crown Volume Estimates By Eastern Native Tree Society. Bulletin of the Eastern
4. Broeckx, L. S., Verlinden, M. S., Vangronsveld, J., & Ceulemans, R. (2012).. https://doi.org/10.1093
5. Dawoe, E., Asante, W. A., Acheampong, E., and Bosu, P. 2016. DOI: 10.1186/s13021-016-0061-x

L02.P.03

Drought experiments in alley-cropping systems, from concepts to field reality: lessons learnt at Restinclières, France

Blanchet G.[1] (guillaume.blanchet@inra.fr), Gosme M.[1], Bourdoncle J.-F.[1], Sellier A.[1], Dufour L.[1], Vincent G.[2], Dupraz C.[1]

[1] *UMR SYSTEM, INRA, Montpellier, France*; [2] *UMR AMAP, IRD, Montpellier, France*

In the context of climate change, the Mediterranean region will be more frequently prone to climate hazards, such as drought and heat waves. In mature alley cropping systems, understory conditions might buffer adverse conditions encountered by cereals during drought events. However, it is still undecided whether facilitation processes will prevail or not on competition interactions.

Rainfall manipulation experiments have been largely used in forests, grasslands or monocrops, with two main types: continuous partial exclusion (e.g. fixed gutters covering a certain percentage of soil) or temporary total exclusion (e.g mobile shelters). In agroforestry systems, rain exclusion experiments are still rare. Experiments published so far only used continuous partial exclusion, with fixed gutters covering the soil below the crop[1] or fixed gutters above the crop[2]. However these devices modify microclimate, and do not allow testing climate scenarios with extreme drought events.

Two different prototypes of rainout shelter allowing temporary total exclusion were designed at the Restinclières Farm Estate, in the south of France. This poster will present the methodological framework of the experiment, the proposed design of rainout shelters and the first results concerning their relative efficiency (edge-effects, experimental artefacts, impacts on soil water availability). Pros and cons of both solutions will be discussed.

Rainout shelters at the Restinclières Farm Estate: on the left, a prototype that aims at excluding rainfall at the crop scale solely ; on the right, another prototype that aims at excluding rainfall for both the crop and the trees.

Keywords: Rainout shelter, Drought experiment, Alley cropping.

References:

1. Schwendenmann L. et al., 2010, Global Change Biology, 16:1515-1530
2. Nasielski J. et al, 2015, Agronomy for Sustainable Development, 35:1541-1549

L02.P.04

Effect of a climat resilient agroforestry technological package on millet yield in the groundnut basin of Senegal

Camara B. A.[1] (ansou1988@yahoo.fr), Sanogo D.[2], Ngom D.[3], Badji M.[3], DIOP M.[2]

[1] *Département d'Agroforesterie, Université Assane SECK, Ziguinchor, Senegal*; [2] *Centre National de Recherches Forestière, Institut Sénégalais de Recherches Agrico, Dakar, Senegal*; [3] *Biologie Végétale, Université Cheikh Anta DIOP, Dakar, Senegal*

In the Sahel, declining crop yields are a major obstacle to food security. This is mainly due to climate variability and land degradation due to unsustainable management practices. This is the case of the agro-ecological zone of the groundnut basin in Senegal where most of the soils are degraded by the effects of continuous cultivation with a peanut-millet rotation. In this area, farmers resort to clearing and/or uprooting of shrubs to extend cropland. For non-uprooted shrubs, their management includes annual spring coppicing and burning of residues before cultivation of row crops. This mismanagement of cultivable land correlated with the low valuation of crop residues and animal excrement as well as climatic disturbances has had adverse consequences on the environment. This study aims to evaluate the effect of a Climat Resilient Agroforestry Technological Package (CRATP) on millet yield in a context of rainfall variability. The CRATP includes native shrubs conservation in the fields through Farmer Managed Natural Regeneration (FMNR), the use of seed varieties chosen according to climate forecasts, climatic information throughout the season, organic and mineral fertilization by micro-dose and minimum tillage. Agroforestry trials were carried out over four successives years in 1250 m2 plots of 20 producers applying the CRATP pathway compared to 20 other producers applying their usual practice (UP). The results show that the CRATP has achieved to obtain in 2014 and 2017 (deficient rainfall P = 441 mm and P = 524 mm) a yield of 1010.5 ± 102.1 kg.ha-1 and 1579.5 ± 129.7 kg.ha-1 versus 632.1 ± 69.3 kg.ha-1 and 970.7 ± 160.3 kg.ha-1 for farmer practice. In 2015 and 2016 (excess rainfall P = 695 mm and P =760 mm) the CRATP also allowed a yield of 1370.3 ± 164.1 kg.ha-1 and 904.1 ± 60.9 kg.ha-1 against 804.8 ± 101.9 kg.ha-1 and 461.8 ± 50.5 kg.ha-1 for farmer practice. Overall the yield increased by 60% and 63% compared to the farmer usual practice in deficit rainfall years (2014 and 2017) and by 96% and 70% in excess rainfall years (2015 and 2016) with a decrease of 33% in the amount of mineral fertilizer and 71% of the amount of Urea used. This agroforestry technological package helps to reduce the negative impacts of climate variability and thus improve the food security and the resilience of small Sahelian farmers.

Keywords: Native shrubs, Rainfall variability, Fertilization, Climate information, FMNR.

L02.P.05

Potential use of coffee agroforestry systems to adaptation-mitigation synergies for climate change

Canal D. (dscanal@ut.edu.co), Andrade H.

Grupo de Investigación PROECUT, Universidad del Tolima, Ibagué, Tolima, Colombia

Mitigation and adaptation have been proposed by the international community as the main strategies to face the climate change, but its integration is taking more relevance. This study estimated the mitigation-adaptation synergy (MAS) in the three most dominant coffee production systems in Líbano, Tolima – Colombia: agroforestry system (AFS) with *Cordia alliodora* (AFS-C), AFS with plantain (AFS-P) and monoculture (M). Carbon footprint and diversity of ants were estimated as mitigation and adaptation indicators, respectively. The inclusion of trees in coffee production systems changed from negative to positive the carbon footprint: 12.8 vs -3.0 vs -6.4 Mg CO2e/ha/year for AFS-C, AFS-P and M, respectively) (Figure 1). In the same way, AFS-C had the highest richness of ants according to Margalef index (1.3) than AFS-P and M (0.6); in contrast, no differences between systems were detected in Shannon-Wiener and Simpson Index (Figure 1). The genera *Cephalotes, Dorymyrmex, Hypoponera, Pachycondyla, Octostruma*and *Proceratium* were exclusively found in AFS-C due to their requirement of high biomass and necromass. The AFS that includes native trees, can be an acceptable strategy for mitigation-adaptation to climate change, due to its advantages in improving carbon footprint and hosting a high diversity of ants. The AFS-C have characteristics more similar to natural forests which allow to generate more services as carbon sequestration and those derived from biodiversity conservation.

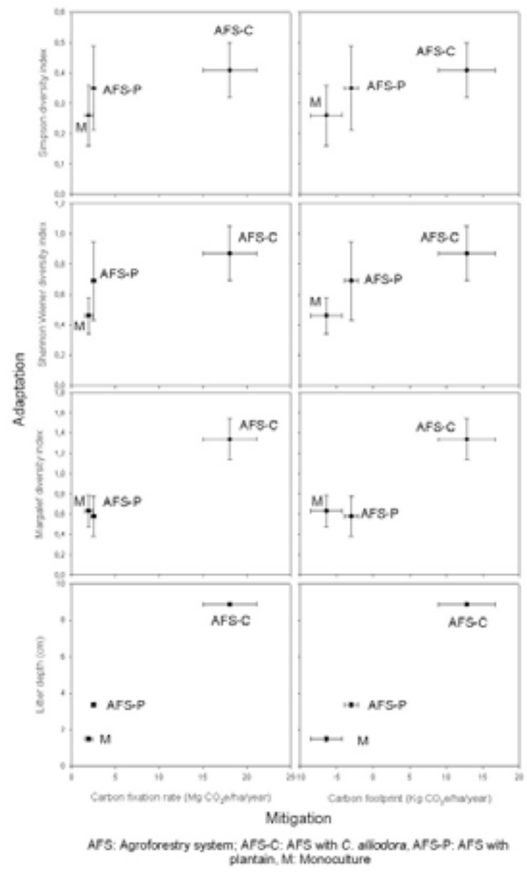


Figure 1. Comparison of adaptation and mitigation indicators in the three most dominant coffee production systems in Líbano, Tolima – Colombia.

Keywords: Ants, Biodiversity, Carbon footprint.

L02.P.06

Adapting agroforestry to future climate scenarios: The LIFE project Desert-Adapt

Castaldi S.[1] (Simona.CASTALDI@unicampania.it), Bijl M.[2], Alduina R.[3], Bastidas M.[4], da Silveira B. R.[3], Catania V.[3], Coppola E.[1], Grilli E.[1], Herguido E.[5], La Mantia T.[6], Lo Verde G.[6], Mastrocicco M.[1], Miranda J.[5], Pulido F.[5], Pérez-Izquierdo C.[5], Quatrini P.[3], Rutigliano F. A.[1]

[1] *DISTABIF, Università degli Studi della Campania, Caserta, Italy*; [2] *Forestry Service Group (FSG), Garderen, Holland*; [3] *STEBICEF, University of Palermo, Palermo, Italy*; [4] *ADPM, Mértola, Portugal*; [5] *INDEHESA, University of Extremadura, Plasencia, Spain*; [6] *SAAF, University of Palermo, Palermo, Italy*

Increasing scientific evidences indicate that agroforestry is a land use that can support economic, social and environmental sustainability, thus promoting resistance and resilience towards ongoing climate changes. The implementation and management of agroforestry systems still face social, economic and political barriers. Mediterranean agroecosystems suffer from increasingly negative climate change effects and urgent measures are needed to improve their rural economy while protecting soils and the environment. In this context, the LIFE Project Desert-Adapt: "Preparing desertification areas for increased climate change" (http://www.desert-adapt.it), aims to demonstrate the feasibility of innovative climate adaptation strategies and measures, based on the agroforestry concept, over 1000 hectares at risk of desertification in Italy, Spain and Portugal. The core of the project is the Desert Adaptation Model (DAM), an integrative development model fitted to the specific requirements of each farm which guide the implementation of sustainable agroforestry systems (e.g. montado, dehesa). The results will be evaluated through an array of multidisciplinary social, economic and environmental indicators. The project will deal with the most common conceptual, technical, and legal constraints encountered along the implementation and management of agroforestry systems in marginal lands and its results will fill the gap between farmers' needs and policy makers at local and global level.

A typical agroforestry system of Sicily in which the scattered almond trees offer shelter to the Cows

Keywords: Sicily, sustainability, value of products, reforestation, desertification.

L02.P.07

Soybean yield responses to rainfall reduction and tree root pruning in a tree-based intercropping system in Québec

Gagné G. (gagg21@uqo.ca), Lorenzetti F., Rivest D.

Sciences naturelles, Université du Québec en Outaouais, Ripon, Qc, Canada

Agroforestry is increasingly viewed as an effective means to buffer crop yield against the impacts of climate change, especially decreases in the availability of soil water. The effects of belowground competition at the tree-crop interface on crop yield under rainfall reduction have not been assessed in well-documented manner in temperate tree-based intercropping (TBI) systems. The objective of this study was to determine the effect of rainfall reduction and tree root pruning on soybean yield in a 7-year-old TBI system. We hypothesized that soybean yield tolerance to rainfall reduction will be higher in TBI system as compared to soybean monoculture. We also hypothesized that tree root pruning will increase soybean yield and tolerance to rainfall reduction at the tree crop interface as compared to unpruned TBI system. Hybrid poplars and high-value hardwood species were planted alternately every 5 m along each tree row that were spaced 40 m apart, resulting in a stand density of 50 stems ha-1. The experimental design was a split-plot design with three systems, soybean monoculture, TBI with tree root pruning (2.5 m from the tree row, within the top 60 cm of the soil profile, both sides) and TBI without root pruning, as the main whole plot effect, replicated in four blocks. Split-plot effects consisted of two randomly assigned treatments of full rainfall or partial rainfall exclusion. In each TBI plot, split-plot effects were observed at three distances from the tree row (4, 12 and 20 m) on both sides. The rainfall reduction treatment consisted in suspending PVC gutters at a height of 2–10 cm above the soil (covering 50% of the soil surface), and the excavation of a deep ditch at the lower part of the plots to intercept water from gutters. Variability of soybean yield and yield components among treatments will be discussed in relation to soil water and light transmittance availability. These results will enhance our understanding of the crop performance under different soil water stress conditions in temperate TBI systems.

Keywords: Agroforestry, soybean, soil, water, yield.

L02.P.08

Impacts of climate change on Cocoa trees species at various temporal scales in West Africa

Gebrekirstos A.[1] (agebrekirstos@yahoo.com), Alban M.[2], Prabhu R.[1], Kouame C.[2]

[1] *World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [2] *World Agroforestry Centre (ICRAF), Abidjan, Côte d'Ivoire*

Cocoa (*Theobroma cacao*) is an important agroforestry tree species that has been providing socio-economic and ecological benefits for centuries. Cote d'Ivoire is the world's largest cacao producing country, followed by Ghana and Indonesia (Franzen et al., 2007). In this region, cacao trees play a significant role in farmers' livelihood and the national economy. For example, cacao production in Côte d'Ivoire contributes 7.5% of the national GDP. A recent study indicated that drought has caused widespread mortality of cocoa seedlings (Siebert, 2002) suggesting that cacao tree growth and productivity is susceptible to climate change, such as rising of temperature and reduction of rainfall amount. Hence, any impact of climate change on the suitability to grow cocoa in West Africa will not only affect farmers' livelihoods and incomes, but the national economies as well. It is becoming increasingly evident that patterns of growth, water use efficiency, and survivorship of tree species are sensitive to climate variations and stress induced mortality is prevalent (Gebrekirstos et al., 2014). However, previous studies did not investigate cacao tree response to changing climate. There is a substantial gap in fundamental knowledge concerning how cacao trees grow in response to climate variability, and therefore how they might react to future climatic change. Our approach considers different temporal scales (e.g., inter-annual and intra-annual wood anatomical variations). Stem disk samples were collected from seven sites across climate gradients in Côte d'Ivoire. Thin sections were cut with a sledge microtome and stained with solutions of astra blue and safranin red to distinguish living and non-lignified cells from lignified cells and to enhance the contrast for successive image analysis.
We observed peculiar anatomical features in macro section and micro cross sections in most of the stem disks collected although the extent appears to vary among sites and or varieties. Often, those structures did not appear along the whole circumference of the stem. We are in the process of further anatomical study to describe the anatomy of this particular features which seem to be unknown and to suggest possible drivers of their formation, whether it is due to climate or attack by pathogens.
Examining the stem cross section and further wood anatomical analysis at different temporal scales clearly showed that the cacao trees have gone through multiple attacks by various pathogens. Trees invest metabolites for different purposes (defense growth, yield etc.), depending on the prevalent conditions. Considering the multiple compartmentalization, chemical defenses and thyloses observed, cacao in Côte d'Ivoire seems to invest a lot in defense and this might have affected cacao yield as well.
We will present methods and tools to assess impacts of climate change on cacao resilience to climate variability, preliminary results and their implications for improved management practices.

Keywords: Tylosis, resilence to drought, disease, Cocoa, climate change.

References:

1. Franzen, M., Borgerhoff Mulder, M., 2007, Biodivers. Conserv. 16, 3835–3849
2. Siebert, S.F., 2002, Biodivers. Conserv. 11, 1889 – 1902
3. Gebrekirstos, A., Bräuning, A., Sass-Klassen, U., Mbow, C.,2014,Curr. Opin. Environ. Susta. 6, 48–53

L02.P.09

Effects of biochar on N cycling under drought conditions

Hosseini Bai S. (shossein@usc.edu.au)

Central Queensland University, Bundaberg, QLD

The frequency of drought spells has increased and is becoming a threat to global food security. Biochar has been used as a tool to mitigate gas emissions (e.g. N2O) and retain soil nitrogen (N). However, biochar effects on N cycling under drought conditions have not been extensively explored. This study aimed to investigate the effects of biochar application and drought conditions on N2O and CO2 emissions. We examined N2O and CO2 emissions, N leaching and microbial communities involved in N cycling using an incubation study. Biochar was applied to a macadamia orchard, five years prior to our incubation study. The presence of biochar significantly mitigated N2O and CO2 emissions following rewetting after drought. Soil available and leached NO3--N was higher in soil with biochar compared with that of control soil, and was associated with increased soil ammonia-oxidising bacteria gene abundance in soil with biochar. Water addition after drought was one of the main driving factors explaining N loss in the soil without biochar. Our results indicated that biochar could be used as a tool to reduce emissions of N2O and CO2 when rainfall events occur following drought spells.

Keywords: biochar, climate change, gas emission.

L02.P.10

The 3U/O-3P initiative to promote agroforestry practices combining the cultivation of medicinal trees with crops in Togo

Koudouvo K.[1] (kkoudouvo@gmail.com), Gbeassor M.[2], Dougnon T. J.[3]

[1] *University of Lome, Lome, Togo*; [2] *CERFOPLAM, University of Lome, Lome, Togo*; [3] *Animal Health and Production, University of Abomey Calavi, Abomey Calavi, Benin*

Background
Following the previous World Agroforestry Congresses (2009 and 2014), the NGO "GASD/SADDA-Togo'' in collaboration with the research centre "CERFOLAM/Univ. Lomé-Togo'' launched an initiative to develop Agroforestry in Togo.
Aims
Initially, the plantation of teak was chosen to promote the reforestation and to fight poverty.
Materials & Methods
From 2007-2016, plantation of teak was undertook. In parallel, ethnobotanical surveys were performed to identify antimalarial and analgesic medicinal plants endangered by habitat destruction and overexploitation [1,2]. A new initiative named 3U/O-3P (Une personne, Une plante, Une Planète/One person, One plant, One Planet) launched on 30/11/2018 to maintain this important biodiversity was created. Agroforestry was chosen as a mean to expand the cultivation of endangered plants.
Results
It was recorded 16 endangered plant species (9 tree, 2 shrub, 3 liana, 2 herb) used mainly in antimalarial and analgesic preparations [3]. 65 ha of agricultural land were planted with 162500 trees of teak. Three species (*Alstonia boonei, Griffonia simplicifolia*, *Lannea kerstingii*) having also international markets, were selected for cultivation, thus reaching 2 objectives at the same time: Conservation of medicinal plants by indigenous users and the increase of farmer's incomes.
Conclusion
Further studies will be needed to identify the best practices for production of both wood for international markets and medicinal products for local markets.

Photos of Endangered Plants of Togo

Keywords: Wood, Medicinal plants, Cultivation, Biodiversity conservation, Agroforestry.

References:

1. Koudouvo et al., 2011, of Ethnopharmacology, 183–90, doi:10.1016/j.jep.2010.12.011
2. Dénou et al., 2016, The J. of Ethnobiol and Trad. Med. Photon. 1160-70. ISJN66423194D821406042016
3. Koudouvo et al., 2017; J. of Agri. and Eco. Res. Int., 1-9; doi : 10.9734/JAERI/2017/29303

L02.P.11

Is there a place for alley cropping in the European forest areas?

Kovács K. (klaudikovacs@gmail.com), Vityi A., Marosvölgyi B.

University of Sopron, Sopron, Hungary

In Africa and South America rainforests forestry intercropping is a used practice to improve tree survival rates and the nutrition supply, while protecting the soil from erosion. Due to the adverse effects of climate change on forest areas and the success of reforestations, the traditional practice of growing crops in an afforested areas might be worthwhile to revive in Europe with the main purpose of protecting the seedlings in the first years and thus ensure the success of reforestation. Researchers examined the effect of soil cover and the shading of herbaceous plants on saplings in a Hungarian experiment. Measurements were made in oak (*Q. robur*) stand mixed with corn and in pure oak stand under the same circumstances as control. Values of soil conductivity, soil temperature and tree growth parameters (DBH and height) were measured during the summer in two consecutive years. Significant difference was found between the data of the two afforested parcels in terms of soil microclimate, the growth of trees and drought damage. The results confirm that the use of intercropping in reforestations can significantly reduce the climate sensitivity of the system.

Keywords: reforestation, forestry, alley cropping, microclimate, soil.

L02.P.12

Shade trees in cocoa agroforestry systems in Ghana: Influence on water and light availability in dry seasons

Kyereh D. (d.kyereh@agroeco.net)

Agro Eco- Louis Bolk Institute Ghana, Kumasi, Ghana

The objective of this paper was to assess the influence of single standing shade trees in cocoa agroforestry systems on soil moisture and light availability for cocoa in the dry seasons and how these environmental factors affect potential pod yields of cocoa. The research was conducted in a moist semi-deciduous forest zone of Ghana. Seven different shade trees that were commonly found in cocoa systems were selected[1,2]. An effect ratio was used to compare tree sub-canopy effects to the open area effects. *Morinda lucida* (0.19), *Spathodea campanulata* (0.16) and *Ficus capensis* (0.13) showed favourable soil moisture conditions, however *Citrus sinensis* (-0.26) revealed a lower soil moisture content in the sub-canopy[3]. *Entandrophragma angolense* and *Terminalia superba* had the highest transmitted percentage light of 69.2% and 67.1% respectively and the lowest being *Mangifera indica* (3%)[4]. The potential pod yields of cocoa were higher under *Morinda lucida* (0.40), *Terminalia superba* (0.40) and *Entandrophragma angolense* (0.35) but lowest under *Mangifera indica* (-0.55)[4,5]. *Morinda lucida, Spathodea campanulata, Entandrophragma angolense* and *Terminalia superba* in cocoa agroforestry systems potentially ensure higher soil moisture content and light availability in the sub-canopy, especially during the dry seasons, which could translate into higher cocoa pod yields.

Keywords: Shade trees, cocoa agroforestry, soil moisture, cocoa yields, dry season.

References:

1. Siebert, S. F. (2002). Biodiversity and Conservation 11: 1889 – 1902.
2. Schroth, G. (1995). Agroforestry Systems 30: 125 – 143.
3. Kummerow, J., Kummerow M., and Souza da Silva W. (1982). Plant and Soil, 65(2): p. 193-201
4. Koko, L. K., Snoeck D., Lekadou T. T., Assir A. A. (2013). Agroforestry Systems. 87:1043–1052
5. Somarriba, E. and Beer J. (2011). Agroforestry Systems. 81(2):109–121

L02.P.13

A simple model to infer the required shade level in coffee plantations

Lara-Estrada L. (leonel_larae@hotmail.com), Rasche L., Schneider U. A.

R.U. Sustainability and Global Change, University of Hamburg, Hamburg, Germany

Climate change will provoke warming conditions that are expected to downgrade the land suitability for *Coffea arabica* L. Agroforestry provides services that alleviate such impacts (IPCC, 2014); the shading creates a cooling effect, which improves the climate suitability under the canopy (Lara-Estrada et al., 2017). So, we introduce a simple Bayesian network model to estimate the required shade level [Sh_r] based on the air temperature [T_i]. The model also evaluates the air temperature suitability without and with shade [*S* and *S'*, respectively] for coffee, and can estimate air temperature data from altitude and provinces information. The model includes equations for Sh_r and *S'* that we created from literature (Barradas & Fanjul, 1986; Siles et al., 2010; Souza et al., 2012); and the feature to infers missing T_i was learned from data using machine learning algorithms. Actual shade levels of coffee plantations from a survey in Nicaragua were used to evaluate the model performance. The model shows a high performance; the best results were observed at lower and higher altitudes (above and below the optimal air temperature). At optimal altitudes, the farmers used higher shade levels than the required [over-shading]; which suggest a high variability of farming strategies under optimal conditions. The model represents a straightforward tool for farming or policy planning during a decision-making process that involves the determination of the required shade level.

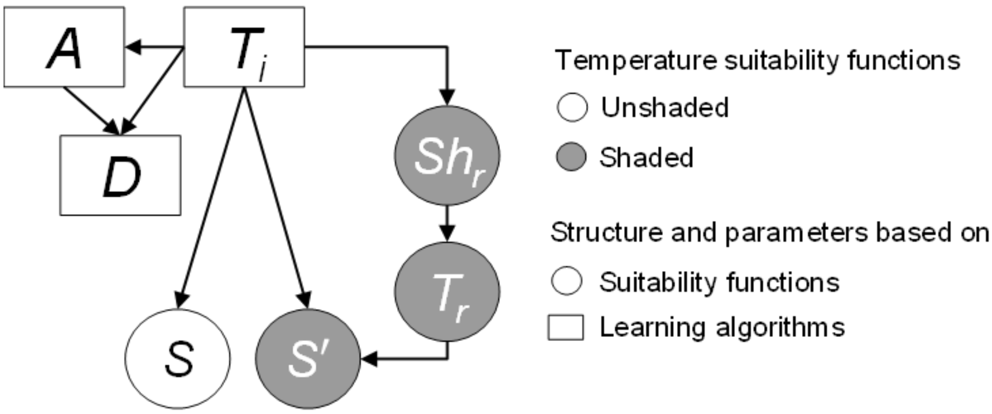


Figure 1. Graphical structure of the shade model. A = altitude [m.a.s.l], D = Nicaragua's provinces, Ti = mean air temperature [°C], Shr = required shade level [%], Tr = air temperature reduction [°C], S = air temperature suitability under unshaded conditions [%], S' = air temperature suitability under shade conditions [%].

Keywords: Bayesian networks, adaptation, cooling effect, agroforestry, temperature suitability.

References:

1. IPCC, in Climate Change 2014: Synthesis Report, March K.., Planton S., von Stechow C. (Eds.), p117
2. Lara-Estrada et al., 2017, Environ. Model. Softw., 196–209.doi.org/10.1016%2Fj.envsoft.2017.06.028
3. Barradas & Fangul, 1986, Agric For Meteorol. 38,101–112. doi.org/10.1016/0168-1923(86)90052-3
4. Siles et al., 2010. Agroforestry Systems 78, 269–286,doi.org/10.1007/s10457-009-9241-y
5. Souza et al., 2012, Agric Ecosyst Environ, 146, 179–196. doi.org/10.1016/j.agee.2011.11.007

L02.P.14

Integrating *Gliricidia sepium* and Chololo pits enhances yield of maize-based cropping systems in semiarid Tanzania

Liingilie A.[1] (evanssalum@gmail.com), Kimaro A., A.[2], Shirima D.[1], Rosenstock T.[3]

[1] *Department of Ecosystem and Conservation, Sokoine University of Agriculture, Morogoro, Tanzania*;
[2] *ICRAF Tanzania Country Programme, Word Agroforestry Centre (ICRAF), Dar-es-salaam, Tanzania*;
[3] *ICRAF Congo Country Programme, Word Agroforestry Centre (ICRAF), Kinshasa, Congo - Kinshasa*

Shifting rainfall patterns and seasons adversely affect the productivity of farming systems in semiarid areas. Although climate smart agriculture (CSA) practices are promoted to mitigate such effects and sustain crop production, there is limited information on the performance of CSA practices under the uncertainty of the on-set of growing seasons. We assessed the effects of integrating agroforestry and rainwater harvesting known as Chololo pits under different planting windows on soil moisture and maize grain yield in Kongwa District, Dodoma, Tanzania. A factorial experiment was adopted to test the effects of planting window (Early, Normal and Late planting), and CSA practices (Maize monoculture, *Gliricida sepium* intercropping and Intercropping with *G. sepium* and Chololo pits). The planting windows were determined based on previous studies and national weather forecasts as Mid-November to Mid-December (Early), Mid-December to Mid-January (Normal) and Mid-January to Mid-February (Late). Results revealed that soil moisture content, maize growth and yield varied significantly between planting windows and CSA practices. The *G. sepium*- rainwater harvesting treatment increased soil moisture content by 43% compared to 35% and 25% in the *G. sepium* and maize monoculture treatments, respectively. Overall, *G. sepium* intercropping alone increased maize grain yield by 23% relative to monoculture (2.6t/ha) due to improved soil fertility. Maize grain was the highest (2.8-4.2t/ha) in the *G. sepium*-chololo pits treatment across all planting windows, reflecting high resilience due to combined effects of improved soil fertility and soil moisture. Higher maize yields at normal planting in all CSA practice affirms that this is the appropriate planting window for Kongwa. This study demonstrates that the combined use of weather information on the appropriate planting window and CSA practice improve yields and build resilience to shifting weather patterns in semiarid maize-based farming systems.

Keywords: Agroforestry, Basin planting, CSA, Planting windows, Soil moisture.

L02.P.15

Agroforestry, adaptation, and the Intergovernmental Panel on Climate Change

Martin A. (adam.martin@utoronto.ca), Isaac M.

Physical and Environmental Sciences, University of Toronto Scarborough, Toronto, Ontario, Canada

The biophysical and social sciences strongly point to agroforestry management as a key pillar in agricultural adaptation to climate change, with decades of research indicating agroforestry management promotes food security and crop yield stability under varying climatic conditions (1). However, it remains unclear if agroforestry has been integrated into global assessments of agricultural adaptation to climate change. Here, we critically evaluate how agroforestry science has been integrated into analyses and adaptation strategies published by the Intergovernmental Panel on Climate Change (IPCC). While climate change impacts on agriculture factor prominently into all five IPCC reports published since 1992, agroforestry science *per se* remains near-completely absent from these reports. Qualitatively, the term "agroforestry" is afforded a brief discussion within the theme of forest management in the first IPCC assessment report (2). Similarly, the term "agroforest*" appears only twice in the extensive 49-page chapter on "Food Security and Food Production Systems" published as part of the fifth IPCC assessment report (3). There is also little evidence that agroforestry has been integrated into quantitative analyses of food security under climate change within any IPCC report (Figure 1). Our review here indicates that stronger integration of agroforestry into global climate change assessments represents a potential avenue for elevating agroforestry onto agricultural policy agendas.

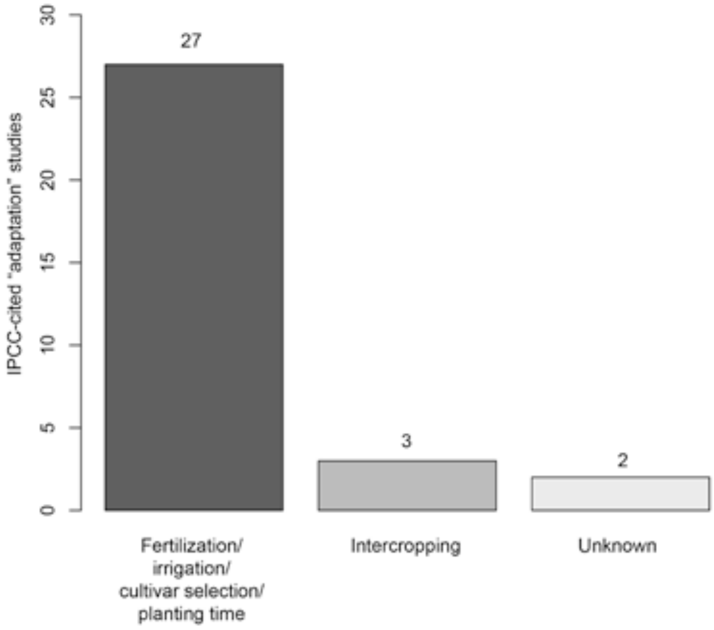


Figure 1. There is a complete absence of "agroforestry" as an agricultural adaptation strategy cited/ assessed by the IPCC (2014) when evaluating crop yield responses to climate change. Presented here is a summary of the agricultural adaptation strategies cited by the Intergovernmental Panel on Climate Change in their empirical assessments of crop yield responses to climate change (namely, increasing global temperature). Names of all of the adaptation methodologies here are consistent with the results published in the 2014 report entitled "Food Security and Food Production Systems" (namely, Table 7-2 in 3), with the numbers above the bars corresponding to the number of studies cited by the IPCC that employ a particular agricultural adaptation strategy.

Keywords: climate change adaptation, Intergovernmental Panel on Climate Change, IPCC assessment report, IPCC, crop stability.

References:

1. Nasielski, J. et al. 2015, Agron Sustain Dev, 1541-1549.
2. IPCC First Assessment Report Overview and Policymaker Summaries and IPCC Supplement. 1992, 168 pgs.
3. Porter, J. R. et al. 2014. In Climate Change 2014: Impacts, Adaptation, and Vulnerability.

L02.P.16

Climate-smart agricultural practices with emphasis to agroforestry: Bangladesh perspective

Miah M. G. (giash1960@gmail.com)

Agroforestry and Environment, Bangabandhu SMR Agril. University, Gazipur, Bangladesh

Bangladesh is one of the largest deltas in the world which is highly vulnerable to natural disaster and climate change. Its agriculture acts as a mainstay of the economy of the millions of people, employs around 62% of the population and contributes over 14.75% of the country's GDP. Agricultural production has been increased tremendously in the last couple of years due to technological development, but climate change and extreme events, for instances increasing temperature and erratic rainfall along with austere and frequent floods, droughts and cyclones have impacted profoundly on Bangladesh's agriculture and their productivity. Many research and development organizations are now doing researches in developing technologies and practices that can be useful for adaptation to climate change. Based on long involvement in agricultural and agroforestry research (as ICRAF's country liaison scientist) of Bangladesh, few agricultural technologies and several agroforestry practices have been identifed, which are considered as climate-smart practices, are being used at field levels for sustainable production and livelihood. Some of the adaptive technologies are: stress tolerant and short duration crop varieties, conservation agriculture using mulching (such as water hyacinth), floating methods of agriculture, *sorjan* method of cultivation, crop rotation, adjusted crop calendar, multiple cropping/intercropping, farmland and integrated homestead agroforestry systems. Because of ecological and economic benefits, farmland dominated with rice crops is being converted to fruit tree based agroforestry systems particularly at coastal and flood plains areas of Bangladesh, Furthermore, rooftop gardening/agroforestry with fruit tree, seasonal vegetables, medicinal and ornamental plants are also found in urban area, which is getting popularity nowadays. Since climate change is a continuous process and its impacts on agriculture are diverse, both technological and non-technological issues need to be addressed properly. Strengthening agricultural/agroforestry research and collaborations with strong support systems are critically important to advocate an effective adaptation process to overcome climate change impacts.

Keywords: Climate Change, Climate-Smart Practices, Agriculture, Agroforestry.

L02.P.17

Climate-growth relationships in juvenile afforestation sites in semi-arid Benin

Noulèkoun F.[1] (florentnoulekoun@yahoo.fr), Khamzina A.[1], Naab J.[2], Khasanah N.'M.[3], van Noordwijk M.[4], Lamers J.[5]

[1] *Environmental Science and Biotechnology, Korea University, Seoul, South Korea*; [2] *WASCAL Competence Center, Ouagadougou, Burkina Faso*; [3] *World Agroforestry Centre (ICRAF), Bogor, Indonesia*; [4] *Plant Production Systems Group / ICRAF, Wageningen / Bogor, the Netherlands / Indonesia*; [5] *Ecology and Natural Resources Management, Center for Development Research (ZEF), Bonn, Germany*

The early growth is the most critical stage of tree development. Climate control of the early tree growth as well as best metrics of climate sensitivity of tropical species remain, however, poorly understood and can hardly be used in assessing risks and adaptation strategies of young forests to climate change. Using a combination of field experiments and modelling, we assessed the climate sensitivity of two promising afforestation species (*Jatropha curcas* L. and *Moringa oleifera* Lam.) by (i) analyzing their predicted climate–growth relationships in the first two years after planting on a degraded cropland in semi-arid zone of Benin, West Africa and (ii) identifying the climate metrics with the greatest predictive power for the juvenile tree growth. The Water, Nutrient, and Light Capture in Agroforestry Systems (WaNuLCAS) model was calibrated and validated with field data on survival, growth traits, soil properties and weather from afforestation experiments conducted over 2014 and 2015, and used to simulate aboveground biomass (AGB) growth under past climate conditions (1981–2016). Linear mixed models related the annual AGB growth to climate metrics, while climate sensitivity indices quantified the strength of climate–growth relationships. Both species successfully established on the degraded cropland as evidenced by their high survival rates (94–100%) assessed 15 months after planting. The seasonal dynamics of stem diameter, height, and AGB were reasonably well reproduced by the model during both calibration ($R^2 \geq 0.9$; RMSE ca 3-26 %) and validation ($R^2 > 0.8$; RMSE ca 6-34 %) for either species. Drought was the dominant constraint to sapling growth as shown by negative and strong climate–growth relationships with annual water deficit (AWD), length of dry season (LDS), and length of dry spells (LDSP). In the first year, LDSP had the strongest effect on tree growth whereas in the second year, AWD and LDS became the strongest predictors. Simulated rooting depths greater than those in the experiments (75 cm) enhanced biomass growth under extreme dry conditions and reduced sapling sensitivity to drought. Projected increases in aridity and the number of days between rainfall implied significant growth reduction, but tree adaptations via deeper root systems would reduce sensitivity to climate variability in young plantations. Our results highlight that modelling combined with field experiments can be a valid approach to assess climate change risks for planted forests and help identify effective adaptation strategies.

Keywords: climate change, climate sensitivity, WaNuLCAS, West Africa.

L02.P.18

Smallholder farmers' Adaptation to drought in Teso Sub region, Uganda. Does Agroforestry have any stake in this?

Odoi J. B. (juventineboaz@gmail.com)

Tree Improvement and Germplasm Research, National Forestry Resources Research Ins, Kampala, Uganda

Agroforestry and drought stress

Mean global temperatures have increased the risk of climate extremes such as drought, affecting smallholder farmers' livelihoods in developing countries like Uganda (IPCC, 2014). Teso sub-region being one of the most affected Fig. 1. This trend presents a strong need for the smallholder farmers to equip themselves with adaptation strategies for resilience if they are to survive. Although many adaptation strategies to drought are available for smallholder farmers in Teso sub region, most of them are not sustainable compared to agroforestry Fig. 2. The global climate change is intensifying the frequency and severity of drought conditions; which has made drought a major driving environmental factor to limit plant productivity through drought stress that increase water loss from the plant thus interfering with normal plant processes fig. 3. Smallholder farmers need to identify in their areas and institute appropriate coping and adaptation strategies such as Agroforestry. This can protect agricultural crops because of the deep roots of tree component able to tap water from underground to promote their normal growth by shading crops and animals from the sun heat.

Applied adaptation mechanisms

Farmers in Teso sub region apply several adaptation measures to cope with drought (table 1), some farmers apply multiple strategies Table 1. Women headed households are more involved in offering labor on other peoples' farms in exchange for food or to earn income for other household needs (Nabikolo, 2014). Raring domestic animals for sale offers a major adaptation by men to maintain their families. Farmers also intercrop a variety of crops with trees such as sorghum, rice, millet, maize, beans, groundnuts, green grams, peas, soya beans, tomatoes, cabbages, potatoes and cassava for adaptation to drought. The root tubers are sun dried for future use. No single adaptation mechanisms to drought is applied in Teso sub-region, Table 2. Agroforestry, household age, area of land owned and family size indicated a weak positive correlation (≤50%), meanwhilehad a weak negative correlation. Area of land owned and offering labor on other people's farms while preserving food were significant at (≤0.05). Such offered labor in exchange for food during period of drought. Family size, farm size, farming experience and access to credit were also reported elsewhere as being key adaptation measures to drought (Wannasai et al, 2013)

Conclusion

Local adaptation strategies such as intercropping, adjustments in planting, agroforestry, mulching among others are practiced. Although more effort is needed in promoting the improved adaptation strategies like drought resistant varieties, irrigation systems, better infrastructures. Both local and external mechanisms should be applied concurrently. Other approaches like early warning mechanisms, encouraging group formation, easing liquidity constraints are strategies that promote adaptation (Kelvin et al, 2017).

Keywords: Agroforestry, Drought stress, Climate change, Productivity, resilience.

References:

1. IPCC, (2014). Climate change 2014: Contribution of working group II to the IPCC Fifth Assessment Rep
2. Nabikolo Diane, (2014). Household headship and climate change adaptation among smallholder farmers i
3. Kelvin M, Shikukaa,d, Peter Laderach b, (2017). Smallholder farmers' attitudes and determinants of a
4. Lasco R, Pulhin F, (2009). Agroforestry for climate change Adaptation and Mitigation. An academic pr
5. Wannasai. N, Sasiprapa W, Suddhiyam P, Kashawatana, C.Prasertsak, P. Kumsuebe, B. Pratcharoenwanich,

L02.P.19

Network Approach for Understanding Rural Farmers Access to Climate Adaptation Knowledge: Ghana Case Study

Ofoegbu C.[1] (ofoegbu.c@gmail.com), New M.[2]

[1] *Africa Climate and Development Initiativ, University of Cape Town, Rosebank, Cape Town, Western Cape, South Africa*; [2] *Africa Climate and Development Initiativ, University of Cape Town, Cape Town, Western Cape, South Africa*

Rural farmers in the developing countries are highly vulnerable to climate change due to their exposure and poor adaptive capacity. However, farmers' social networks play an important role in their access to knowledge on climate risk and risk response strategy. This paper examines the pathways of climate knowledge generation and dissemination among actors in the climate change and agriculture sector in Ghana, focusing on the cross-scale processes to tailor knowledge to better fit rural farmers' context. It employs social network analysis of both the organisations in the agriculture and climate change sectors and rural farmers in the Lawra district of Ghana. We explored two networks of configurations: i) relations of collaboration in knowledge production and ii) relations of collaboration in knowledge dissemination. We used three measures of network cohesion; density, core-periphery, and degree centrality to analyse the network structure and influence on knowledge flow and adoption. It finds that the network (both the production and dissemination) consists of socially integrated centralized government and civic organisations that have developed over time. Our analysis reveals that overlaps between these organisations produce more usable knowledge for rural farmers as NGOs collaborates with governmental organisations at mostly community level to produce locally relevant knowledge for rural farmers. However, the challenges associated with cross organisational collaborations and the sustainability challenge of local NGOs threatens this existing network and knowledge communication to local farmers. Based on these findings, we recommend that effort aimed at tailoring climate knowledge to rural farmers' context in Ghana be supported by actions targeted at enhancing cross-organisational cooperation and the sustainability of local NGOs.

Keywords: Farmers, Climate Change, Adaptation, Livelihood, Networks.

L02.P.20

Importance of shade for coffee cultivation under extreme rain events of precipitation

Parada P.[1] (cepala1@hotmail.com), Cerdán C. R.[2], Cervantes J.[3], Ortiz G.[2], Barradas V.[4]

[1] *Doctorate in Agricultural Sciences, Universidad Veracruzana, Xalapa, Veracruz, Mexico*; [2] *Faculty of Agricultural Sciences, Universidad Veracruzana, Xalapa, Veracruz, Mexico*; [3] *Earth Sciences Center, Universidad Veracruzana, Xalapa, Veracruz, Mexico*; [4] *Institute of Ecology, Universidad Nacional Autónoma de México, Mexico City, Mexico*

Coffee cultivation has a high sensitivity to climate changes, because of its narrow climate range (Camargo, 2010). Many coffee areas in Mesoamerica are traditionally managed under a range of agroforestry systems. There is a trend to decrease tree cover in order to plant more-productive coffee varieties which are tolerant to fungal diseases (coffee leaf rust). Tree cover degradation, in addition to the growing patterns of climate change, provoke unpredictable conditions for growing coffee (Bunn *et al*., 2015). On a traditionally recognized coffee region of Mexico, we evaluated the trends of weather extremes based on daily rainfall, after that, we assessed the function of shade trees facing the changes in weather patterns.
Daily data precipitation, maximum temperature and minimum temperature series were obtained from three weather stations in Veracruz, Mexico (Period 1961-2016). These stations (Coatepec, Briones and Xalapa) surround a coffee region. Data was provided by the national climatological base (from the Mexican National Meteorological Service). The data were subjected to analytical quality assurance, as well as a test of homogeneity. Subsequently, a set of 27 climate change indices proposed by the Expert Team on Climate Change Detection Monitoring and Indexes (Peterson, 2005) and its trends for the Xalapa-Coatepec zone were determined. Correlation and linear regression analyzes were performed, as well as the Mann-Kendall test to identify significant trends.
During the period of time analyzed, there have been significant increments of total annual precipitation (PRCPTOT), (78.83 mm/decade), and seasonally precipitation in the months of March-April-May (MAM) and September-October-November (SON). Simple daily intensity index (SDII), number of heavy precipitation days >10 (R10), >20 (R20) and >25 millimeters (R25), very wet days (R95p) and extremely wet days (R99p) were also increased. This shows a tendency of an increament in quantity and intensity of precipitation within the study area. The current rainfall patterns would affect coffee crop, mainly for a lack of water during the stage of fruits development. On the other hand, the increase in quantity would affect the flowering stage (incomplete flowering and scattered blooms); decelerate the growth and filling of the grain and slowing coffee fruits maturation (Camargo, 2010). Moreover, the increase in the intensity of the rain combined with a low presence of shade trees would increase surface runoff and soil erosion. In addition, in the seasons of MAM and SON, rain events would cause the fall of coffee flowers and fruits (Läderach *et al*., 2010). Considering the current conditions, the maintenance and promotion of shade trees is a recommended strategy in climate smart agriculture. Additionally, shade trees within coffee plantations are a carbon stock that mitigates climate change at a local scale, diminishing the impacts of rainfall intensity and extreme temperatures (Beer *et al*., 1997).

References:

1. Beer, Muschler, Kass & Somarriba, 1997, Agroforest Syst, 38(1-3), 139-164
2. Bunn, Läderach, Rivera & Kirschke, 2015, Clim. Change, 129(1-2), 89-101
3. Camargo, 2010, Bragantia, 69, 239–247
4. Läderach et al., 2010, CIAT Policy Brief, 2, 4 p
5. Peterson, 2005, WMO Bulletin, 54(2),83-86

L02.P.21

Effect of forage-tree species supplementation from the tropical dry forest on weight gain in zebu steers

Pérez Almario N.[1] (nperez@agrosavia.co), Orjuela Franco O. E.[1], Carvajal Bazurto C. T.[1], Moreno Turriago J. M.[1], Castañeda Serrano R. D.[2]

[1] *Agrosavia, El Espinal, Tolima, Colombia*; [2] *Universidad del Tolima, Ibagué, Tolima, Colombia*

Colombian dry tropical region presents dry spells of up to six months, quantity and yields of foraging species depend upon this phenomenon which can cause a considerable decrease of the productivity of pastures and subsequently causing degradation of the soils being subjet to animal husbandry. In order to mitigate this problematic it has been proposed to include dry-tolerant forage-tree species with animal husbandry occuring in dry-tropical ecosystems (Bs-T). The aim of this study was to evaluate the weight gain of steers being fed with foraging fodder managed ex situ. This study was carried in the Agrosavia Research Centre of Nataima, municipality of Espinal in Tolima, Colombia; mean temperature of 28°C, at 410 m.a.s.l. and 1200 mm of rain per year. 12 zebu (*Bos indicus*) steers were used in the study, they weighed on average 321 kg, being distributed into three diferent groups. Each groups was managed under rotational grazing with Tanzania grass (*Megathyrsus maximus*) in 16 plots of 1260 m2 each. The steers of each group receives a balanced diet adjusted to the dry matter (MS) of the fodder and the weight of the animals so: 1,5 to 2,4kg/MS/animal/day of sorghum silage var. "Corpoica JJT-18" mixed with 2kg/MS (5 to 8kg/green forage <1cm diameter of twigs/leaves) made up from all forage trees (manages as bushes) and mineral salt 7% of P. A latin square 4x4 array was applied. It was developed in three independent experimental cycles of 40 days each, where 4 species were assesed in periods of 10 days each. These periods were divided into 4 days of adjustment to the new diet and 6 days of assesments with initial/final weighing to determine the weight gain of the steers with the new diets. Experimental cycle 1 used the following species: *Clitoria fairchildiana, Cordia alba, Gliricidia sepium y Leucaena leucocephala*. Experimental cycle 2: *Moringa oleífera, Guazuma ulmifolia, Albizia guachapele y Tithonia diversifolia.* Experimental cycle 3: *Spondias mombin, Bauhinia variegata, Albizia saman y Albizia niopoides*). On the experiment 1 it was observed a major increase of the daily weight by the diet including *C. alba* (1.466,7g-1/animal/day), followed by *C. fairchildiana* (1.216,7g-1/animal/day) R2 = 0,89, p<0,002. Experiment 2 showed that *A. guachapele* presented weight gains of 1.225g-1/animal/day R2 = 0,88 p<0,002 And experiment 3 showed that *A. niopoides* generated an increase of 841,7g-1/animal/day R2 = 0,84 p<0,002. Bearing in mind all that, the inclusion of *C. alba* and *A. guachepele* managed as bushes could be a good alternative for the nutrition of animals at silvopastoral husbandry systems in dry-tropical regions, achieving a quicker weight gain and a reduction of the fattening time.

Keywords: dry tropics, Ruminants, silvopastoral systems, tropical trees, forage tree.

L02.P.22

Agroforestry dynamics, climate landscape and food secuirty: Experience from Bangladesh

Rahaman M.[1] (rana.bries@gmail.com), Bijoy M. R.[2]

[1] *Songshoptaque, Chittagong, Chittagong, Bangladesh*; [2] *Network on Climate Change Bangladesh, Dhaka, Bangladesh*

possible background of the work, aims, materials and methods, major results and conclusion.

Agroforestry is an sustainable landuse system that ensure food security through climate resilient agricultural promotion and increasing homestead yield by combining food crops (annuals) with tree crops (perennials) and/or livestock on the same unit of land. Coastal belt of Bangladesh is vulnerable due to different climate induced slow onset and sudden disasters. These catastrophic events significantly hinder the agriculture production systems, economic and social development of the community people who are mostly poor and disadvantaged groups and also depend on agricultural production for their livelihoods. Agroforestry is effective climate change adaptation practice in the climate vulnerable coastal areas of Bangladesh. The study aims to explore the climate landscape and food security paradigm in the study area to understand how climate vulnerable communities are adapting with climate change through agroforestry practices in updating climate landscape and food security nexus. Randomized Complete Block Design (RCBD) and Split-Plot Experiment were used as a action research tool to achieve the research goal and Statistical packages (ANOVA) for data analysis was undertaken in the study. PVA, LRP, food security index, adaptation measurement were conducted during the study period for 3 years in the study are. 300 households were taken as study sample among them 200 were adopted with agroforestry and 100 were control sample. Based on the baseline vulnerability index, resilient index and food security status, we have analysed ANOVA for six month duration during the study. The study reveals that in the case of agroforestry system (AFS) there is easy, fast, and pragmatic solution to climate change adaptation and short term and long term resilient food security can be achieved. And the approach we follow that agroforestry domestication is interacting with individuals and communities who will ultimately benefit by sustaining their agricultural crop. Therefore, the severity of climate change will be reduced or mitigate and food security would be increased to the contrivable stage by the hands of the community through agroforestry adoption in large scale.

Keywords: agrofprestry, climate change, food security, Bangladesh.

References:

1. Pratap Toppo and Abhishek Raj, 2018, Journal of Pharmacognosy and Phytochemistry; 7(2): 241-243
2. Abrha Brhan Gebre, 2016, Journal of Natural Sciences Research, 83-89
3. Nair, P.K.R, 1998. Directions in tropical agroforestry research: past, present and future. Agrofores
4. Richard, L., Charles, Emmanuel, F., Nzunda & Munishi, P.K.T. 2014. Agroforestry as a Resilient Strat
5. Singh GB. Role of Agroforestry in improving the environment. Indian Fmg. 1993; 33(3):15-19

L02.P.23

Climate change adaptation potentials of traditional agroforestry systems of the Eastern Himalayas

Sharma G. (banstolag@gmail.com)

The Mountain Institute India, Gangtok, Sikkim, India

Farm-based (FB), forest-based (FoB), *Alnus*-cardamom (AC), forest-cardamom (FC), and *Albizia*-mixed-tree-mandarin (AMT) agroforestry managed by small-holders in traditional agroecosystems were studied in the Eastern Himalaya in order to evaluate potentials of organic agriculture for stand nutrient dynamics, N_2-fixation, and cost-effectiveness, and also in relation to social-ecological resilience to climate change. Overall soil nutrient availability was highest in AC, followed by AMT. N_2-fixation in AC was highest (95 kg ha^{-1}), followed by FoB (59 kg ha^{-1}), and lowest in FC agroforestry (9.5 kg ha^{-1}). Annual economic return was highest in AC (US$ 1895), followed by FC (US$ 1275), and AMT agroforestry (US$ 1166). Output-input ratio was highest in AC (12.05), and lowest FoB agroforestry (4.21)[1,2]. Communities perceptions over 20-year period revealed that vulnerabilities due to climate change is increasing in the form of erratic rainfall/snowfall/hailstorm events, increased flash-floods, emergence of pests/diseases, crop productivity decline, shift of crop seasons, prolonged dry spells, decline of spring water for crops/livestock/irrigation, upward migration of species and a perceived shift in phenology of agroforestry species posing threats on future sustainability[3,4,5]. The future socio-ecological and economic resilience lies in implementation of Sikkim State Action Plan on Climate Change, and organic farming policy as a strategy for sustaining ecosystem services and livelihoods.

A traditional cultivated system with farm-based agroforestry practices in Sikkim, India

Keywords: Traditional Agroforestry, Eastern Himalayas, Cultivated Systems, Climate Change, Resilience.

References:

1. Sharma and Sharma (2017) In: Agroforestry: Anecdotal to Modern Sciencedoi.org/10.1007/978-981-10-
2. Sharma G, Honsdorfur Ben, Singh KK (2016) Tropical Ecology, 57(4): 751-764
3. Sharma, et al (2016) ICIMOD Working Paper 2016/5 Kathmandu: ICIMOD
4. Sharma and Acharya (2013) Agriculture Systems and Management Diversity. Gazetteer of Sikkim, India
5. Sharma G and Rai LK (2012) http://www.sikenvis.nic.in/writereaddata/12-Chapter_Climate_...pdf

L02.P.24

Agroforestry in southern Africa - new pathways of innovative land use systems under a changing climate (ASAP)

Sheppard J. P.[1] (jonathan.sheppard@iww.uni-freiburg.de), Bohn Reckziegel R.[1], Borrass L.[2], Carr S.[3], Chirwa P.[4], du Toit B.[5], Funk R.[6], Hassler S. K.[7], Helmschrot J.[8], Kahle H.-P.[1], Kleinschmit D.[2], Lang F.[9], Maelicke M.[7], Maier R.[9], Morhart C.[1], Ndlovu N. P.[2], Nyoka B. I.[10], Seifert T.[11], Syampungani S.[12], Veste M.[13]

[1] *Chair of Forest Growth, University of Freiburg, Freiburg, Germany*; [2] *Chair of Forest and Environmental Policy, University of Freiburg, Freiburg, Germany*; [3] *Economic Botony Programme, National Botanical Research Institute, Windhoek, Namibia*; [4] *Department of Plant and Soil Sciences, University of Pretoria, Pretoria, South Africa*; [5] *Department of Forest and Wood Science, Stellenbosch University, Stellenbosch, South Africa*; [6] *Institute of Soil Landscape Research, Leibniz Cntr. Agri.Landscape Research, Leibniz, Germany*; [7] *Inst. for Water & River Basin Management, Karlsruhe Institute of Technology, Karlsruhe, Germany*; [8] *SASSCAL, Windhoek, Namibia*; [9] *Chair of Soil Ecology, University of Freiburg, Freiburg, Germany*; [10] *Southern African Node, World Agroforestry Centre, Lilongwe, Malawi*; [11] *Scientes Mondium UG, Altomünster, Germany*; [12] *Dept. of Plant and Environmental Science, The Copperbelt University, Kitwe, Zambia*; [13] *Centrum for Energy Tech Brandenburg e.V., Cottbus, Germany*

New and innovative land use solutions are needed to adapt to a rapidly changing climate and to mitigate the predicted impacts on rural livelihoods. Projected changes to current climate patterns are suggested to severely impact southern Africa in the near future. This may be realised as an increase in drought and flooding events and shifts in rainfall patterns causing a loss of productive cropland, thus, negatively affecting economic, ecological and social aspects of sustainable development.

Agroforestry systems (AFS) present the potential to improve the bio-economy in rural areas, to provide an adaptation strategy for human needs, and to preserve natural resources and biodiversity against climate change influences. Targeting the application of AFS as a suitable response to the impacts of climate change, the research project 'Agroforestry in southern Africa - new pathways of innovative land use systems under a changing climate (ASAP)' with a project period of 2018 to 2021 incorporates research partners from Namibia, Mozambique, Malawi, Zambia, South Africa and Germany.

In a transdisciplinary approach the ASAP project aims to both develop and cement knowledge concerning AFS in southern Africa, utilising simple easily replicable methodology across the entire study region. The project will utilise traditional knowledge and combine it with innovative technical solutions, learning from existing systems and technology. ASAP targets an understanding of the social demands and impacts that AFS can bring to the study region. This is undertaken by attaining an understanding of the needs of stakeholders, land managers and subsistence farmers, as well acknowledging the potential pressures such actors will face due to a changing climate. Results of the project will aid regional policy makers in evaluating future support for such innovative land-use systems in a science-policy exchange. The project consortium will perform an examination of the effects of the utilisation of trees within a farmed landscape in terms of soil processes, hydrological fluxes and flows, shading and nutrient export as well as assessment of woody biomass production, to allow researchers and land managers to target future research where it is needed. Project output will be designed to promote AFS as a viable approach to land use, agriculture and food production and as a modified alternative to conventional or traditional agricultural practices. The project stands as an interdisciplinary platform for transnational research, capacity building, information exchange, contributing knowledge and solutions for sustainable AFS management, while meeting stakeholder's needs at a grassroots level and promoting the implementation of AFS as an innovative, flexible and sustainable land use system under a changing climate.

The ASAP project is funded by the BMBF (German Federal Ministry of Education and Research) under grant number 01LL1803, as part of the SPACES II funding program.

Keywords: Agroforestry, Innovation, Interdisciplinary, Stakeholders, Sustainability.

L02.P.25

Agroforestry: Enhancing resiliency in Canadian agricultural landscapes under changing climatic conditions

Soolanayakanahally R. (Raju.Soolanayakanahally@canada.ca), Ward T., de Gooijer H.

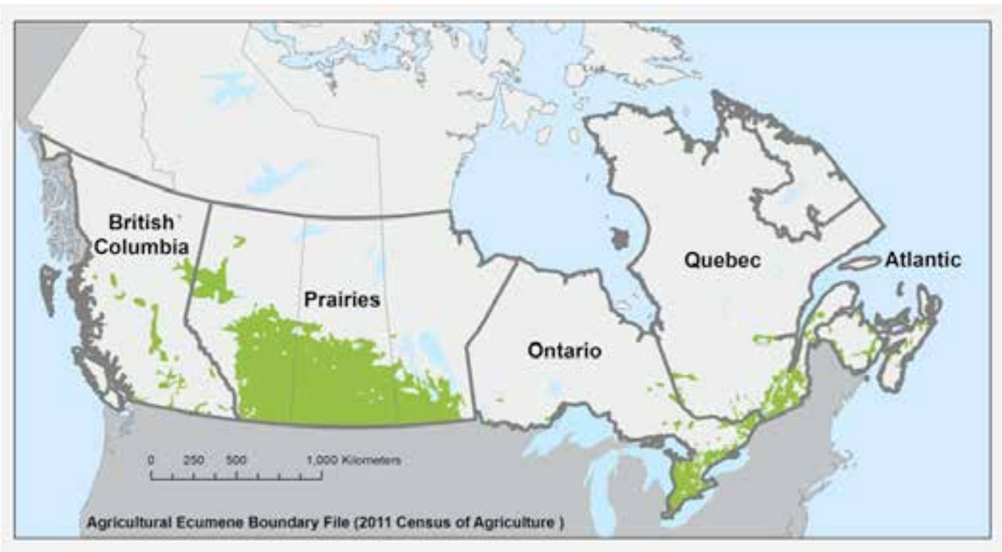
Agriculture & Agri-Food Canada, Indian Head, Saskatchewan, Canada

Canada has approximately 65 million hectares of productive agricultural land on which its food system is based primarily on a model of large-scale, industrial monoculture production of food and other agricultural products for consumers locally and internationally. Climate change and associated extreme weather variability is a challenge that is bringing urgency to concerns about the long-term sustainability of Canadian agriculture.

Agroforestry can play a critical adaptation role in existing agricultural areas to more extreme and variable weather events, increased pest infestations, and other climate-related stressors. Agroforestry can also have a significant effect in mitigating greenhouse gas emissions from agricultural activity if its implementation is increased.

Farmers and ranchers need land management alternatives that minimize risks of shifting climate and markets, while also trying to maximize ecological services. Increased use of temperate agroforestry practices with diverse species could play an important role in agro-ecosystems to increase the resiliency of Canadian agricultural lands and enhance food security. Climate, soils, and agricultural systems vary considerably across the farming and ranching areas in Canada, agroforestry solutions will be required to be region specific.

This poster will summarize the main conclusions from a recent report[1] on the potential role of agroforestry to enhance the resiliency of Canadian agricultural landscapes to climate change.



This map of Canada illustrates that most agricultural land is in the southern portion of the country (green areas).

Keywords: temperate agroforestry, carbon sequestration, Canada.

References:

1. Ward. T.; H. de Gooijer. 2017. USFS Gen Tech Report WO-96. Pages 101-112

L02.P.26

Integrated Risk Assessment in Gliricidia Based Farming Systems in Dryland Areas of Dodoma Region, Tanzania

Swamila M.[1] (M.Swamila@cgiar.org), Phillip D.[2], Akyoo A. M.[2], Kimaro A. A.[3], Sieber S.[4], Rosenstock T.[5]

[1] *Sokoine University of Agriculture; ICRAF, Dar es Salaam, Tanzania*; [2] *Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Morogoro, Tanzania*; [3] *ICRAF;ZALF, Dar es Salaam, Tanzania*; [4] *Sustainable Land Use, ZALF; Humboldt University, Müncheberg, Germany*; [5] *World Agroforestry Centre (ICRAF), Nairobi, Kenya*

Environmental and climatic risks are a major obstacles to sustainable agricultural productivity in most dryland areas of Sub Saharan Africa (Coulibaly et *al.,* 2015). As a way to deal with this problem, gliricidia agroforestry technologies were developed to address the stated risks in dryland areas of Dodoma region, Tanzania. However, the major question is to what extent have farmers used these trees to reduce risks and improve farm level productivity and profitability? Employing utility theory, this study was conducted to assess the roles of gliricidia intercropping in reducing risks and increase farm level profitability and to determine farmer's perception of risks. Moreover, monoculture and pigeon pea intercropping systems were assessed for comparisons. The study adopted a cross-sectional research design whereby data was collected from 83 smallholder agroforestry households in dryland areas of Kongwa and Chamwino districts using a pre-structured questionnaire: households involved were those that had maintained agroforestry plots for at least two years. A linear regression model was used to analyses farmers' attitude towards climatic risk and their perception towards agroforestry as a coping strategy towards these risks. In addition, the maximum likelihood technique was used to estimate probability distribution functions. Most farmers (96%) considered agro-forestry and intercropping (80%) systems to be less risky compared to monoculture systems. Probably, this is because these systems can provide a diversified production with a large variety of agricultural and forest products (Stainback et *al.,* 2012). Farmers practicing agroforestry are not likely to be affected by climatic change risks (i.e. drought, heavy rainfall and floods) compared to monoculture practitioners. This can be associated with their ability to act as buffer against increased climatic variability (Shibu, 2009). Findings further show that adoption of agroforestry technologies reduced the impact of climatic risks on crop productivity by 75%. Hence most (84.4%) of the agroforestry project beneficiaries intercrop *Gliricidia Sepium* with other crops for risk minimization and profit maximization. Study findings also show variation in farmers' attitude towards risk coping measures based on age and levels of individual household income. Age of individual farmer negatively influence farmers attitude towards risks in gliricidia farming systems ($p < 0.05$). This implies that, younger farmers have more positive attitude towards risks coping measures than older farmers. It is concluded that gliricidia intercropping has a great potential in addressing environmental and climatic risks thus, enabling farmers to cope with the associated risks. Therefore, it is recommended that there is need to promote agroforestry among other farmers as a farm risk management strategy against climatic and environmental risks and for enhanced crop productivity.

Keywords: Risk, Attitude, Dryland areas, Agroforestry, Utility theory.

References:

1. Coulibaly Y. J., Mango J., Swamila M., Kundhlande G., Tall A., Kaur H., Hansen, J., 2015. What Clim
2. Kimaro, A.A., Sileshi, G.W., Mpanda, M., Swai E., Kayeye, H., Nyoka, B.I., Majule, A.E., and Perfect
3. Shibu, Jose. Agroforestry for ecosystem services and environmental benefits: an overview Agroforestr
4. Stainback, Andrew et al. Smallholder agroforestry in Rwanda: A SWOT: AHP analysis. Small-scale Fores

L02.P.27

Productivity and use of arboreal and arborescent species in cocoa-trees agroforestry complexes (Centre of Cameroon)

Tchieudjo Nzukou C.[1] (christynzukou@outlook.com), Chekuimo G.[2]

[1] *Department of Geography, FALSH, The University of Yaounde I-UY I, Yaounde, Centre, Cameroon*;
[2] *Department of Forest Phytology, FFTW - MENDELU, Brno, South Moravia, Czechia*

Climate change is a global phenomenon posing new challenges in achieving food security and improving the livelihoods of the poor who are in the majority in developing countries. Climate change is likely to change the interactions between humans and forests in several important ways. Degradation of forests soils and related loss of soil carbon, as well as exogenous inputs in agriculture, also contribute to global climatic change.
Many plant species grow spontaneously in cocoa-trees agrosystems or can be deliberately introduced to provide many goods and services. This study was carried out in Nkolo-Bang and Ngat (in the Centre Region of Cameroon) with objective to assess the productivity and the use of the arboreal and arborescent species in cocoa-trees agroforestry complexes. We investigated how climate change and changed human use interacted and what these effects have had on these agroforestry systems.
We have identified other tree species present in cocoa-trees plantations, products and services rendered by these tree species; we also determined the seasons, frequencies and quantities produced annually; and finally determined the motivations of cocoa-trees farmers to associate these species with cocoa-trees, as well as the relative importance they attribute to different species. The Sorensen index gave a value of 0.55, indicating that there is a 55% probability of finding identical species in both zones. The motivations of the producers to associate the species are to: generate income, produce wood, increase the fertility of the soil and create shading, and especially to fight against climatic change.
Farmer's decisions regarding agroforests' management are crucial to fostering the desired balance between conservation and productivity, as it affects the vegetative composition.

Keywords: agroforest, cocoa-trees, productivity, food security, Cameroon.

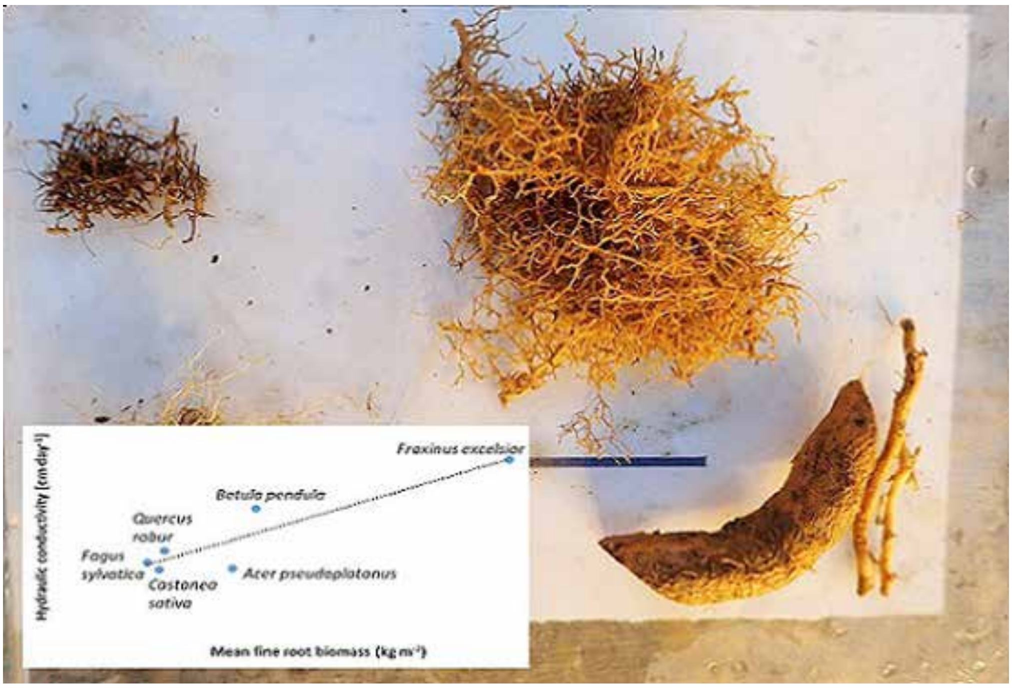
L02.P.28

Investigating the relationship between tree species and soil hydraulic condition: The importance of tree roots

Webb B.[1] (afp821@bangor.ac.uk), Ford H.[1], Pagella T.[1], Healey J.[1], Robinson D.[2], Smith A.[1]

[1] *Bangor University, Bangor, United Kingdom*; [2] *Centre for Ecology and Hydrology, Bangor, United Kingdom*

Incorporation of trees into farming systems to increase ecological complexity and sustainably intensify agricultural production has led to an upsurgence of natural flood risk management strategies. Here we examine how species-specific traits of trees influence soil hydraulic properties to quantify their potential role in flood mitigation. The relationship between tree roots and hydraulic conductivity (K) was determined for seven tree species (*Alnus glutinosa*, *Betula pendula*, *Fagus sylvatica*, *Fraxinus excelsior*, *Acer pseudoplatanus*, *Castanea sativa* and *Quercus robur*) planted in monoculture, and two species mixtures (*B. pendula – F. excelsior* and *C. sativa – B. pendula*), *n*=4. Root morphology and biomass were determined at 0-10 cm, 10-20 cm and 20-30 cm and correlated with soil hydraulic properties. Soil porosity was determined from water release curves using the HypropFit implementation of the Fredlund-Xing model[1]. Two distinct soil pore size classes were determined, and a higher abundance of large (~0.01 mm) radius pores found under *F. excelsior*. Fine root biomass of *F. excelsior* was two- to four-fold larger (P<0.01) than the other species studied. Consequently, dieback of *F. excelsior* across Europe due to the fungal pathogen *Hymenoscyphus fraxineus* could negatively affect landscape flood resilience. Strategic planting of trees with species-specific traits that maximise the hydrological benefits could improve the resilience of agricultural systems to extreme events.



Keywords: Tree species, Hydrology, Natural flood risk management, Fraxinus, Tree roots.

References:

1. Fredlund & Xing, 1994, Can. Geotech. J., 521-532, https://doi.org/10.1139/t94-061

L02.P.29

Agroforestry systems for protection & restoration of landscape functions endangered by climate change and human activity

Weger J.[1] (jan.weger@vukoz.cz), Houška J.[2], Vávrová K.[1], Lojka B.[3], Kotrba R.[4], Knápek J.[5], Dumbrovský M.[6], Malec M.[7], Bubeník J.[1], Jobbiková J.[1], Majewski R.[1]

[1] *Dept. of Phytoenergy, Silva Tarouca Research Institute, Průhonice, Czech Republic*; [2] *Dept. of Landscape Ecology, Silva Tarouca Research Institute, Průhonice, Czech Republic*; [3] *Dept. of Crop Sciences and Agroforestry, Czech University of Life Sciences, Praha, Czech Republic*; [4] *Dept. of Animal Sci. and Food Processing, Czech University of Life Sciences, Praha, Czech Republic*; [5] *Fac. of Electric. Engineering, Czech Technical University in Prague, Praha, Czech Republic*; [6] *Inst. of Landscape Water Management, Brno University of Technology, Brno, Czech Republic*; [7] *Geocart CZ Ltd., Brno, Czech Republic*

Czech cultural landscape and its components have changed significantly over the past decades as a result of climate change, but especially of new trends in farming. Among the main trends in "post-communist" period, one can cite intensification of agro-technologies and creation of very large fields and farms (average farm over 200 ha, by far the largest in EU) with the aim to be competitive within European and world agricultural markets. Unwanted result comprise a growing evidence of biodiversity loss (genetic, species and ecosystem/landscape), soil degradation, decrease of soil and ground water and more frequent disasters of cultural and semi-natural systems due to extreme climatic events or outbreaks of harmful organisms/agents in Czechia and also other European states. According to the results of the research in foreign countries, agroforest systems (**AFS**) in the area of temperate zones can significantly contribute to the prevention and solution of these risks and to increase the resilience of the landscape to the changing climate[1,2]. The results of the project will contribute to the extension of the knowledge about the possibilities of AFS in the Czech Republic and will provide the basis for selected adaptation measures of the Czech National Action Plan for Adaptation to Climate Change.

The main objective of this new project (2019-2022) is research and quantification of expected non-production (ecological, environmental) functions and benefits of traditional and modern agro-forestry systems for landscape, especially on soil protection, temperature and water regime at level of selected stands and landscapes, as well as a possible increase of biodiversity. An important goal is to obtain information on planting, growth and appropriate management of tree crops on farmland and their impact on agricultural production (growth, yield, livestock welfare). The aim is also to identify appropriate support of agro-forestry systems development in natural and property-economic conditions of the Czech Republic for protection and restoration of landscape functions endangered by impacts of climate change and human activities

Keywords: agroforestry, landscape, soil, climate, biodiversity.

References:

1. Burgess PJ, Rosati A. (2018): Agroforest Syst 92: 801-810. https://doi.org/10.1007/s10457-018-0
2. USDA Forest Service (2017): Gen. Tech. Report WO-96a - 228pp.

L02.P.30

The diminution of the effects of the lengthening of the dry season on the production of the robusta coffee

Yawo T. (ptefe@yahoo.fr), Techimondjro K.

ONG Avenir de L'environnement, Kpalimé, Région des Plateaux, Togo

The coffee-tree is a tropical plant culivatedin areas where the dry season doesn't exceed three months. While these last decades are markedin Togoby a clear climatic change.Thus this reduces the amount of market coffee and the export earnings of producing countries. This situation imposes search for measures aimed at reducing the effects of this climatic phenomenon. It is in this context that from 1995 to 2018, an association of four agroforestry legumes trial with robusta coffee cultivation was implemented in station. They are:*Albizzia adianthifolia, Samanea saman, Erythrophleumguineensis* and *Albizzia lebbeck*. The first results were published in 2001. The observations are from 2003 to 2018 in station on the diameter of the agroforestry speciesand the yield in commercial coffee*.* *Albizzia adianthifolia*and *Erythrophleumguineensis*are associated with two densities, 118 plants / ha and 59 plants / ha, in robusta coffee in a trial in 2000.The observations concerned the yield of commercial coffee. In resort in Tové, *Albizziaadianthifolia* has a recovery of 86 m2 at 5 years, 217, m2 at 10 years,226 m2 at 15 years, and 235m2 at 20 years.*Erythrophleum guineensis* in the following way: the speed of recovery on the ground is 44m2at 5 years, at 132 m2 at 9 years, at 175 m2 at 15 years and 216m2 at 20 years. *Samanea sa*man slowly grows the first year, after itgrows quickly the following three years. In Togo the horizontal development of this species expressed by the ground covers is 126 m2 at 5 years, 254 m2 at 9 years, it reaches 290 m2 at 15 years and 327 m2 at 20 years. *Albizzia lebbeck* covers the ground on 139 m2 at the age of 5, at 9 years it reaches 197 m^2. Marketable coffee yields under forest legumes are: *Albizzia adianthifolia* 851 kg/ha,*Samanea sa*man 1024 kg/ha,*Erythropheum guineensis* 1068 kg/ha,*Albizzia lebbeck* 1492kg/ha, NPK 1336 kg/ha, Control 986 kg/ha. In the peasant environment, under*Albizzia adianthifolia*shadow,the coffee-tree produces 563 kg/ha and under *Erythrophleum guineensis*shadow, the coffee-tree produces 527 kg/ha, NPK produces 281 kg/ha and Control produces 195 kg/ha.

Keywords: robusta coffee, lengthening, dry, season, agroforestry legume.

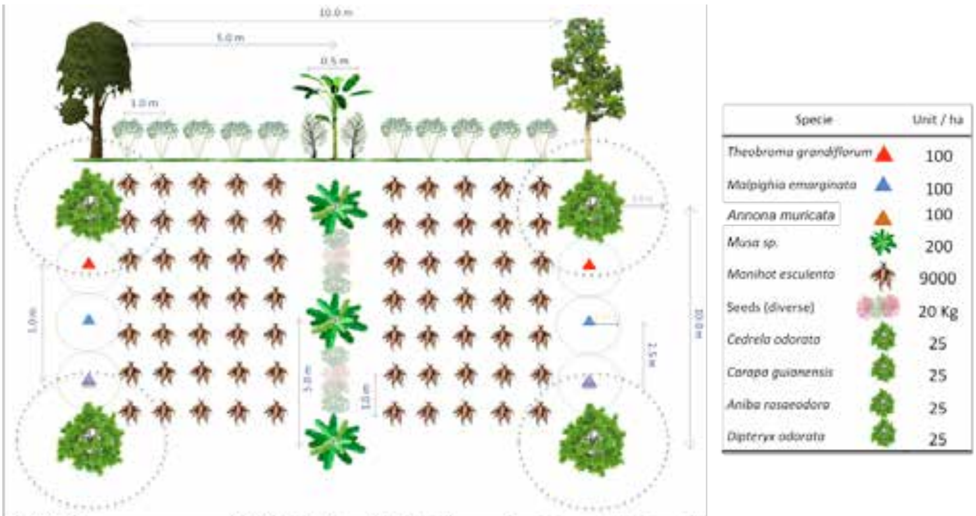
L02.P.31

Replicable and elastic regenerative agroforestry models as an alternative for slash and burn in Juruti, Brazilian Amazon

Ziantoni V. (ziantoni.valter@gmail.com), Costa P.

Agroforestry, PRETATERRA / WRI, São Paulo, SP, Brazil

Juruti (HDI[1] 0.592) relies on agro-extractivism and cassava slash-and-burn for subsistence. It's mandatory creating new agriculture regenerative models to thrive in climate change conditions. The study aimed to develop participative agroforestry designs; prototyping and implementing modular replicable units in a successional decision-making logic as an alternative for slash and burn. During 2 months (Jul-Sep, 2018) RRA[2], freelisting, participatory mapping, semi-structured interviews and pairwise sessions were conducted in 25 communities (157 farmers). Data were analyzed using selected principles, criteria and indicators. Adjustments were made merging local ecological knowledge, empirical information and scientific data. As a result it was co-created an elastic regenerative design, maximizing biomass production and inserting high-value fruit and NTFP[3] indigenous trees. Final model with explained arrangements; acronyms and units are shown in table 1. Based on literature and previous experiences within the zone the annual hectare expected production is: cassava 12 ton, fruits 24.4 ton, and dry biomass 3.53 ton. Based on farmers' preferences, at the 4th year system can migrate to (1) agrosilvipasture, (2) perennial fruit orchard or (3) biodiverse NTFP forest. Creating an elastic and highly acceptable agroforestry model for amazon cassava-based agriculture, will drastically improve food resilience and cash flow while building a new productive paradigm, sustainable and resilient.



List of acronyms used in the text: (1) HDI – Human Development Index; (2) RRA – Rapid Rural Appraisal Methodology and (3) NTFP – Non-timber Forest Products

Table 1. Close-up (1/10 of a hectare) of the vertical and orthogonal view of the proposed elastic and bottom-top based agroforestry design with timber/NTPF trees and fruit trees arrangement on top of a cassava field including biomass production stripe and plants per hectare and list of acronyms used in the text.

Keywords: slash and burn, cassava, agroforestry elastic model, amazon, climate change.

References:

1. Mazoyer et al. in: Histoire des agricultures du monde. Du néolithique à la crise contemporaine, 2002
2. Mikkelsen, in: Methods for Development Work and Research: A New Guide for Practitioners, 1995, SAGE
3. Aaron et al., 2011, Agroforest Syst, 81:1–14; DOI 10.1007/s10457-010-9356-1

ABSTRACTS

Agroforestry and world challenges

Agroforestry: riding to the world's rescue

- L3 -

Agroforestry for combating land degradation and desertification in dry areas

It's all about the 'how': regreen the drylands with agroforestry and grazing management

This session will focus on the role that agroforestry plays in enhancing soil restoration for combating land degradation and desertification in the dry regions of the world. Arid and semi-arid zones are characterized by low and erratic rainfall that does not exceed 700mm per year, and periodic droughts. Human-induced factors, especially overgrazing and other forms of inappropriate land use such as overexploitation of vegetation, excessive tillage and crop-residue removal, may result in significant degradation of land. Degraded land can be defined as land that has lost some degree of its natural productivity due to human-caused processes. Land degradation usually involves soil degradation, which refers to negative changes in the physical, chemical, and biological properties of the soil, as well as vegetation degradation. Land degradation also embraces negative changes in the capacity of ecosystems to provide social and environmental goods and services. At the landscape level, such a degradation can lead to negative microclimatic changes, thus facilitating desertification. Land degradation and desertification can have serious consequences for the livelihoods of rural communities by decreasing water supply and reducing food security, while increasing their vulnerability to biological and environmental hazards and to the effects of climate change. Many agroforestry technologies may help to restore land productivity.
For example, trees can stabilize the soil, especially when they are used in terracing and contour cultivation to combat soil erosion. They can also protect soils against wind erosion. Their branches can be pruned and applied as mulch to increase soil organic matter and nutrient status. Presentations of scientific findings on the performance of different agroforestry technologies in providing soil restoration and combating land degradation and desertification in dry regions, including social aspects and scaling-up, are welcomed.

L03_O.01

Investment in agroforestry systems as an integral component of tropical peatland restoration

Applegate G.[1] (gapples@usc.edu.au), Freeman B.[2], Jessup T.[3], Fideles J.[2]

[1] *University of the Sunshine Coast, Tropical Forests and People Research Ctr, Maroochydore, QLD, Australia*; [2] *Indufor Asia Pacific, Melbourne, Vic, Australia*; [3] *GGGI, Jakarta, Indonesia*

Tropical peatlands are being eroded on a large scale. Indonesia, which contains over 45% of the world's tropical peatland, large areas of peatland have been deforested and drained, contributing directly to peatland and peat fires, which in 2015 burnt 2.6 m ha and caused USD 16 bn in damage.Restoration of tropical peatlands based on full protection or cultivation has generally failed to address environmental requirements and local community needs. However, agroforestry provides an investment model for the integrated approach to peatland restoration that can secure conservation of deep peat areas while enabling the shallow peat to be used for limited economic activities. There is much literature on species suitable for agroforestry; but much less on financially viable business models for agroforestry systems for livelihood and sociocultural aspects of smallholders.
A set of agroforestry systems for Indonesia to attract investment by local communities and the private sector were assessed. Options were designed to balance short term cash flows with longer term profitability and economic benefit (Figure 1). Estimates of revenues for these systems cover a broad range, from below USD 500/ha/year low input systems (e.g. sago) to over USD 5,000/ha/year for small-scale models producing high value timber and oil products. Returns vary across countries and sites, but this study highlights the potential for mixed agro-forestry systems on peatlands to support local community livelihoods.

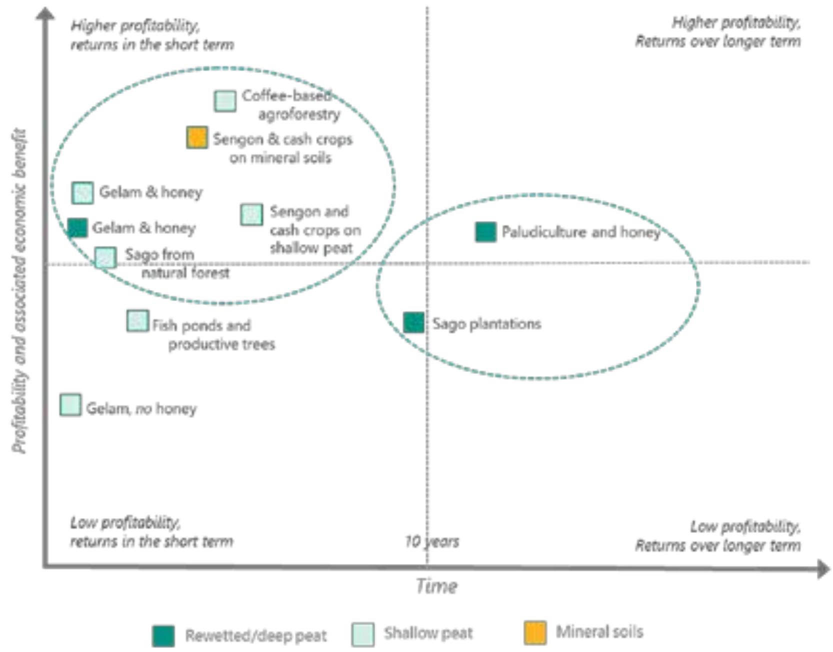


Figure 1 Comparative assessment of agroforestry models based on timeframe for profitability and associated benefits

Keywords: tropical peatlands, landscape restoration, agroforestry.

References:

1. Applegate, G., et al 2018, Internal GGGI Report, 60pp
2. Giesen, W. 2015, Journal of Indonesian Natural History, Vol. 3, No. 2.
3. Osaki, M. and Tsjui, N. (Editors) 2016,Tropical Peatland Ecosystems. Springer.
4. Sofiyuddin, M., Rahmanulloh, A., and Suyanto, S. 2012, Open Journal of Forestry Vol.2, No.4, pp. 252
5. World Agroforestry Centre 2016, Policy Brief: No 70

L03_O.02

Land use and management effects on vegetation characteristics and termite distribution in Malawian Miombo ecosystems

Nyirenda H.[1] (harrynyims@gmail.com), Assédé E. S. P.[2], Chirwa P.[3], Geldenhuys C.[3], Nsubuga F.[1]

[1] *Geography, University of Pretoria, Pretoria, Gauteng, South Africa*; [2] *Université de Parakou, Parakou, Benin*; [3] *Plant and Soil Sciences, University of Pretoria, Pretoria, Gauteng, South Africa*

Different land uses and/or agricultural interventions result in different vegetation structure and formation and macro-fauna distribution in a landscape. Information on land use condition is paramount for development of strategies that enhance biodiversity conservation and sustainable resource use. A study was conducted to characterise the vegetation and termite distribution in the three land use types: protected area (PA), harvested woodland (HW) and traditional agriculture (TA) in Salima District, Malawi. Data were collected from 42 plots on tree species, diameter at breast height, tree regeneration (measured as density ha-1), and termite species and abundance. The study found that there was significantly ($p < 0.05$) higher tree species diversity and stem density in the HW and TA than in the PA, supposedly, due to tree harvesting effect on tree regeneration in the HW and TA. The HW and TA showed stable tree population while PA was characterised with an ageing tree population. Tree regeneration density was also significantly higher ($p < 0.05$) in HW and TA fields than in the PA. *Macrotermes natalensis* termite species dominated in all land uses with highest density and abundance in TA while *Psammotermes allocerus* were only found in the HW. We conclude that strict preservation of forest reserves may not achieve tree diversity; and recommend a 'suite' of management measures to balance conservation and promotion of tree diversity. Integrated pest management approach is proposed to prevent field crop losses due to termites.

Keywords: tree density, vegetation structure, regeneration, Macrotermes natalensis, Malawi.

References:

1. Donovan et al. 2001, Ecol Entomol, 356-366
2. Jew et al. 2016, Forest Ecol Manag, 144-153
3. Muller, 2014, J Stat Softw, 1-34
4. Poovoli, Rajmohana, J Entomol Zool, Stud, 114-116
5. Shirima et al. 2011, Afr J Ecol, 332-342

L03_O.03

Agroforestry in Dryland: Supporting Farmer Initiatives for Rehabilitation of Degraded Arable Lands

Khan S. I. (si.rfanullah@gmail.com)

P&D Department, Sustainable Land Management Programme, Islamabad, Federal Capital, Pakistan

Drylands in southern Pakistan are home to communities living in poverty and depending on livestock rearing for their livelihood. The subsistence agriculture is losing its importance under the effects of climate change i.e. uncertain rainfall and very low productivity. To fill the livelihood gap, local communities are increasing their livestock herds. Thus pressure on silvo-pastures is increasing resulting in degradation of natural resources and loss of soil fertility, a fact that adversely affects the livelihood of communities.
The Farm Forestry Support Project of the Intercooperation (IC) and Swiss Agency for Development & Cooperation (SDC), initiated collaboration with local communities to pilot adaptive agroforestry measures in 2014 in extreme dry region of Karak. Major elements of these measures included the strengthening of the agro-silvo-pastures using hillside ditches and sand dune stabilization techniques. The objective was to harvest, conserve and use rain water for recovering fodder vegetation and increase productivity of the area with minimum cost and hence support livelihoods. The activity was carried out with participation of civil society organizations and farmers' associations.
The results recorded in 2018 showed a profuse plant growth in terms of trees, shrubs and fodder crops with a potential to provide timber, fuel wood and fodder for livestock. Maximum harvesting of rainwater and conservation of moisture also resulted in growth of natural grasses and shrubs. Within a short period of 5 years, plant growth in height and diameter of 6 meters and 20 centimeters respectively was recorded. The average vegetation cover increased from 23% to 45%, and increase in soil organic matter and nitrogen content was also recorded. All this happened with a cost of only US$ 82 per hectare. The rejuvenation of wells in few cases was an additional positive effect of the activity. On the other hand, an annual income of US$ 735 per hectare from *Saccharum spontaneum* planted in sand dunes was a real benefit to farmers compared to other land-uses in sand dunes.
The results of these pilot activities have provided options for adapting to severe and changing climatic patterns in the dryland ecosystem leading to providing a sustainable livelihood base. The involvement of pastoral communities is essential for sustainability of the system. Keeping in view the wide pattern of natural resource use (particularly the open grazing system in many arid countries of the region) it can be recommended to apply a landscape approach beyond the boundaries of a single community or land-ownership.

Keywords: Farmers, Fodder, Drylands, Growth, Trees.

References:

1. Anwar J,M. 2012, Pakistan Journal of Forestry, Vol 3, 224-236.
2. Subhash P, 2011, Nomadic People, 421-428.
3. Khan, S.I., 2011, Joint Forest Management, 112-123.
4. GoP, 2009, Development Statistics of Karak, 67
5. GoP, 2009, Agriculture Statistics of Pakistan, 105

L03_O.05

Agroforestry Systems for land restoration and food security in eastern Amazon

Celentano D. (danicelentano@yahoo.com.br), Rousseau G., Paixão L., Medina J., Gomez-Cardozo E.

Agroecology Graduate Program, UEMA, Sao Luis, MA, Brazil

Land degradation and rural poverty are strongly correlated in the Amazon region of Maranhão - the Brazilian state that registers the worst social indicators. Slash-and-burn agriculture is the main source of livelihood in small farms but also the main driver of land degradation. In this context, Agroforestry Systems (AFS) are an attractive alternative for land restoration, allying food security and ecosystem services reestablishment as carbon sequestration. We evaluated increment of above-ground carbon stock (trees, shrub, palms and herbaceous), plant (trees and shrub) richness and diversity (Shannon index) in AFS and compared with areas protected for natural regeneration (Control). Additionally we estimated food production in the AFS. Treatments were established in plots of 30 x 30m at six blocks in very degraded soils at the UEMA research farm in Sao Luis. In AFS, planted species included 16 tree species of local interest (for fruit, timber, N-fixing) in a density of 1,588 trees ha-1, and the agricultural species associated were corn (*Zea mays*), beans (*Canavalia ensiformis* and *Cajanus cajan*) and manioc (*Manihot esculenta*) -the main food resource in rural areas of the State. C stock and plant diversity were measured in 2018, 5 years after treatments establishment. C was also measured in 2012 prior to experiment setup (baseline), what allowed the calculation of C increment. Trees (DBH >10 cm) and palms biomass were measured in the entire 900m2 plots. Shrub (DBH 1-9.9 cm) was evaluated in three subplots (3 X 3 m2) per plot, and herbaceous vegetation was measured destructively in 1m2 quadrant per sub-plot. Tree survival and growth have been monitored each 4 months since planting, and due to accidental fire episode, tree mortality was 69.6% (±22.1) in the first year and plots were replanted in the second year. After 5 years, aboveground C increment (Mg ha-1) was higher in AFS (27.84 ± 22.82) than in the control (5.7 ± 6.2), because of tree and shrub cover. Indeed, abundance (ind.ha-1) of trees (144.44 ±142.12) and shrub (3,703.7 ± 2,761.68) in AFS was much higher than in control (Trees: 7.41 ±11.48; shrub: 2,962,96 ± 4,891,13). In AFS, plant richness (8.50 ±2.88) and diversity (1.88 ±0.35) was higher than in control (Richness: 3.83 ±2.14; Diversity: 1.03 ±0.56), as a result of planting efforts. In 2016, crop production in AFS was: *Z.mays* (3,000 cobs ha-1±961.9), *C.ensiformis* (198.1 kg ha-1 ±80.4); *C.cajan* (13.9 kg ha-1 ±19.9); *M.esculenta* (2,025.9 kg ha-1 ±1,240.9). Even though it represents a low productivity as compared to conventional systems, it was higher than expected for degraded soils. Fruits trees of the AFS are not producing yet. In deprived communities, forest restoration must be a process that combines environmental and social gains. Our preliminary results suggest that AFS can be a strategy to restore carbon stock through a diverse tree cover reducing costs through the engagement of communities and food production.

Keywords: Amazon, AFS, restoration.

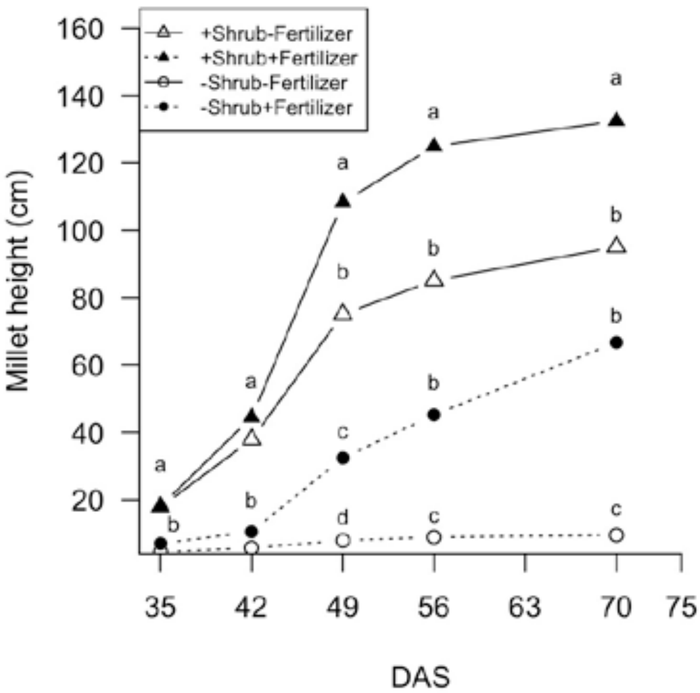
L03_O.06

Association with *Guiera senegalensis* speeds up crop development in a Sahelian agroforestry system

Bayala R.[1] (roger.bayala@gmail.com), Diedhiou I.[1], Bogie N.[2], Bright M.[3], Ndour Badiane Y.[4], Ghezzehei T. A.[2], Dick R.[3]

[1] *Productions Vegetales, École Nationale Supèrieur d'Agriculture, Thies, Senegal*; [2] *Life and Environmental Sciences, UC Merced, Merced, CA, USA*; [3] *School of Environment and Natural Resour, Ohio State University, Columbus, OH, USA*; [4] *Institut Sénégalais de Recherche Agricol, Dakar, Senegal*

Intercropping with the native woody shrub *Guiera senegalensis* J.F. Gmel, can improve soil-plant-water relations, nutrient availability, and crop yields. However its effect on crop development throughout the course of the growing season in the Sahel has not been demonstrated. This study conducted from 2013 to 2016, focuses on phenology and growth of crops in the presence or absence of shrubs under varying rates of fertilizer. Appearance of the major developmental phases was determined and the number of leaves and height of the main stem of peanut and millet were measured weekly. The experimental design was in a split-plot factorial design. The presence or absence of *G. senegalensis* was the main plot and fertilizer rate (0, 0.5, 1 or 1.5 times the recommended N-P-K rate) was the subplot factor. The flowering period of crops in presence of shrubs is 7 to 18 days earlier than no shrub plots for all years, regardless of rainfall distribution, which varied significantly including, periods of drought stress during critical developmental phases. Crop growth was also improved by shrubs. The number of crop leaves (26 to 45%), stems (42-81%) and plant height (2-4 times more) in shrub plots were significantly higher than no shrub plots. This shows that the presence of shrubs allows associated crops to grow larger and mature faster, which can allow crops to persist through early as well as late-season periods of moisture shortage in the uncertain rainfall regime of the Sahel.



Millet growth in the 2013 season in presence and absence of shrubs and added fertilizer. Different letters next to points on the same date indicate significant differences ($P<0.05$)

Keywords: pearl millet, groundnut, native woody shrubs, Sahel.

L03_O.07

Measuring changes in soil health under agroforestry

Shepherd K. (k.shepherd@cgiar.org), Sila A., Towett E., Weullow E.

Land Health Decisions, World Agroforestry Centre (ICRAF), Nairobi, Kenya

Agroforestry can play a role in enhancing soil restoration for combating land degradation and desertification in the dry regions of the world. Soils in dry areas are often fragile, of low potential and susceptible to degradation. Small changes in soil organic matter can have large impacts on soil functional capacities, such as erodibility, infiltration, water storage capacity and nutrient retention and supply capacity. Although remote sensing may provide information on regional trends in soil degradation, ground-based measurements are required to detect impacts of agroforestry interventions as well as to validate regional trends. However measuring soil health attributes using conventional methods is slow, expensive, and methods lack standardization resulting in poor reproducibility. Infrared spectroscopy can provide a robust, low cost, integrated indicator of soil functional capacity. Relationships between soil functional properties and soil spectra are illustrated in agroforestry trials from Africa. A spectral index of soil organic carbon levels is demonstrated that gauges soil carbon status relative to upper limits under good management and lower limits under poor management for given textural classes. Critical limits of soil organic carbon index are shown where non-linear changes in erodibility occur for a wide range of Africa soils. Low cost handheld infrared instruments are evaluated relative to benchtop lab instruments for measuring soil health changes.

Loss of soil function when soil organic carbon levels become depleted below critical limits

Keywords: Soil carbon, Soil health, Infrared spectroscopy, soil monitoring, drylands.

L03_O.08

Shelterbelts for crop protection as the main type of agroforestry system in Romania

Mihăilă E.[1] (lilianmihaila@yahoo.co.uk), Costăchescu C.[1], Dănescu F.[2], Popovici L.[3]

[1] *Silvotehnics, INCDS "Marin Dracea", Voluntari, Romania*; [2] *Forest ecology, INCDS "Marin Dracea", Voluntari, Romania*; [3] *Silvotehnics, INCDS "Marin Dracea", Focșani, Romania*

Introduction
Romania has no legislation that specifically refers to agroforestry systems but indirectly supports the realization of forest shelterbelts, through Submeasure 8.1 of the National Rural Development Program. Thus, the Forest Research Institute realised projects of forest shelterbelts for the southern area of the country which are the most affected by climate changes.
Material and methods
The design of shelterbelts was done using GIS techniques, current rectified aerial images and detailed pedological maps. Over the successive layers of diverse information (geographical, hydrographical, pedological, administrative etc.) the network of shelterbelts was placed. The GIS database has been completed.
Results and discussion
The network of forest shelterbelts was designed for each commune in the 12 counties from the southern area of the country (Figure 1). The main goals are to mitigate climate imbalances, avoid agricultural production losses and increase the area occupied with forest vegetation that is below 8%. We have selected a wide range of species like oak species (mainly pubescent oak), elm, ash, maple, wild pear and shrubs. The number of seedlings was also established.
Conclusion
The percentage of occupation of the agricultural land with shelterbelts is 2 % which could improve the microclimatic conditions and the crop production. The variation of ecological site factors in each county means different afforestation compositions, thus shelterbelts increase biodiversity.

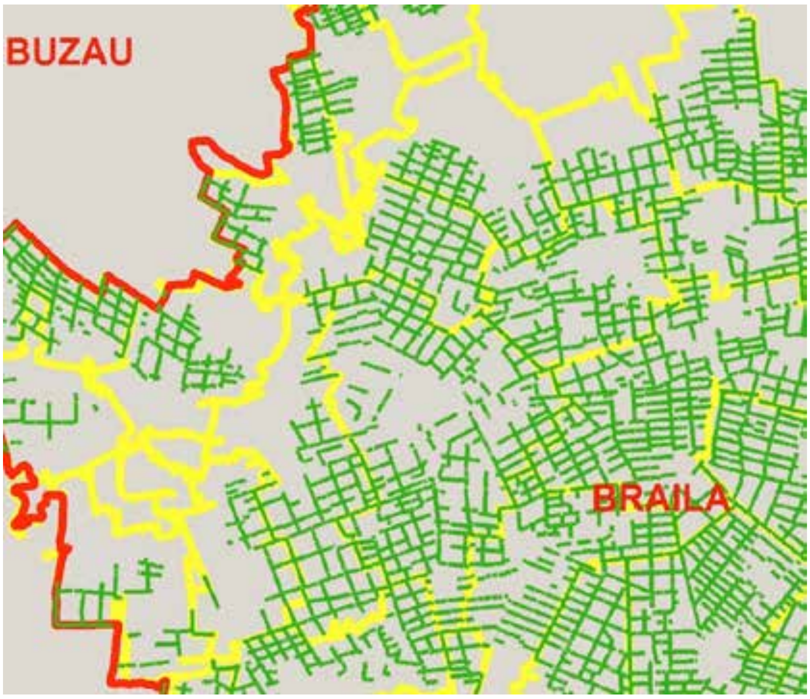


Figure 1: The network of forest shelterbelts in Braila County (shelterbelts - green line, boundary of county - red line, boundary of commune - yellow line)

Keywords: agroforestry systems, forest shelterbelts, climate changes, protection.

L03_O.09

Valorisation of salty soils by using phosphogypsum and peanut shell on growth of 3 forest trees under salt conditions

Ba O. (ousseynouba205@gmail.com)

Dakar, Common Microbiolgical Laboratory/IRD, Dakar, Senegal

In Senegal, 1 700 000 ha of the 3 800 000 ha of arable land are affected by salinity. This causes a degradation of the biological, chemical and physical properties of the soils causing a decrease in their fertility and the disappearance of the natural vegetation cover. Thus, the restoration of these salted lands is a concern especially in the context of climate change. The improvement of the properties of salt soils and the tolerance to salinity of plants, would facilitate this restoration. The overall objective of this work is to contribute to the restoration and valorisation of saline soils by agro-biological methods. Specifically, our work is to compare the effects of phosphogypsum and peanut shell on the growth, physiological and symbiotic parameters of multiple forest species such as *Senegalia senegal*, *Vachellia seyal* and *Prosopis juliflora* under saline conditions. The plants were grown in greenhouses in sheaths containing Sadioga unsalted soil (Fatick region) under four salinity levels (0, 5, 10 and 15 g / l). Four amendments (control, peanut shell var 77-33 6 t / ha, phosphogypsum 3t / ha and peanut shell 3t / ha combined with phosphogypsum 0.5 t / ha) were tested. Our results showed a significant positive effect of the amendments on height, collar diameter, leaf number, aerial, root and total biomass of *S. senegal, V. seyal* and *P. juliflora* plants grown under salt conditions. Our results also showed a positive effect of the amendments on chlorophyll and proline levels of *S. senegal, V. seyal* and *P. juliflora* plants grown under salt conditions. Peanut shell, phosphogypsum or their combination improves mycorrhization and nodulation of *S. senegal, V. seyal* and *P. juliflora* plants grown under saline conditions. The best rates of mycorrhization were obtained in most cases with the combination of peanut shells (3 t / ha) and phosphogypsum (0.5 t / ha). On the other hand, the lower rates of mycorrhization were noted in plants amended with peanut shells. The peanut shell was better than the phosphogypsum on the growth of the species used. These results will enable us to participate in the restoration of salt soils in Senegal. However, field trials over several years would be necessary to confirm our results.

Keywords: Peanut shell, Nacl, Restoration, S.senegal, P.juliflora.

References:

1. Fall. D (2016) Journal of Agricultural Biotechnology and Sustainable Development Vol.9(5), pp. 36-44
2. Jabnoune. M (2008) Adaptation des plantes au stress salin MontpellierII 289p

L03_O.10

Afforestation and agricultural production through salt-affected soil amelioration with coal bio-briquette ash in China

Sakai Y.[1] (sakai@cc.kogakuin.ac.jp), Nakamura M.[1], Murata H.[1], Ebato C.[1], Wang C.[2]

[1] *Dept. Environ. Chemisty and Chem. Eng., Kogakuin University, Tokyo, Japan*; [2] *Dept. Environ. Sci. & Technology, Tianjin Univ. of Science & Technology, Tianjin, China*

The decrease in agricultural production due to excessive salts is a very serious problem in China. Salt-affected soil is mainly distributed in the northeast and northern parts of China, and the alkalization of soils has progressed rapidly in many areas. In addition, because SO2 emissions have increased remarkably during the last decade following the dramatic growth of the economy and energy use, the desulfurization equipment has been installed in large plants such as coal-fired power plants. However, the indoor pollution due to the combustion of the low-rank coal containing high percentages of sulfur and ash in rural area is crucial problem, and there are many instances about health damages. In addition, China faces the strong pressure to decrease CO2 emission by reducing fossil fuel consumption and examine the renewable energy sources such as biomass energy. So we have examined the amelioration of salt-affected soil with desulfurization by-products since 1996, and revealed the benefits of soil amelioration and afforestation in China. In this paper, we report the changes in agricultural production, soil chemical properties and soil carbon in coal bio-briquette ash (BBA) application. After that, we estimate the changes in carbon stock due to afforestation in Liaoning province.

Salt-affected soil amelioration tests with coal BBAs were performed in 2008 at Kangping in Liaoning province. Two types of bio-briquette were made from low-quality coal (sulfur content = 2.1 % and 4.1 %), corn stem as biomass, and calcium hydroxide as desulfurizer. These BBAs were added to four experimental plots of salt-affected soil at the application rate of 0wt%, 0.5wt%, 1.0wt%, 2.0wt% and 3.0wt% (6.96 kg/m2) in three replications. Their soil amendments were incorporated into the plow layer of the soil by mixing with a scoop, and were added to all plots at the same time as the seeding in the first year. Moreover, an ammoniacal fertilizer was added to all plots and a pig manure as the organic fertilizer was added to two experimental plots at the application rate of 3.0 kg/m2. In addition, BBA was used as soil amendment for tree (*Populus canadensis cv. Zhelin*) planting in the northern part of Liaoning and simulated the effect of carbon sequestration due to the utilization of BBA for tree planting. Consequently, the corn production increased with the increase of the application rate at all test plots. BBA containing higher sulfur indicated better effect on corn production. And the pH, ESP, Na, CO3 and HCO3 concentration of soil solution decreased with the increase in BBA. Moreover, the increase in soil carbon at the application rate of 3.0wt% could be confirmed. Lastly, the increase in the carbon stock in tree biomass and soil in Liaoning and Tianjin due to afforestation with BBA could be calculated. Therefore, the increase in carbon stock due to salt-affected soil amelioration with BBA indicated the possibility as carbon sequestration technology in China.

Keywords: afforestation, carbon stock, coal bio-briquette, salt-affected soil, soil amelioration.

References:

1. Yuji Sakai et al., 2015, Journal of Chemical Engineering of Japan, 48(6), 491-497, 2015
2. Yuji Sakai et al., Journal of Arid Land Studies, 25(3), 93-96, 2015

L03.P.01

Multipurpose benefits of Acacia saligna in drylands of northern Ethiopia

Birhane E.[1] (emiru.birhane@gmail.com), Hagazi N.[2], Mezgebe K.[3], Cunningham P.[4], Resom M.[3], Gebrewahid Y.[3], Darcha G.[3], Brhan A.[1], Bongers F.[5], Gessesse A.[6], Mariame A.[7], Kelly R.[4]

[1] *Mekelle University, Mekelle, Ethiopia*; [2] *World Agroforestry Centre, Addis Ababa, Ethiopia*; [3] *Tigray Agriculture Research Institute, Mekelle, Ethiopia*; [4] *World Vision Australia, Melbourne, Australia*; [5] *Wageningen University, Wageningen, Netherlands*; [6] *World Vision Ethiopia, Mekelle, Ethiopia*; [7] *World Vision Ethiopia, Addis Ababa, Ethiopia*

Land degradation is an important problem in Ethiopia, largely driven by the high removal of vegetative cover through clearing, cutting or overgrazing. Population pressures are increasingly forcing farmers to cultivate more and more marginal lands. This situation is particularly evident in the drylands of northern Ethiopia where the problems are exacerbated by increasingly erratic and decreasing rainfall. Consequently, rural communities can especially experience poverty and malnutrition. Multipurpose trees integrated into the farming system are options for both mitigating land degradation and can significantly contribute to the livelihood of small-scale farmers. Our six years of research support the view that *Acacia saligna* is a valuable multipurpose tree for the mid-elevation highlands of northern Ethiopia that can support livelihoods of rural communities and address the need to rehabilitate degraded areas. *Acacia saligna* supports livelihoods through the provision of feed, wood and fodder. Trees can readily integrate into existing systems as farm or plot borders, woodlots or as homestead shrubs. Pruning trees to 1.8-2.3 m height is most suitable when trees are being actively browsed by goats. Trees can be pruned early to mid-dry season (January to May) to address potential ruminant feed gaps. Seeds may be collected in December and May; seed meal fed as a supplement to laying hens can be used to improve egg production. Test results suggest the wood quality is similar to the standard required for manufacture of medium density particleboard, offering income-generation for smallholders. An alley cropping trial showed that the overall production – wheat yield, fodder, fuelwood – from *Acacia saligna* hedgerows pruned to 1.8 m height alongside wheat was more productive than wheat alone. Multi-year provenance resource stands have been established to select improved types of *Acacia saligna* for pole and multi-purpose use so that farmers will have eco-types to suit their requirements for feed, fuel and fodder. Acacia saligna successfully colonizes degraded slopes and gullies, providing shade and protection for native herbs, grasses and shrubs. Pruning of trees in exclosure areas provides farmers with supplementary fuelwood and fodder. There is potential for selective pruning and coppicing of these trees. Ongoing work in Tigray will focus on the development and release of improved germplasm to assist communities wanting to restore degraded land or farmers who can see an opportunity to make use of *Acacia saligna* to support their livelihoods.

Keywords: Acacia, Multipurpose, Livelihoods, Management.

L03.P.02

Carbon sequestration potential of the *A. senegal* agroforestry along distance gradient from human settlement in Ethiopia

Birhane E.[1] (emiru.birhane@mu.edu.et), Gebreslassie H. G.[1], Giday K.[1], Teweldebirhan S.[1], Hadgu K.[2]

[1] *Land resource managment, Mekelle University, Mekelle, Tigray, Ethiopia*; [2] *World agroforestry center, Addis Ababa, Ethiopia*

In Ethiopia, dry land agroforestry including the fairly intact lowland western escarpment woodlands are the largest parkland resource of the country. These resources play a central role in environmental regulation and socio-economic assets, yet they received less scientific attention than the moist agroforestry systems. This study evaluated the woody plant species composition, population structure and carbon sequestration potential of the *A. senegal* parkland across three distance gradients from human settlements. A total of 45 sample quadrants were laid along nine systematically established parallel transect lines to collect vegetation and soil data across distance gradients from settlement. Mature tree dry biomass with diameter at breast height (DBH) >2.5cm was estimated using allometric equations. A total of 41 woody plant species that belong to 20 families were recorded and *A. senegal* was the dominant species with 56.4 imprtance value index. Woody plant species diversity, density and richness were significantly higher in the distant plots compared to the nearest plots to settlements ($P<0.05$). The cumulative DBH class distribution of all individuals had showed an interrupted inverted J-shape population pattern. There were 19 species without seedlings, 15 species without saplings and 14 species without neither seedlings nor saplings. A significant increment in above ground carbon (5.3 to 12.7 ton ha-1), root carbon (1.6 to 3.6 ton ha-1), soil organic carbon (35.6 to 44.5 ton ha-1), total carbon stock (42.5 to 60.7 ton ha-1) and total carbon dioxide equivalent (157.7 to 222.8 ton ha-1) was observed consistently with an increasing distance from settlement ($P<0.05$). Species diversity (0.64**) and carbon stock (0.78**) proved settlement is the causal factor for the variation of species composition, richness and density along the *A. senegal* parkland. Woody plant species composition, population structure and carbon sequestration potential of the *A. senegal* parkland were positively affected by an increasing distance from settlement. Management interventions that limit disturbance should be encouraged to enhance the sustainability of dryland parkland agroforestry systems.

Keywords: A. senegal, Regeneration, Carbon stock, Biomass, Disturbance.

References:

1. Alam, A., Star, M. and Clark, B., 2013. Journal of Arid Environments, 89: 67-76.
2. Daryanto, S., Eldridge, J. and Throop, L., 2013. Agriculture, Ecosystems and Environment, 169: 1– 11
3. Casey, M., Mathew, W. and John, G., 2010. Bio tropical, 1(1): 1-10.
4. Eshete, A., Frank, S. and Frans, B., 2011.Forest Ecology and Management, 261: 1499–1509
5. Zhang, Y., Duan, B., Xian, J., Korpelainen, H. and Li, C., 2011. Forest Ecology and Management, 262:

L03.P.03

Faidherbia parklands under threat in South-West Niger

Boubacar A. K.[1] (kanfobon@yahoo.fr), Gafsi M.[2], Sibelet N.[3], Toudou A.[4], Montagne P.[5], Gazull L.[5], Peltier R.[5]

[1] *Direction générale des Eaux et Forêts, Ministère de l'Environnement, Niamey, Niger*; [2] *UMR LISST-Dynamiques Rurales, Université de Toulouse Jean Jaurès, Toulouse, Occitanie, France*; [3] *UMR INNOVATION, INRA-Supagro-Cir, CIRAD, Université de Montpellier, 34398 Montpellier, Occitanie, France*; [4] *Faculté d'Agronomie, Université Abdou Moumouni, Niamey, Niger*; [5] *UPR Forêts et Sociétés, CIRAD, Université de Montpellier, 34398 Montpellier, Occitanie, France*

Many authors have emphasized the importance *of Faidherbia albida* Parklands (FaP) in Niger, and have described their restoration by Assisted Natural Regeneration (ANR) (Montagne et al, 1996; Larwanou et al, 2010). A study was conducted in 2018 to check the parklands biodiv. status in the Niamey region. In 3 villages, a FaP area of 15,000 ha was mapped and an inventory was carried out on 75 plots of 1 ha. A survey was conducted to assess the importance of wood in household consumption. Results show that: FaP are poor in trees diversity (24 sp.), natural regeneration has even fewer species (21 sp.), tree density is low (5-8 / ha), trees with a diameter greater than 40 cm and less than 20 cm are rare (Fig 1) and many old trees are dead (4-8% of all trees in 2 villages) (Boubacar et al, 2017). In 2 villages, wood has become so scarce that people must use palm leaves or straw for domestic energy. It is therefore estimated that the efforts to restore the FaP by ANR either were not continued over the past 20 years or were ineffective.

Further studies are urgently needed to understand the ecological and socio-economic determinants of the degradation of this AFS that is vital for the populations. A large-scale policy then must be launched to support the restoration of trees in the landscapes, one that probably should include training, the shared and secure management of territories, and subsidies for community forest management and the restoration of parks by ANR and plantations.

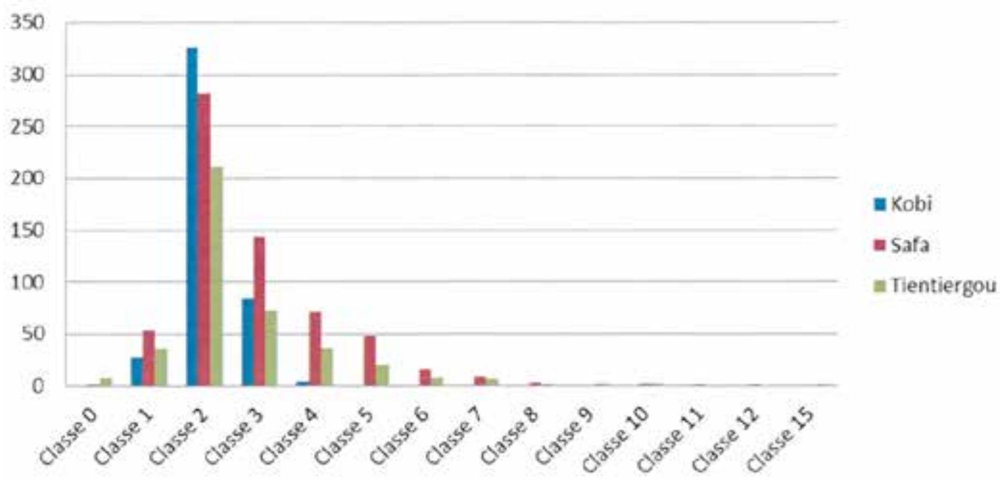


Figure 1: Distribution of trees (Y axis: number of individuals) by diameter class (Class 0 = 0 to 9 cm, class 1 = 10 to 19 cm, etc.) and village, over 75 ha.

Keywords: Sahel, Agroforestry systems, Acacia albida, Degradation, Restoration.

References:

1. Montagne et al, 1996. In: Les parcs à Faidherbia, Cahiers scientifiques du CTFT, 12: 283-296.
2. Larwanou et al, 2010. Tropicultura 24(1): 14-18.
3. Boubacar et al, 2018. Actes du Col. inter. sur la gestion des ress. forestières au Niger, Niamey.

L03.P.04

Berberis microphylla: **a component to protect regeneration of *Nothofagus antarctica* in silvopastoral systems, Argentina**

Bustamante G.[1] (gime.nb@hotmail.com), Arena M.[2], Blazina P.[1], Soler R.[1]

[1] *CADIC, CONICET, Ushuaia, Tierra del Fuego, Argentina*; [2] *Universidad de Morón, CONICET, Buenos Aires, Buenos Aires, Argentina*

Cumulative effects of several anthropic disturbances in native forest makes the regeneration of woody species more difficult. In silvopastoral systems where the impact of herbivory is constant, protective species play a fundamental role to ensure tree seedlings establishment. In Tierra del Fuego, *Nothofagus antarctica* (ñire) forests were intervened to maximize livestock, but some sectors were burned and overgrazed resulting in a degradation hardly reversible. In these sites, the spiny shrub *Berberis microphylla* (calafate) grows naturally and vigorously after fire, being less palatable for livestock. The objective of this study was to evaluate the possible nursing effect of calafate shrubs on ñire seedlings in silvopastoral systems of Tierra del Fuego, Argentina. We established a manipulative assay by planting ñire seedlings (2-3 years) under and out of the crown influence of calafate shrubs during spring 2017. After 3 months, we analysed seedling survival and growth: diameter (DAC), height (H), leaf number (LN), leaf size (LL, LW). In addition, in eight different sites we compared isolated advanced regeneration (trees <2m height) and trees growing in association with calafate shrubs by measuring tree height (HA), shrub height (HC) and browse intensity. The manipulative assay showed that 50% of ñire seedlings survived regardless of the location (under/out of shrub crown). DAC of seedlings under shrubs was smaller (0.32mm, $p=0.023$) and with higher H (2.46cm, $p<0.001$) than out of shrub crown (DAC: 0.34mm, H: 2.18cm). Seedlings under shrubs had fewer leaves (LN=2.57, $p=0.005$) but larger (LL=5.20mm, LW=4.72mm, $p<0.001$) than out of shrub crown (LN: 2.87, LL: 4.63, LW: 4.28). Tree-shrub association in comparison to isolated advanced regeneration showed that the browse height was higher (52.2±23.9 cm) and of lower intensity (1.8±3.0 cm) when trees were associated with shrubs compared to isolated trees (34.3±16.8 cm and 2.2±2.0 cm, respectively). In addition, ñire trees had higher height in association with shrubs (101.2±54.1 cm) than ñire alone (75.1±39.7 cm). In addition, browsing height was positively correlated to shrub height ($R^2 = 0.61$, $p<0.001$). Although morphological variables show evidence of some competition for light it is evident that ñire manages to develop under the shrub. It is expected that over time protected plants by shrubs achieve greater survival than those exposed to livestock. Our results also provide evidence of the protective role of calafate shrub: although it does not escape browsing damage, it acts as a deterrent to protect advanced regeneration of ñire. Furthermore, seedling plantation under shrub is applicable to possible restoration actions of degraded forest areas.

Keywords: browsing, forest, Tierra del Fuego, Plant association, shrubs.

L03.P.06

Local perceptions of and priorities for land restoration in northwest Ethiopia

Crossland M.[1] (afp43d@bangor.ac.uk), Winowiecki L. A.[2], Pagella T.[1], Hadgu K.[3], Sinclair F.[2]

[1] *School of Natural Sciences, Bangor University, Bangor, UK*; [2] *World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [3] *World Agroforestry Centre (ICRAF), Addis Ababa, Ethiopia*

Clashes between national level priorities for land restoration and those held by local actors may hinder the uptake of restoration actions at local scales. Yet, priority mapping for restoration rarely incorporates the knowledge or perspectives of multiple stakeholders, especially those of local land users, resulting in a lack of information regarding their preferences and priorities. Combining participatory mapping, farmer interviews and a field survey of soil erosion prevalence, we explore local perceptions of land degradation and restoration activities in the Gilgal-Abay watershed located in the Amhara National Regional State of Ethiopia. The watershed has experienced extensive land degradation in the form of soil erosion and soil nutrient depletion, largely attributed to the over-exploitation of communal resources and conversion of marginal land. Over the past decade, local communities have invested heavily in restoration efforts, including the establishment of area exclosures – an agroforestry-based intervention that promotes the regeneration of natural forest vegetation through the exclusion of livestock. Our study reveals discontinuity between current scientific perspectives and local values regarding when and where to act. While research has frequently shown that the prevention of land degradation is more cost-effective than its reversal, land users prioritised the areas they considered the most degraded for exclosure, despite being aware that once severely degraded land may become increasingly difficult to recover. This was because of the perceived opportunity costs associated with the establishment of exclosures on land that still maintained some productive potential, albeit very low. Perceptions of degradation and priority areas for restoration efforts were also found to vary with gender and that substantial disagreement between farmers existed over the establishment of exclosures on communal grazing lands. Two key factors were reported to influence farmers acceptability of exclosures: (i) farm size, and (ii) number of livestock. Farmers with many livestock or little or no land relied heavily on communal grazing and were strongly opposed to the establishment of exclosures. In contrast, farmers with sufficient farmland and fewer animals were able to designate an area of land for private grazing.

Such findings demonstrate that land users may not share the same priorities, in terms of where, when and how to address degradation, as one another, or with other actors involved in restoration initiatives (e.g. researchers, government staff, and local planners) which implies a need for negotiation, and that the impact of restoration actions such as exclosures are likely to be socially differentiated. This makes it important to understand how livelihoods interact with different restoration interventions and to take measures to ensure that restoration efforts do not disadvantage the most vulnerable people.

Keywords: Land restoration, Priorities, Exclosure, Local perceptions.

L03.P.07

Characterization of two agroforestry species lignins and the effects of ramial chipped wood on crop yields in Benin

Daassi R.[1] (rodrigue.daassi.1@ulaval.ca), Stevanovic T.[1], Khasa D. P.[2]

[1] *Renewable Materials Research Centre, Laval University, Quebec, Quebec, Canada*; [2] *Department of Wood and Forest Sciences, Laval University, Quebec, Quebec, Canada*

Lignins are the most abundant aromatic polymers on Earth's ecosystem which play a major role in the humus formation. The aim of the present study is to characterize ramial chipped wood (RCW) lignin of two candidate agroforestry species, *Gmelina arborea* Roxb. ex Sm. and *Sarcocephalus latifolius* (Smith) and to evaluate RCW amendments on crop yields and soil quality. RCW composite samples of each species were performed, and their lignins were isolated through organosolv process (Koumba & Stevanovic, 2016). The mineral compositions (ICP-AES) and chemical constituents (Klason and acid soluble lignin, sugars, ash) of the RCW including organosolv lignin isolation, were determined using standard methods developed in our laboratory. Structural characterizations of these lignins were performed using Fourier-transform infrared (FT-IR) analysis. The results showed that RCW of *S. latifolius* exhibited both higher mineral compositions (g.kg-1 N: 6.14, mg.kg-1 P: 1034.45, g.kg-1 K: 8839.23, g.kg-1 Ca: 7110.85, g.kg-1 Mg: 3391.16) and chemical compositions (% lignin: 35.03 ± 1.05, % sugars: 46.97 ± 0.81, % ash: 6.52 ± 0.13) than those of *G. arborea* (g.kg-1 N: 4.97, mg.kg-1 P: 537.22, g.kg-1 K: 5199.09, g.kg-1 Ca: 6072.23, g.kg-1 Mg: 2150.90) and (% lignin: 24.6 ± 0.24, % sugars: 60.50 ± 1.37, % ash: 3.26 ± 0.06). On the other hand, the result of FT-IR analysis demonstrated the structural similarities between RCW lignin of the two species whereas their average molecular mass (Mw) were determined to be 3849 g/mol and 1778 g/mol, respectively. Other studies are in progress to elucidate main contrasting characteristics of RCW lignins of these two species to be selected as agroforestry species and their effect in tomato yields (Barthes et al., 2015; Félix et al., 2018). The analysis of results on crop yields and soil quality is also in progress and the results will be presented.

Keywords: Ramial chipped wood, agroforestry species, Organosolv lignin, Soil quality, Tomato yields.

References:

1. Koumba-Yoya & Stevanovic , 2016, ChemistrySelect, 6562-6570. https://doi.org/10.1002/slct.2016014
2. Barthes et al., 2015, Agroforestry systems, 81-93. http://dx.doi.org/10.1007/s10457-014-9759-5.
3. Félix et al., 2018, Land Degradation & Development, 2694-2706, https://doi.org/10.1002/ldr

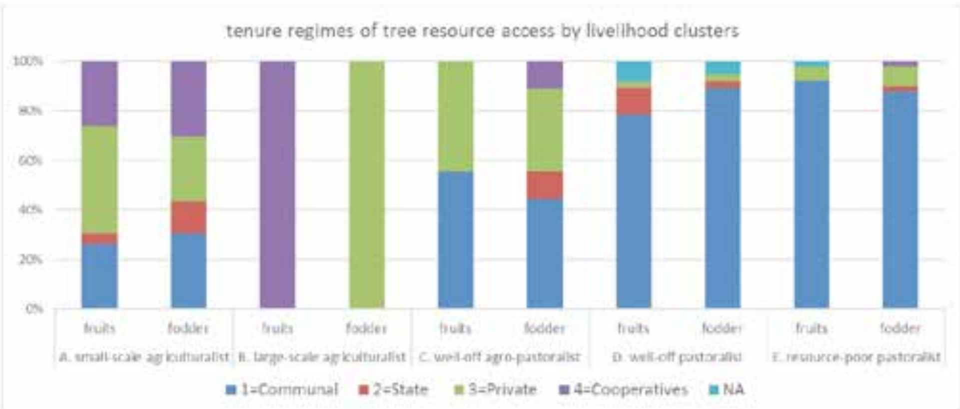
L03.P.08

Changing tree access regimes in the livelihood transitions from pastoralism to agro-pastoralism in Afar, Ethiopia

Dimenso A. D.[1] (abaynehdd@yahoo.com), Waktole S.[1], Iiyama M.[2]

[1] *EEFRI, Addis Ababa, Ethiopia*; [2] *JIRCAS, Tsukuba, Japan*

Background: The livelihood strategies of pastoral communities in drylands have gradually shifted to agro-pastoralism, which is accompanied by changing accessibility to natural resources and significant sustainability implications. .
Aims: The study documented changing modes of access to tree resources along with livelihood transitions to agro-pastoralism in traditionally pastoral communities, aiming to guide interventions to promote tree regeneration and plantation while addressing livelihood needs.
Materials and methods: The socio-economic data was collected from 122 households in pastoral – agro-pastoral communities in Afar, Ethiopia. Cluster analysis was performed to group households with similar livelihood strategies. Then differences among livelihood clusters in perceptions of livelihood contributions of fruits/fodder tree resources and their physical as well as tenurial accessibility were examined.
Results: The five clusters varied significantly for livelihood proxy variables. The resouce-poor pastoralists and well-off pastoralists collected fruit and fodder tree resources from communal land. As livelihoods shifted from pastoralism to agro-pastoralism physical access to fruits/fodder trees decreased as communal land was increasingly diminishing and becoming remote from homesteads.
Conclusion: Strategies targeting agro-pastoralists and agriculturalists should be urgently developed to promote tree regeneration and planting through awareness raising and capacity building.



Keywords: Fodder, Fruit, Household, Land holding, Livelihood strategy.

L03.P.09

Intercropped Woody Species in the Sahel to Resist Drought: Agronomic Performance and Soil Quality

DIck R.[1] (dick.78@osu.edu), Diedhiou I.[2], Bogie N.[3], Bright M.[4], Chapuis-Lardy L.[5], Ghezzehei T.[3], Bayala R.[6], Kizito F.[7], Dossa E.[8], Assigbetse K.[5], Cournac L.[5], Ndour Badiane Y.[9]

[1] *Environment and Natural Resources, Ohio State University, Columbus, Ohio, United States*; [2] *University of Thies, Thies, Senegal*; [3] *University of California, Merced, Merced, United States*; [4] *Ohio State University, Columbus, United States*; [5] *IRD, Dakar, Senegal*; [6] *ISRA, Thies, Senegal*; [7] *CIAT, Nairobi, Kenya*; [8] *IFDC, Accra, Ghana*; [9] *ISRA, Dakar, Senegal*

The Sahel is an ecologically fragile environment under threat from over population & grazing, & intensification of cropping with continuing soil degradation. Additionally, drought is common, causing chronic low yields, crop failures & food insecurity. The main food is millet or sorghum for the majority Sahelian populations, that is largely outside the market economy. Green Revolution technologies have not been successful & yields of staple cereals are unchanged in five decades. Biologically based systems are desperately needed that utilize local resources. A solution, is intercropping of native shrubs, (*Guiera senegalensis or Piliostigma reticulatum)* , that coexist with row crops throughout the Sahel. Unfortunately, currently shrubs are coppiced & residue burned prior to cropping depriving soils of needed organic matter. Our >15 years research on the agronomic performance of an optimized, non-thermal shrub intercropping system (***1500 shrubs/ha & return of coppiced biomass to soil)*** (OSS), at 2 long-term experiments (11 years) in Senegal, showed the intriguing ability of *G. senegalensis & P. reticulatum t*o dramatically increase yields of millet & groundnut, while maintaining yields in drought years. Shrub intercropping has more than doubled soil carbon & increased the availability of most macronutrients in soil over non-shrub cropping. Shrubs significantly increase microbial diversity & enrich genera known to have plant growth promoting properties. A key discovery of our team is that these shrubs perform hydraulic lift (HL), which is the movement of water via deep roots from wet subsoil to dry surface soil, at night when photosynthesis stops. The long-term data shows that shrubs reduce drought impacts in crops by significantly increasing rainfall water use efficiency (WUE) (kg ha/mm), maintaining yields even in very dry years. Recently a ***simulated drought experiment*** (with total water control in the dry season) showed that stopping irrigation at late millet flowering resulted in a harvestable millet with OSS, whereas non-shrub plots had crop failure. We attribute the improved WUE & ability to buffer drought periods of OSS to improved soil quality & to hydraulic lift. Indeed, during the simulated drought experiment we confirmed that HLed labeled water (deuterium) was taken up directly by adjacent millet plants - ***meaning shrubs are "bioirrigating" crops***. Another valuable observation is that OSS reduces time to harvest by about 15 days – further buffering against erratic rainfall of the Sahel. Optimized shrub-intercropping is advantageous for subsistence farmers, because it is a ***local resource*** they are familiar with while remediating degraded soils & resisting drought. With the sound scientific basis of optimized shrub intercropping established & the fact that these shrubs are found throughout the Sahel – we are poised to pilot test & demonstrate this system throughout the Sahel as a key management tool for beating famine across the region.

Keywords: Optimized Shrub Intercropping, remediating degraded soils, Sahel, millet, groundnut.

References:

1. Bogie, N, R. Bayala, I. Diedhiou, R. P. Dick, T. A. Ghezzehei. 2018 Front Env. Sci. Vol 6
2. Bright, M, I. Diedhiou, R Bayala, K Assigbetse, L Lardy, Y. Ndour, RP Dick 2018 Ag Eco&Env 242:9
3. Debenport S, K Assigbetse, R Bayala, L Lardy, RP Dick, B. McSpadden 2015 Ap Env Micro 81:2841
4. Dossa, E.L., I. Diedhiou, M. Khouma, M. Sene, RP Dick et al. 2012 Agron J 104:1255
5. Kizito, F., M. Dragila, M. Senè, R.Brooks, F. Meinzer, RP Dick et al. 2012. J. Aird Env 83:69

L03.P.10

Long-term *Piliostigma reticulatum* intercropping in the Sahel: Impact of the density of shrub on sorghum yield

Douzet J.-M.[1] (jean-marie.douzet@cirad.fr), Dusserre J.[2], Lahmar R.[3]

[1] *UPR AIDA, CIRAD, Ouagadougou, Burkina Faso*; [2] *UPR AIDA, CIRAD, Montpellier, France*; [3] *UPR AIDA, CIRAD, Tunis, Tunisia*

Continuous cropping of cereals and reduction of fallow periods contribute to soil degradation in Africa drylands, altering the soil functions and the systems' resilience. Alternatively, appropriate intercropping of cereals with native evergreen woody shrubs is proposed as a way to restore degraded lands and, ultimately, positively impact crop yields (Lahmar et al., 2012; Bright et al., 2017). The effect of the density of shrubs (*Piliostigma reticulatum*) was tested on a continuous sorghum crop (*Sorghum bicolor*).
The experimentation is located in the 2iE Campus – Kamboinsé, Burkina Faso (12°28.031'N; 1°32.929'W) including randomized block design with four replicates. Shrubs were installed in August 2012 with different shrub densities: 0, 488, 976 and 1953 shrub ha-1; Sorghum was cultivated using the Zaï technique (traditional planting pits) since 2013 season. Fertilizers were provided on the sorghum crop only in the first 2 years. Each year, the shrubs were coppiced before the start of the rainy season in June, and during the cropping season (starting from 2016). All the shrub biomass was used as soil cover. After sorghum grain yield was harvested, the remaining sorghum biomass was also left on the soil surface.
Piliostigma aboveground dry matter have increased during the 4 years of monitoring (from 2015 to 2018), reaching in 2018 a production of 6160 kg ha-1 (dry matter) for both the highest shrub densities (976 and 1953 shrub ha-1), and 3890 kg ha-1 for the lowest density (488 shrub ha-1). Sorghum grain yields declined progressively since 2014 when we stopped using fertilizers, and for all treatments.
Our results over a 5-year trial support the fact that Piliostigma intercropping alone do not significantly increase sorghum yield. Piliostigma is a non-nitrogen-fixing legume shrub that allows the stabilization of soil carbon content but not of soil nutriment nitrogen and phosphorus (Félix et al., 2018). Further researches combining Piliostigma with other sources of nutrient would need to be tested. For example in 2018 we started to study the effect of adding cowpea *(Vigna unguiculata* L. Walp, nitrogen-fixing legume) to the intercropping of shrub with sorghum. Another consideration is the time required to achieve measurable benefits. It was observed that it took more than 4 years to obtain consistently increased yields of sorghum when shifting to an optimized Piliostigma system (Bright et al., 2017).
This experiment is the support for various studies on hydrology of soil and on nutrient cycling (CGIAR Research Program "Grain Legumes and Dryland Cereals", LeapAgri "Ramses II" project, MacKnight "3F" project).

References:

1. Bright et al., 2017. Agric. Ecosyst. Environ. 242, 9–22. doi:10.1016/j.agee.2017.03.007
2. Félix et al., 2018. L. Degrad. Dev. 29, 2694–2706. doi:10.1002/ldr.3033
3. Lahmar et al., 2012. F. Crop. Res. 132, 158–167. doi:10.1016/j.fcr.2011.09.013

L03.P.11

WÉGOUBRI, le bocage sahélien (WÉGOUBRI, The Sahelian Bocage)

Girard H.[1] (eau.terre.verdure@gmail.com), Kabore S.[2]

[1] *ONG TERRE VERTE, Ouagadougou, Burkina Faso*; [2] *ONG TERRE VERTE, Guiè, Burkina Faso*

The action of the NGO TERRE VERTE (Green Earth) in Burkina Faso is to create bocage landscapes. Those are called wégoubri in Moore, a local language. This new rural development concept was first and successfully developed in the 90s, at the pilot farm of Guiè, and has since been replicated in the pilot farms of Filly, Goema and Barga.

The degradation of the Sahel environment has dramatically escalated during the last decades, endangering rural populations. In addition, damages caused by the on-going traditional practice of extensive agriculture have worsened the matter. Creating bocage landscapes in rural areas helps solve the problem.
Using a holistic approach that encompasses applied research, training and direct support to the farmers, the pilot farm succeeds in integrating environmental conservation principles in agricultural methods.
The concept is based on the creation of bocage areas in co-ownership, including individual and common plots. Its management is organized through a land beneficiaries' group. The result is a fully restored environment where agriculture is no longer synonymous with erosion, where cattle breeding is no longer synonymous with overgrazing, and where trees and shrubs are harmoniously integrated in the environment.
The increase in agricultural yields obtained after only a few years of soil restoration demonstrates the economic viability of the concept. It is the only solution to restore millions of deteriorated hectares of land across the Sahel.

Sahelian bocage 20 years old in Guiè (Burkina Faso)

Keywords: bocage, Sahel, Hedged farmland, Land restoration, Greening the Desert.

References:

1. crédit photo : TERRE VERTE Burkina Faso / www.eauterreverdure.org 2014

L03.P.12

Enhanced energy security for smallholder farmers via integrated agroforestry systems in Tanzania

Hafner J. M.[1] (johannes.hafner@zalf.de), Kimaro A. A.[2], Temu E.[2], Rosenstock T.[3], Uckert G.[1], Hoffmann H.[1], Sieber S.[1]

[1] *ZALF Müncheberg, Research Area 2: Land Use and Governance, Müncheberg, Germany*; [2] *World Agroforestry Center Tanzania, Dar es Salaam, Tanzania*; [3] *World Agroforestry Center, Kinshasa, Congo - Kinshasa*

Domestic firewood consumption is one driver of deforestation in Tanzania. A lack of availability of clean cooking energy sources and the use of energy inefficient cooking devices contribute to high firewood demand at household level (~50 kg/week and household). In this study, we tested whether a firewood production and consumption equilibrium including both, on-farm firewood production through agroforestry systems (treatment 1: maize, pigeon pea and Gliricidia sepium (G. sepium); treatment 2: maize and G. sepium) and adoption of locally made artisan mud-based improved cooking stove (ICS) at household level could be reached. Our hypothesis was that households' firewood demand could be met by on-farm firewood production from Gliricidia sepium coupled with ICS technology leading to firewood autarky of households. The research was conducted in the semi-arid region of Dodoma, Tanzania. In order to determine the firewood production potential of G. sepium, we used data from a randomized block design with six blocks à 256 m^2. One-year old G. sepium wood (spacing 4m by 4m) was pruned and measured at the beginning of the planting season. Wood yield was extrapolated to estimate the firewood production potential per hectare (ha). In order to determine firewood consumption, we adopted the Controlled Cooking Test (CCT) and compared the firewood consumption patterns of traditional three-stone-fires (TSF) and ICS using G. sepium and the forest-based firewood species (Mrama). We standardized the cooking task and used the meal "rice and vegetables" in order to make firewood consumption patterns comparable. Our analysis showed that less firewood from G. sepium was needed to conduct the cooking task. The firewood consumption per meal of ICS compared to TSF was reduced by 24.3% with Mrama and 28.5 % with G. sepium. With a combined transition from TSF to ICS and from Mrama to G. sepium firewood, a substantial reduction of firewood demand per meal of 42.9 % might be realized. Assuming 2.5 cooking tasks per day, a 5-head household consumes 1,298 kg of G. sepium wood per year under an ICS scenario to meet its cooking energy demand (respectively 1,815 kg per year under a TSF scenario). With treatment 1 G. sepium-maize-pigeon pea intercropping, 2.1 ha of G. sepium firewood are needed to meet the annual firewood demand for cooking using ICS and respectively 2.9 ha using TSF (fuelwood from pigeon pea was neglected). With treatment 2, Gliricidia sepium-maize intercropping, 1.1 ha with ICS and 1.6 ha with TSF are needed to meet the annual firewood demand of a household. As shown, implementing these agroforestry systems would make households' independent from external firewood and present a significant reduction in pressure on forests. This might have knock-on effects like: reduced costs associated with firewood collection and utilization, climate change mitigation as well as reduced environmental degradation in semi-arid areas of Tanzania.

Keywords: intercropping, on-farm firewood, forest degradation, improved cooking stoves.

L03.P.13

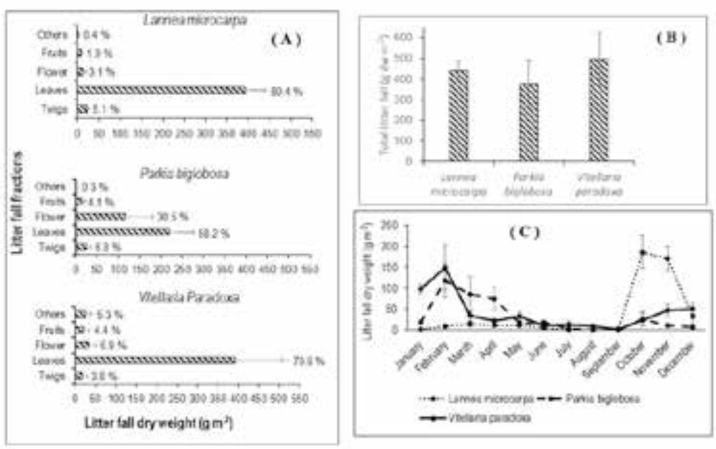
Litterfall dynamics of agroforestry systems in parkland of the North Sudanian zone, Burkina Faso

Koala J.[1] (ezeyamb@yahoo.fr), Takenaka K.[2]

[1] *Environnement et Forêts, INERA/ CNRST, Koudougou, Burkina Faso*; [2] *Rural Development Division, JIRCAS, Ohwashi Tsukuba Ibaraki, Japan*

Poor soil fertility is a problem for agriculture in Burkina Faso. Litterfall is an important way for bioelements to return to the soil (natural ecosystems)1,2. Therefore, dynamics and quantity of litterfall were studied with aim to better manage agroforestry landscape with principle of multifonctionality of trees.
Five 0.25 m2 litter traps were placed under 5 trees of 3 species (total 15 trees) that have economic and ecologic purposes in agroforestry parklands. Every 2 weeks, litter was sorted into leaves, twigs, fruits and other non-foliar components, which were oven dried and weighed. We calculated total annual litter production by species and fractions. *Vitellaria paradoxa*, *Lannea microcarpa*, and *Azadirachta indica* litter fall were composted and N, P and K content compared with *Sorghum* crop residues compost.
Mean total litterfall (±SE) was 440±50, 377±110, and 494±130 g dw m-2 yr-1 for *L. microcarpa*, *Parkia biglobosa*, and *V. paradoxa, respectively* (Fig. 1). Leaves fraction varied from 63% to 89% of total litterfall depending on species. Largest litterfall input occurred in dry season, October–April. Litter quantity showed that agroforestry parkland is productive (Fig. 1). Litterfall compost had better chemical quality than conventional crop residue compost, but decomposition rate of *V. paradoxa* litter was very low (29%) (Table 1).
These results suggest that with proper management, litterfall could contribute significantly to enhancing soil fertility in agroforestry landscape.

1)



2)

	DR (%)	C (%)	O.M (%)	N (%)	C/N	P (%)	K (%)
Crop residues	73,3	7,34±0,21	12,7±0,01	0,41±0,01	17,8±0,1	0,04±0	3,6±0
LF_A. indica	79,9	9,98±0,03	17,2±0,03	0,65±0	15,5±0,02	0,08±0	3,8±0
LF_L. microcarpa	87,3	10,32±0,02	18,1±0,04	0,64±0	16,1±0,03	0,07±0	3,7±0,01
LF_V. paradoxa	29,0	11,91±0,04	20,5±0,1	0,61±0	19,4±0,1	0,07±0	4,1±0,01
F		14638	14638	13491	859	1435	3053
P_Value	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001		<0,0001

DR: Decomposition rate, **C**: Total carbon, **OM**: Organic matter, **N**: Nitrogen, **P**: Total phosphorus, **K**: Total potassium

Components litter fall proportion (A), Mean total litter fall per species (B) and litter fall dynamics during year (C) of the three agroforestry species (1) and Chemical composition of compost of sorghum residue and litter fall (LF) of three woody species in agroforestry systems, Burkina Faso (2)

Keywords: Litterfall, Soil fertility, Parkland, Agroforestry species, Agroforestry landscape.

References:

1. Becker, J., Pabst, H., Mnyonga, J., Kuzyakov, Y. (2013). Biogeosciences 12: 5635–5646
2. Celentano, D., Zahawi, R.A., Finegan, B., Ostertag, et al. (2011). Biotropica 43 (3): 279-287
3. Ostertag, R., Marı´n-Spiotta, E., Silver, W.L., Schulten, J. (2008). Ecosystems 11: 701-714

L03.P.14

Effectiveness of farmer-managed natural regeneration as a restoration technique

Lohbeck M.[1] (madelon.lohbeck@wur.nl), Albers P.[2], Boels L.[2], Bongers F.[2], Morel S.[2], Smith-Dumont E.[1]

[1] *World Agroforestry Centre, Nairobi, Kenya*; [2] *Forest ecology and forest management, Wageningen University, Wageningen, Netherlands*

Background
Farmer-managed natural regeneration (FMNR) is a low-cost restoration technique promoted widely amongst smallholders in the parkland agroforestry systems of the Sahelian drylands. However we know little of what vegetation regenerates naturally, how people manage it and what restoration benefits can be derived.
Aims
We aim to understand the woody regeneration dynamics and their drivers in agroforestry landscapes. Specifically we assess the state of FMNR, what are the environmental and human drivers of regeneration, and what are the consequences for the restoration of important functions and for climate change resilience.
Methods
We used a unique combination of ecological and social data from two sites: Centre-Southern Burkina Faso and Northern Ghana. Using the land degradation surveillance framework (LDSF) we assessed soil health, management and woody communities across 320 randomly selected plots (1000m2). 10 plant functional traits were measured on the 44 most important woody species. Semi-structured interviews were carried out with 76 farmers to understand farm practices and species preferences.
Results
FMNR was practiced by 65% of the farmers interviewed although the level of intensity differed. Seedling density is about 2500 seedlings per hectare, of which 99% regenerated naturally (from seed and rootstock). 48% of regeneration is considered as beneficial to the farm system, while 49% is considered a weed. Weeds usually regenerated from root stock, are persistent and farmers need to keep cutting them. Farmers promote a small subset of species that provide them with benefits in terms of litter, fodder and income. Regeneration on farmers fields is about 5 times less diverse than regeneration in the nearby protected forest. Taxonomic and functional diversity of seedlings on farmers fields is not different from the adult community although there is a shift in species and functional composition of the seedlings compared to the adults where the seedlings represent a higher abundance of shrub species and increased representation of functional traits that indicate drought tolerance (low adult stature, high wood density, small and thick leaves).
Conclusions
Understanding regeneration dynamics, drivers and consequences is vital to restore degraded drylands using FMNR. This research shows that regeneration is successful in the two study sites, though only about half of the seedlings is useful for farmers while the other half needs to be continuously removed. Our results further show that FMNR contributes to drought resilient systems but for biodiversity conservation enrichment planting may be needed.

Keywords: restoration, farmer-managed natural regeneration, drylands, degradation, agroforestry parklands.

L03.P.15

Residue management effects on biomass productivity and N_2 fixation by *Sesbania sesban* and *Cajanus cajan*

Makhubedu T.[1] (itmakhubedu@gmail.com), Letty B.[1], Mafongoya P.[1], Scogings P.[2]

[1] *Crop sciences, University of KwaZulu-Natal, Pietermaritzburg, KwaZulu-Natal, South Africa*; [2] *Life sciences, University of KwaZulu-Natal, Pietermaritzburg, KwaZulu-Natal, South Africa*

Pruning of N_2-fixing woody legumes is a compulsory management practice in most agroforestry systems for minimizing shade, improving soil fertility or harvesting livestock fodder. However, the effects of residue management on biomass and symbiotic N_2 fixation are poorly studied. A factorial experiment was conducted to evaluate the effects of pruning residue management on biomass yield and N_2 fixation by *Cajanus cajan* (pigeon pea) and *Sesbania sesban* using the ^{15}N natural abundance technique. Three prunings were conducted between April 2017 and February 2018 by cutting trees back to 75 cm height. After pruning, leaves and twigs were either spread evenly (retain) or completely removed (remove) from plots. The results showed that retention of prunings improved DM yield of test legume species as compared with removal of prunings. Pigeon pea derived between 44 – 100% of their N nutrition from N_2 fixation. The amounts of N_2 fixed in prunings varied between 17 and 175 kg ha^{-1} and were, on average, 78.5 kg ha^{-1} (retain) and 61.5 kg ha^{-1} (remove), with mean soil N uptake values of 14.6 and 12.5 kg ha^{-1} for retain and remove, respectively. In the case of *S. sesban*, %Ndfa values ranged from 13 to 72% and the amounts of N_2 fixed in prunings ranged between 11 – 113 kg ha^{-1}. On average, the amounts of N_2 fixed by *S. sesban* were 57 and 34.7 ha^{-1} (retain versus remove), with mean soil N uptake values of 70.5 and 67.3 kg ha^{-1} for retain and remove, respectively. Taken together, retention of prunings enhanced biomass productivity and symbiotic N nutrition of pigeon pea and *S. sesban* most probably through the improvement of soil physical and biological properties.

Keywords: Agroforestry systems, pruning, natural abundance, nutrient cycling, fodder.

L03.P.16

Juvenile tree seedlings establishment in the dry lands of the Lake Albert Crescent Zone (LACZ) Uganda, using hydrogels

Masanyu J.[1] (juliusmasanyu@gmail.com), Mugabi D.[1], Nkosi J.[1], Enyau K.[2], Hafashimana D.[3], Baguma D.[1], Agaba H.[2]

[1] *NARO - BuZARDI, Hoima, Uganda*; [2] *NARO - NaFORRI, Kampala, Uganda*; [3] *NARO - BuZARDI - EIMCOL, Hoima - Kampala, Uganda*

Dry lands in Uganda as elsewhere have problems of tree seedlings establishment due to little moisture in the soils as rains received in these areas is not enough. This situation is getting worse with the extreme long periods of drought that are now more prevalent due to climate change and variability. However trees are known to reduce such vulnerability to climate change effects (ICRAF, 2013). As a form of sustainable land management in these dry lands, we established an experiment of juvenile tree seedlings of *Cassia siamea*, *Eucalyptus camaldulensis,* (Neem) *Azadirachta indica* and *Melia volkensii* in three dry land areas of Butiaba, Ngwedo and Kaiso Tonya within the Lake Albert Crescent Zone (Kibale, Masindi, Hoima, Buliisa, Kiryandongo, and Masindi Districts of Western Uganda). We used varied hydrogel concentrations of 5 grams, 10 grams and 15 grams together with a control of no hydrogels at all for each of the above tree spp for each site. Hydrogels can absorb water 400 times their weight and make it available to plants for uptake and use in the dry season (Agaba *et al*, 2014). The tree seedlings were planted at a spacing of 3m by 3m following a completely randomized block design using slope as a blocking factor. For each hydrogel treatment and each site 5 tree seedlings for each spp were planted giving a total replication of 15. Data on tree heights attained and Number of branches was taken after 3 months and 6 months and analysed using R 3.4.2 (R-Studio). It was observed that in Butiaba and Kaiso Tonya that all the Eucalyptus seedlings without any hydrogels had dried after 3 months showing that without hydrogel use, there can't be any Eucalyptus tree establishment. It was also observed that the maximum height attained by *Azadirachta indica* (Neem) of 145.7cm and Eucalyptus trees at 116cm for 10 grams of hydrogel in Butiaba was significantly different (T=13.122 and p=0.001429). In Kaiso Tonya, it was only *Cassia siamea* tree seedlings that survived the dry season and were growing maximally at a hydrogel concentration of 10 grams while for Ngwedo which is a little bit wet, the hydrogel concentration that produced maximum growth of the tree seedlings was 5 grams. It was concluded that hydrogel technology enhances tree seedling establishment in dry areas and should be recommended for uptake by farmers as more research on other tree spp e.g. *Faidherbia albida* and others goes on.

Keywords: Hydrogel, tree seedlings, dry lands.

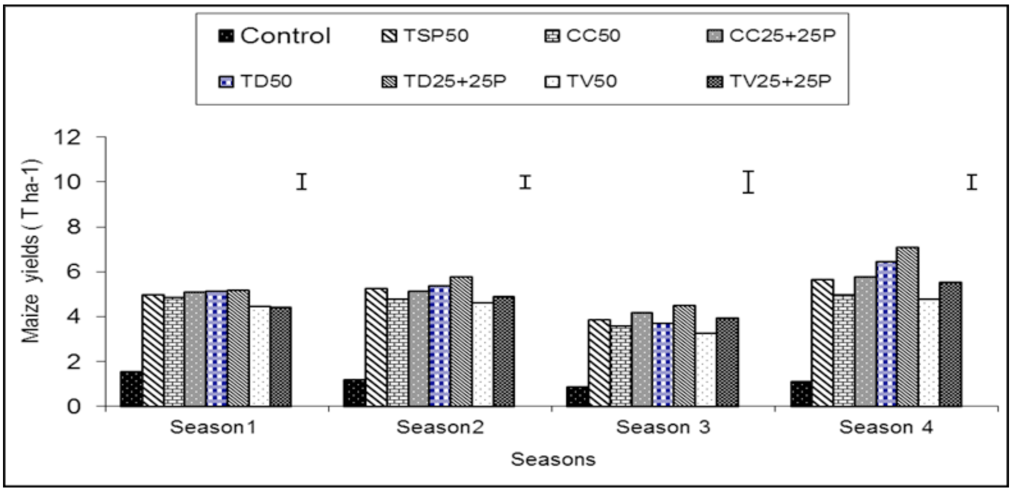
L03.P.17

Green manure application an option for restoring degraded lands and increase crop productivity in Central Rwanda

Mukuralinda A. (a.mukuralinda@cgiar.org)

Eastern and Southern Africa, ICRAF, Kigali, Huye, Rwanda

Soil and Land degradation are widespread Worldwide. Returning green manure to the soil is considered a good management practice to restore degraded soil particularly, building soil carbon, available phosphorus and crop yield. Soil organic carbon (SOC) plays an important role in mitigating major constraints to crop productivity. In this study we determined the effects of tree foliage and triple super phosphate application on soil carbon, microbial biomass carbon, P, available P, P uptake and increase of maize yield and relationship between maize yield, available P and P uptake. We used a RBCD with three replications. Eight treatments consisting of control, Calliandra calothyrsus Tithonia diversifolia, Tephrosia vogelii applied each alone at 50 kg P ha-1,TSP at the rate equivalent to 50 kg P ha-1, combination of species green manure at rate of 50 kg P ha-1. Results showed that green manure combined with TSP increased significantly SOC, available P and P uptake. Tithonia in combination with TSP significantly (R2=0.49) increased yield from 1.8-6.1 t ha-1. The relationship between yield, BPi (R2=0.42) and total P uptake (R2=0.75) were also highly significant. Application of inorganic P with green manure improved P availability and yield, hence a better strategy to restore degraded lands.



Maize yield response to the application of mineral fertiliser and green manure in Central Platteau in Rwanda. Vertical bar represents LSD (0.95)

Keywords: Agroforestry species, Yield, P availability, Microbial biomass P.

L03.P.18

Role of *Casuarina equisetifolia* and *Melia volkensii* systems in Improving Soil Fertility in Coastal Kenya

Mwadalu R.[1] (zikiemwa@gmail.com), Muturi G.[2], Mbuvi M.[1], Gathara M.[2]

[1] *Research and Development, Kenya Forestry Research Institute, Malindi, Kenya*; [2] *Research and Development, Kenya Forestry Research Institute, Nairobi, Kenya*

Over 80% of Kenya's landmass is considered arid or semi-arid; characterized by erratic and inadequate rainfall and poor inherent soil fertility; this is coupled with other factors hampering agriclture development such as high cost of mineral fertilizer that many smallholder farmers cannot afford. Declining soil fertility is a major hindrance to agriculture development in Kenya. In most parts of the country, soils are deficient in nitrogen, phosphorus and in some cases potassium. Drought tolerant agroforestry trees are an important alternative for enhancing soil fertility to enable farmers meet nutrient demand in agricultural systems. The aim of the study was to determine the potential of *Casuarina equisetifolia* and *Melia volkensii* systems in soil fertility improvement in semi-arid coastal Kenya (Kwale and Kilifi Counties) for adoption by smallholder farmers to address soil fertility challenges. Casuarina and Melia are fast growing drought tolerant tree species that have widely been adopted in Coastal Kenya. The experiment was set on-farm in a randomized complete block design with three treatments: Casuarina, Melia and control (pure maize crop stands) each replicated four times. Each plot measured 40m by 100m; with a spacing of 2m by 2m for Casuarina plots (with 1000 trees per plot) and 4m by 4m for Melia plots (with 250 trees per plot). Casuarina and Melia plots were intercropped with maize within the first two years. Soil fertility dynamics were evaluated from Casuarina ,Melia and control plots two years after establishment for three consecutive years. Soil samples were obtained from depths of 0-20cm, 20-40cm and 40-60cm. Data was subjected to Analysis of Variance using GenStat software at 95% confidence level. Results indicate that by the end of the fifth year, total Nitrogen was higher in *C. equisetifolia* (0.15%) and *M. volkensii* (0.22%) plots compared to the control treatment (0.1%). There was however low buildup of soil Carbon throughout the sampling period (0.36%, 0.38% and 0.39% for Control, Casuarina and Melia plots respectively); this can be attributed to high decomposition rates resulting from high temperatures in the study areas. Soil Carbon also declined with increased soil depth. Soil Phosphorus was highest in *C. equisetifolia* and *M. volkensii* plots (4ppm and 6ppm respectively) compared to the control (2.9ppm). There was a positive correlation between soil pH and soil P (r2=0.1777 and 0.3201) in the fourth and fifth year respectively. There was clear trend that *C. equisetifolia* and *M. volkensii* enhanced soil fertility, which can be attributed to N fixation by Casuarina through Frankia bacteria and nutrient cycling by Melia. The results of this study are essential for advising farmers engaging in *C. equisetifolia* and *M. volkensii* farming and for promotion of agroforestry using these tree species in semi-arid coastal Kenya.

Keywords: Agroforestry, Soil fertility, Melia, Casuarina, nutrient.

References:

1. Kandioura, et al., (2013). Journal of environmental management 128c: 204-209.
2. Mulatya, et al., (2002). Agroforestry systems 56: 65–72.
3. Pinho, et al., (2012). Applied and environmental soil science, Doi: 10.1155/2012/616383.
4. Rao, M.R., Nair, P.K.R. and Ong, C.K. (1998). Agroforestry systems 38:3-50.
5. Ye, et al., (2012). Journal of tropical forest science, 24(4): 546-556.

L03.P.19

Linking local and scientific indicators of soil quality to agroforestry contributions in maize-based production systems

Nyaga J. (J.Nyaga@cgiar.org), Barrios E., Muthuri C., Öborn I., Sinclair F.

World Agroforestry Centre, Nairobi, Kenya

Soil fertility decline is a major limiting factor for achieving household food security in sub Saharan Africa and has led to increasing concern on agricultural sustainability. Development of indicators of soil quality to monitor changes resulting from land use and soil management have been proposed to address the issue. To better understand the soil fertility problem in the study area, we hypothesized that local farmers can detect differences in soil quality within their farms by using local soil quality indicators which would in return assist in highlighting changes in soil resulting from agroforestry trees. Forty-seven (47), smallholder farmers were interviewed on local soil classes, biological indicators of soil quality and agroforestry tree attributes influencing soil quality. In addition, they were asked to orally describe the characteristics of the local soil classes that occurred in their farm. This was followed by soil sampling guided by local soil classes and soil qualities recognized for each farm. Twenty-seven (27) out of 117 fields were classified as intermediate (transitional) between productive (good) and non-productive (poor) soil. To substantiate farmers' perception of soil quality we carried out common soil chemical analyses on samples collected from local soil classes identified by local farmers. Results shows farmers had detailed knowledge of plant species they use as bio indicators of soil quality and their influence on farming activities. Plant species such as *Sesbania* spp, *Acacia abyssinica*, *Bidens pilosa*, *Digitaria scalarum*, *Tagetes minuta* and *Galinsoga parviflora* were named by different farmers as bio-indicators of productive soil. Farmers associated invading species and grasses with unproductive soils. Most of the farmers in the study area were found to be aware of macrofauna as bio-indicators and their activities whereby earthworms and beetle larvae were indicators of productive soil. In contrast, majority of interviewed farmers attributed ants to destruction of crops and regard them as detrimental in the soil. Lastly, laboratory tests results of soils corroborated respective farmers' perceived soil qualities. The study conclude that farmers hold complex ecological or local knowledge on indicators of soil quality and contribution of agroforestry tree in their farms. They can also recognize the tradeoffs underlying a biodiverse agroforestry system and their creative capability in the utilisation of local knowledge was demonstrated. It is therefore necessary to find a realistic and common ground between scientific and local knowledge in order to implement a sustainable agricultural program.

Keywords: Local indicators, Scientific indicators, Agroforestry systems, Maize production, Smallholders.

L03.P.20

Reproduction abilities of *Dalbergia melanoxylon*, an endangered species but with potentials for dry lands reforestation

Ouédraogo A.[1] (amadeouedraogo@gmail.com), Glèlè Kakaï R.[2]

[1] *University Ouaga I Pr Joseph Ki-Zerbo, Ouagadougou, Burkina Faso*; [2] *University of Abomey-Calavi, Cotonou, Benin*

Dalbergia melanoxylon (African blackwood) is a multipurpose shrub, mainly used for pharmacopoeia, fodder, fuel and woodcarving. It produces one of the finest timber in the world which round logs fetch up to US$ 590 / m3 (Lemens, 2008). The species provides good mulch and may improve the soil by nitrogen fixation. It can be used to avoid soil erosion because of its extensive root system (Lemmens, 2008). Now, the natural populations of *D. melanoxylon* are exposed to a serious declining risk across its distribution range in West Africa (Ouédraogo, 2006; Lemmens, 2008). However, previous studies provide evidence that the species seedlings are good planting materials with high survival rate (Lemmens, 2008). This study aims at assessing the natural regeneration of *D. melanoxylon* across its natural distribution range in Burkina Faso and testing the germination capacities of seeds as well as the seedlings early growth. The results are expected to provide better understanding of the species reproduction in order to promote it for the restoration of degraded agricultural soils. Quantitative inventories were used to describe the natural regeneration stands and monitoring was carried out in permanent plots to assess the recruitment dynamics. Seeds from different provenances were used for germination tests and to assess the seedlings growth. The results revealed a scarcity of regeneration individuals that was traduced by comparable (p = 0.28) low densities in both Sahel (3 individuals / 25 m2) and sub-Sahel (1.8 individual / 25 m2) stands. Regenerating individuals originated exclusively from root sprouting and exhibited multi-stratum population structures. The spatial distribution pattern of recruitments revealed grouping trends around the mother-trees. The survival rates of recruitments were relatively good but their growth was unpredictable. *D. melanoxylon* had a relatively high rate of damaged fruits by pests (44-88%), which largely accounts for its poor rate of natural regeneration by seedlings. However, the experiments revealed average to high germination rate (52-77%), according to the duration of seeds conservation. The speed of germination (5.3 -12.8 days) and the longevity of healthy seeds are an advantage for sexual reproduction. Even though seedlings have poor resilience ability in the natural stands, the good capacities of germination as well as the high growth and survival rates in nursery are assets for the sylvicultural promotion of *D. melanoxylon* among local populations.

Keywords: African blackwood, germination, seedling growth, natural regeneration, dry lands.

References:

1. Lemmens, RHMJ. 2008. Dalbergia melanoxylon Guill. and Perr. Plant resources of Tropical Africa 7(1)
2. Ouédraogo A. 2006. Diversité et dynamique de la vegetation ligneuse de la partie orientale du Burkin

L03.P.21

Acacia senegal fallow, a tool to restore Sudano-Sahelian landscapes

Peltier R.[1] (peltier@cirad.fr), Kissi Offossou D›A.[2], Freycon V.[3], Palou Madi O.[4], Guibert H.[5]

[1] *ES, UPR Forêts et Sociétés, Cirad, Université de Montpellier, Montpellier Cedex 5, Occitanie, France*; [2] *PN Comoé, OIPR, Abidjan, Côte d'Ivoire*; [3] *ES, UPR Forêts et Sociétés, Cirad, Montpellier Cedex 5, Occitanie, France*; [4] *CRRA Wakwa, IRAD, Ngaoundéré, Adamawa, Cameroon*; [5] *Persyst, UPR AIDA, Cirad, Université de Montpellier, Montpellier Cedex 5, Occitanie, France*

Background: In the Sudanian region of North Cameroon, population growth has led to reduced fallow periods, soil fertility and trees (Peltier *et al*., 1993). Since 1984, CIRAD, Irad and Sodecoton have been testing techniques for planting tree legumes to restore soil fertility (Harmand *et al*., 2017). A 15-year-old *A. senegal* plot was harvested in 2011.It produced 1200 kg/ha of gum arabic for 8 years (750 €/ha) and 40 m3/ha of fuel-wood for 15 years (1100 €/ha) (D'Andous *et al*., 2013).
Aims: After *A. senegal* were harvested, we studied the evolution of chemical soil properties and the production of successive crops.
Mat. & methods: On sandy ferruginous acidic soil, rainfall 1000 mm/year, the farmer planted successive crops of maize, cotton and groundnuts (2011-2013). In 2011 & 2015, the soil was analyzed (composite) on 2 plots of 12 x12 m after *A. senegal* (Post-fallow = Pf) and on 2 control plots continuously cultivated (Cc).
Results: Crop production was much higher for all 3 years and soil chemical properties (C, N, pH, CEC) were higher in Pf than in Cc (Table 1).
Conclusion: Further studies are needed to determine for how long crop cultivation remains profitable (Dubiez et al. 2018). This will pave the way for farm and landscape management including plots planted with tree legumes, to improve biodiversity, carbon storage, wood energy production, food and cash crops of the territories, while limiting population migration and the destruction of the last Sudanese natural ecosystems.

Year of Cultiv-ation	Crop	Yield ($kg\ ha^{-1}$)		Soil analysis							
				C ($g\ kg^{-1}$)		N ($g\ kg^{-1}$)		pH in water		CEC ($cmolc\ kg^{-1}$)	
		Cc	Pf	Cc	Pf	Cc	Pf	Cc	Pf	Cc	Pf
2011	Corn	2582	6600	2.7	4.4	0.2	0.3	5.8	7.5	1.1	2.3
2012	Cotton	592	1647								
2013	Peanuts	461	838								
2015				2.5	4.7	0.2	0.4	6.1	6.7	1.2	2.3

Table 1: Crop production and soil analysis at a depth of 0-20 cm in two control continuously cultivated plots (Cc) and in two plots after the fallow in 2011 of a 15-year-old A. senegal (Pf)

Keywords: Improved fallow, Acacia senegal, Cameroon, Soil fertility, Restoration.

References:

1. D'ANDOUS O. K. et al., 2013. Revue Française Forestière 3: 241-253
2. DUBIEZ E. et al., 2018. AgroForestry Syst: 1-12 https://doi.org/10.1007/s10457-018-0222-x
3. HARMAND J-M. et al., 2017. In: Restauration de la productivité des sols tropicaux et méditerranéens
4. PELTIER, R., BALLE PITY., 1993. Bois et Forêts des Tropiques, 235: 49-57

L03.P.22

Soil conservation structures on soil water content and plant survival on hillslopes in Mediterranean central Chile

Prat C.[1] (christian.prat@ird.fr), Martínez I.[2], Ovalle C.[3], Uribe H.[3], del Pozo A.[4], Valderrama N.[5], Ruíz G.[6]

[1] *Inst. de Rech. pour Devpt (IRD France), Marseille, France*; [2] *Fac. Ing. en Cienicas Agropec. y Amb., Universidad Técnica del Norte (UTN), Ibarra, Ecuador*; [3] *Inst. Invest. Agropecuarias (INIA), Chillán, Chile*; [4] *Facultad de Ciencias Agrarias, Universidad de Talca, Talca, Chile*; [5] *Facultad de Ciencias Agrarias, Universidad de Concepción, Chillán, Chile*; [6] *Protección de los Recursos Naturales, Servicio Agrícola y Ganadero (SAG), Santiago de Chile, Chile*

Agroforestry activity of central Chile is developed on degraded and compacted soils under mediterranean climate. This study evaluate during 4 years, the effect of 2 soil conservation techniques (subsoiling with contour ridges (SB) and infiltration trench (IT), which were compared to a control treatment without soil management (CO)) on soil water content (SWC) and the survival and growth of two exotic (*Chamaecitisys proliferus* and *Quercus suber*) and one native tree (*Quillaja saponaria*). SWC was determined with a neutron probe in aluminum access tubes of 1,2 m. 4 were installed in each replicate and located at 0,5 and 1 m up and down the system.

Soil conservation structures allowed higher SWC especially in the years of higher rainfall (1). At 20-40 and 40-60 cm depth SWC was higher in SB followed by IT and CO, whereas at 60-80 and 80-100 cm depth there was no differences. Conservation techniques had an effect on plant height, crown and trunk diameter in the 3 evaluated species (2). Plant height in *C. p.* was higher in IT>SB>CO, while in *Q. s.* it was higher in SB>IT>CO; *Q. s.* exhibited similar growth in both systems, but it was higher than in CO. The survival rate of *Q. s.* was lower in the CO system (57%), while *C. p.* and *Q. s.* had similar survival rates in the 3 systems (97% and 87%). Subsoiling with ridges has a great potential for degraded and compact soils of the Mediterranean region, allowing higher soil water content in the profile and better tree establishment and growth.

Conservation techniques a) subsoiling with contour ridges (SB) and b) infiltration trench (IT), and c) Control (CO).

Keywords: soil water content, Compacted soils, Infiltration trench, Subsoiling, trees.

References:

1. Guto, S.N., Ridder, N. de, Giller, K.E., Pypers, P., Vanlauwe, B., 2012. Field Crop. Res. 132, 129-1
2. Makurira, H., Savenije, H.H.G., Uhlenbrook, S., Rockström, J., Senzanje, A., 2011. Agr. Water Manage

L03.P.23

Agaveforestry in Michoacán, México: a sustainable remediation of degraded land with benefits for small farmers

Prat C.[1] (christian.prat@ird.fr), Martínez-Palacios A.[2], Sánchez-Vargas N. M.[2]

[1] *Inst. Rech. pour le Devpt (IRD France), Marseille, France*; [2] *Inst. Invest. Agropec. y Forest. (IIAF), Universidad San Nicolas de Hidalgo, Tarímbaro, Michoacán, Mexico*

27% of lands of Michoacán (Mexico) are eroded. Our studies show that overgrazing is the main cause of degradation. After participative actions with farmer communities and field experimentations, we define all together a new strategy: agaveforestry (1). The local agave (*Agave cupreata*) is used to produce a high-valued alcohol drink (mescal) as well as medicines and cosmetics (2). The agave's high value would means less cattle and so, less soil erosion. While waiting for the agave to mature, the farmers intercrop trees plants and grasses that produce marketable products and women earn income in greenhouses by selling small agaves from the seeds they have collected.
Since 2012, our agaveforestry proposal (2,500 agave.ha^{-1} with 80 trees.ha^{-1}) based on a combination of trees, shrubs and herbaceous plants, free of agrochemicals, with grazing animal is tested, measuring different parameters (3). We show that there is no difference between the sizes of plants growing under the canopy (development during dry season) and in the open sky (development during rainy season). We compare also the development of *Agave cupreata* under an agaveforestry (pruning at the height of crops) and a conventional management (continuous applications of agrochemicals and a dry grass burning).
After 6 years in both systems, agaveforestry registered losses of agaves <5% for diseases and <1% for pests, and losses of 30-60%, due to *Erwinia*, *Fusarium* and *Scyphophorus acupunctatus for* the conventional system.

6 years old agaveforestry plantation in Mexico (C. Prat, IRD)

Keywords: Agaveforestry, México, land remedation, small farmer.

References:

1. Prat, C., Martínez-Palacios, A., Ríos Patrón, E. 2012. In: Desire for Greener Land. Options for
2. Martínez-Palacios, A. , Prat, C., Ríos Patrón, E. 2015. In: Understanding Mountain Soils: A co
3. Martínez Palacios, A., et al. (Eds) 2012. Aspectos sobre el manejo y la conservación de Agave me

L03.P.24

Adaptive Multi-Paddock Grazing for Enhancing the Ecosystem Services Provision in Mediterranean Silvopastoral Systems

Pulina A.[1] (anpulina@uniss.it), Frongia A.[1], Caria M. C.[2], Pala T.[1], Nieddu D.[3], Dettori D.[3], Bagella S.[2], Franca A.[3], Roggero P. P.[1], Seddaiu G.[1]

[1] *Dipartimento di Agraria - NRD, University of Sassari, Sassari, Italy*; [2] *Dipartimento di Chimica e Farmacia - NRD, University of Sassari, Sassari, Italy*; [3] *ISPAAM, CNR, Sassari, Italy*

The Quercus-based silvopastoral systems of the Mediterranean basin are declining due to both abandonment and intensification trends[1]. Grazing management is a major driver of plant communities dynamics and, therefore, of forage productivity and quality[2]. Adaptive Multi-Paddock (AMP) grazing system[3], i.e. rotational grazing with high instantaneous stocking ratesand resting periods long enough to allow an optimal plant regrowth, has been recommended as a potential tool to manage rangelands to sustain forage productivity and improve livestock management.

The experimental hypothesis of the study is that AMP grazing can be more effective than current grazing systems in supporting the biodiversity and the provision of ecosystem services in Mediterranean wooded grasslands.

The study site was in a private farm located in the Central-western Sardinia, Italy (40°8’N, 8°35’E), consisting of two distinct areas located at 850 m (A) and 400 m (B) a.s.l., which main activity is the beef cattle and goats breeding. Since August 2018, at the A area, where animals graze during summer and winter season, 8 paddocks (size from 0.6 to 1.2 ha) were identified and electrically fenced, aiming to start the AMP system to be compared to the ordinary one (control). Furthermore, two typologies of soil cover where there identified: the Dehesa Type (DT) and the Permanent Grassland (PG). In each paddock animals graze for few days with high instantaneous stocking (Livestock Units[4], LSU) rates (up to about 7 LSU ha^{-1}) followed by long resting periods, while in the ordinary system grazing will occur according to a continuous scheme with lower stocking rates (up to 2 LSU ha^{-1}).

Plant biodiversity is assessed at each season in AMP and control areas according to the vertical point method integrated by the floristic relevé in order to record also rare species. Forage production is monitored at the beginning and the end of the grazing period by measuring the sward height (H) with a HFRO sward stick in both AMP and control areas. The sward stick is being seasonally calibrated in order to obtain robust and reliable regression equations between sward height and dry matter (DM) biomass.

The results referring to autumn 2019 are preliminarily shown. Distinct relationships between H and pasture DM biomass of species belonging to *Poaceae* and *Fabaceae* families were identified. Significant relationship between sward stick height and DM biomass were observed for both *Poaceae* (n=12, $P<0.001$) and *Fabaceae* (n=10, $P<0.05$), which represent on average the 83% and the 56% of plant cover on DT and PG, respectively. The grass+legumes utilization factor in DT (79%) were higher in AMP paddocks than control areas (43%), while less difference between AMP (40%) and control (32%) were observed in PG, suggesting an higher consumption of less quality forage[5], which presence is higher in PG than DT.

The study is being carried out within the framework of the LIFE-Regenerate project (LIFE16 ENV/ES/000276 Regenerate).

Keywords: Adaptive Multi Paddock, Silvopastoral systems, Grassland production, Grazing management, Pasture quality.

References:

1. Moreno et al., 2018, Agroforestry Systems, 92 877-891
2. Tilman and Downing, 1994, Nature, 367 363-365
3. Teague et al., 2011, Agriculture Ecosystems and Environment, 141 310-322
4. Allen et al., 2011, Grass and Forage Science, 66 2-28
5. Probo et al., 2014, The Rangeland Journal 36 445-458

L03.P.25

Soil properties and moisture status under various spacings of poplar based agroforestry system in Northern India

Sirohi C. (chhavisirohi22dec@gmail.com), Bangarwa K. S., Dhillon R. S., Chavan S. B.

Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana, India

To combat land degradation and achieve biological production on a sustainable basis, poplar (Populus deltoides) is a promising species recognized as an important tree component in agroforestry system (AFS). The soil is enriched through the addition of leaf litter in large quantities by this tree, which ultimately improves the fertility in terms of soil organic carbon (SOC), available N, P and K. However, scanty information is obtainable related to associations between soil properties and poplar based AFS. This study was conducted in seven and eight-year old agroforestry system (AFS) in Northern India, where different spacings, i.e. 5 × 4 m, 10 × 2 m and 18 × 2 × 2 m (paired-row) of poplar were intercropped with winter wheat, and in adjacent agricultural control plot, where winter wheat was the sole crop (devoid of tree). We quantified soil properties such as soil pH, electrical conductivity (EC), soil organic carbon (SOC) and available N, P and K at 0-15 cm and 15-30 cm depths and studied their spatial variability in relation to different spacings of poplar based AFS during 2013-14 and 2014-15. Poplar based AFS had better available nutrients status in comparison to sole wheat crop. The lowest value of soil pH (7.5) was recorded under 5 × 4 m spacing after harvesting of wheat crop during April 2015. The decrease in EC was maximum (67%) under 5 × 4 m spacing followed by 10 × 2 m and 18 × 2 × 2 m spacing with a reduction up to 63% and 61%, respectively. SOC accumulation rates increased with the decrease in tree spacing and was maximum (0.74%) under 5 × 4 m spacing; it followed the order 5 × 4 m > 10 × 2 m > 18 × 2 × 2 m > control plot after harvesting of wheat crop during April 2015. The available soil N, P and K increased significantly under different spacings of poplar based AFS in all the treatments from their initial values. The highest available soil N (366.3 kg ha–1), P (21.4 kg ha–1) and K (355.3 kg ha–1) were recorded under 5 × 4 m spacing. Among all the spacings of poplar based AFS, the maximum moisture content (13.3%) was found in 5 × 4 m spacing at a soil depth of 15-30 cm which was closely followed by 10 × 2 m (12.4%) before 1st irrigation (pooled data). The macro-nutrients tended to increase with time due to higher inputs of organic matter with the age of tree. The moisture content was higher under different spacings of poplar as compared to control during both the year of study. Planting of poplar at 5 × 4 m resulted in maximum moisture content (12.3%) than 10 × 2 m (10.8%) and 18 × 2 × 2 m (9.9%) at a soil depth of 0-15 cm throughout the study. After eight years of poplar plantation, soil chemical properties and moisture content had improved under different spacings of poplar-based AFS. The effect was more pronounced under 5 × 4 m spacing; therefore this is more suitable for improving soil fertility and moisture by the accumulation of leaf litter with the advancement of tree age.

Keywords: Moisture, nutrient status, poplar, spacing.

ABSTRACTS

Agroforestry and world challenges

Agroforestry: riding to the world's rescue

- L4 -
Agroforestry and biodiversity conservation

"Listen, mummy! Birds!":
using agroforestry to restore biodiversity

Agroforestry has been demonstrated to be a feasible alternative to less biologically diverse agriculture in balancing biodiversity conservation and production. However, different studies have also demonstrated that the biodiversity conservation value of agroforestry systems fluctuates depending on management decisions. Multiple management decisions might affect the vegetative composition as well as the resource availability for animal species, thereby affecting their overall conservation value. Management decisions are crucial to fostering the desired balance between conservation and productivity, and more information is needed to accurately identify the trade-offs between them. Identification and measurement of these trade-offs is crucial in the development of biodiversity friendly management practices since these are the best options for preserving ecosystem functions and the services needed to secure sustainable production. This session aims to cover research related to the value of agroforestry systems for biodiversity conservation and the different effects that management might have on the value of particular agroforestry systems.

L04.1_O.01

Tree and litter composition influences soil macrofauna in multi-strata agroforestry systems of Talamanca, Costa Rica

Rousseau G.[1] (luigisour@yahoo.com.br), Celentano D.[1], Deheuvels O.[2], Somarriba E.[3]

[1] *Agroecology, Maranhão State University, São Luis, Maranhão, Brazil*; [2] *CIRAD, Lima, Peru*; [3] *CATIE, Turrialba, Costa Rica*

Humanity is facing a rapid decline in global biodiversity, caused mainly by tropical forest deforestation for industrial and smallholder agriculture. However, smallholder agriculture landscapes host areas of home gardens and other agroforestry systems (AFS) that have proven highly relevant for soil and biodiversity conservation. The positive interactions between aboveground and below-ground biodiversity is probably a key element to understand and promote the efficiency of these agro-ecosystems. To determine whether a relation exists between tree and soil macrofauna diversity and composition, we compared cacao AFS with contrasted tree diversity along a topography and forest cover gradient in Talamanca, Costa Rica. To determine which components of the tree cover composition (species), structure (density, richness, Shannon, Pielou) and agroforest floor (litter more ground cover) best explain the composition (orders and families) and structure (density, richness, Shannon, Pielou) of the macrofauna community we performed two separate redundancy analyses (composition and structure) and constructed the "best models" based on the tree composition, tree structure and agroforest floor as explanatory matrices. Macrofauna composition was best explained by a mix of tree species and litter composition variables (R2=26.5%) and macrofauna and vegetation share a low but significant co-variation with topography (R2=12%). Conversely, macrofauna structure is best explained by a selection of seven tree species (R2=41.2%). The shared variation with topography remained low (R2=10.9%). Tree evenness (Pielou index) only explained 7% of macrofauna community structure while other diversity indices were not correlated with macrofauna composition or structure. The soil macrofauna is therefore more influenced by tree and litter composition than by the overall diversity or evenness of the tree community. This information is important to design the optimal combinations of species for the intensification of production and ecosystem services provision in cacao-based AFS.

Keywords: Ecosystem services, soil ecology, biodiversity, aboveground-belowground.

References:

1. Deheuvels, 2014, Agroforestry systems, doi 10.1007/s10457-014-9710-9
2. Rousseau, 2012, Ecological indicators, 535
3. Sayer, 2010, Biotropica, 194

L04.1_O.02

Alpha and beta diversity patterns of butterflies along forest-agroecosystem gradient in Sikkim Himalaya, India

Acharya B. K.[1] (bkacharya@cus.ac.in), Sharma K.[2], Sharma G.[3]

[1] *Department of Zoology, Sikkim University, Gangtok, Sikkim, India*; [2] *Sikkim University, Gangtok, Sikkim, India*; [3] *The Mountain Institute-India, Gangtok, Sikkim, India*

Agroecosystems have been recognized to possess high biodiversity including endemic, specialists and conservation concern species. We assessed the patterns of alpha and beta diversity of butterflies in the Indigenous Farming Systems (IFS) {large cardamom-based agroforestry systems (LCAS), mandarin orange-based agroforestry systems (MOAS) and farm-based agroforestry systems (FAS)} along with adjacent natural forests (Forests) of the Sikkim Himalaya, India during December 2012-August 2016. We used fixed-width point count method for sampling butterflies along the predetermined transects and conducted 1760 point counts in 24 transects during this study. We recorded 8019 individuals representing 268 species and six families of butterflies which included two-third forest specialist, one-third larval host specialist and one-fifth conservation concern species. We observed contrasting patterns of alpha and beta diversity along agro-ecosystems-forest gradient in the present study. Alpha diversity was significantly highest in MOAS and declined towards Forest and it showed similar trend across season, butterfly family, larval host specificityand habitat specialization. However, Forests had significantly highest pair-wise beta diversity than the three IFS. The organic and traditionally managed agroecosystems of Sikkim Himalaya may complement the protected areas in biodiversity conservation, especially in the human dominated areas with low PAN and forest coverage.

Typical Large Cardamom-based agroforestry systems in Sikkim, Eastern Himalayas: a biodiversity hotspot

Keywords: Forest specialist, monophagous, indicator species, indigenous farming systems, spatial turnover.

References:

1. Acharya & Vijayan (2015) Ecological Research, 30, 909-919
2. Haribal (1992) The butterflies of Sikkim Himalaya and their natural history. Sikkim Nature Conservat
3. Sharma, G. (2009) Journal of Hill Research, 22, 68-85

L04.1_O.03

Plant diversity in understory vegetation strips of alley cropping agroforestry systems

Boinot S.[1] (sebastien.boinot@inra.fr), Fried G.[2], Storkey J.[3], Metcalfe H.[3], Barkaoui K.[4], Lauri P.-E.[1], Mézière D.[1]

[1] *UMR 1230 System, Inra Montpellier, Montpellier, Hérault, France*; [2] *Unité Entomologique et Plantes invasives, ANSES, Montferriez-sur-Lez, Hérault, France*; [3] *Sustainable Agriculture Sciences, Rothamsted Research, Harpenden, Hertfordshire, United Kingdom*; [4] *UMR 1230 System, Cirad, Montpellier, Hérault, France*

Understory vegetation strips (UVS) are uncropped vegetation strips associated with tree rows in alley cropping agroforestry systems (Fig. 1). UVS are in appearance similar to other semi-natural habitats, such as field margins, which can constitute refugia for flora and fauna (Marshall & Moonen, 2002). To our knowledge very few studies have described the vegetation of UVS. Mézière *et al*., (2016) showed that 33% of the species present within UVS were never found in adjacent crop alleyways. However this result was restricted to only one field, in Southern France (Hérault). The purpose of this study was to confirm this result over more fields. Vegetation surveys were carried out in May 2017 in South-Western France over 16 winter cereal fields (8 alley cropping systems and 8 pure crop controls), either under conventional or organic management. The study revealed that UVS harboured richer, more even and more abundant floras – including species that are rarer in arable habitats – compared to crop alleyways and pure crop controls, especially under conventional management. Enhanced plant diversity at field scale is likely to have positive impacts on higher taxa that provide ecosystem services, such as pollinators and natural enemies.

Figure 1. Understory vegetation strips of alley cropping systems in South-Western France (March 2017). Picture: J.Poulmarc'h.

Keywords: semi-natural habitats, agricultural landscape, biodiversity conservation, weeds, community ecology.

References:

1. MARSHALL EJP & MOONEN AC, 2002, Agriculture, Ecosystems and Environment 89, 5–21
2. MÉZIÈRE D et al., 2016, EURAF 2016 Celebrating 20 years of Agroforestry research in Europe, 66–69

L04.1_O.04

Agroforestry and beekeeper-agriculturist relations in arable land (France)

Guillerme S. (sylvie.guillerme@univ-tlse2.fr), Maire E., Rhoné F.

GEODE, CNRS, Toulouse, France

For the past twenty years, bees have been threatened in French field crop regions. Nectar and pollen resources are gradually being depleted, both quantitatively and qualitatively, in particular as a result of ecosystem degradation through the reparcelling, the disappearance of hedges, the increasing use of herbicides and insecticides for field crops and early grassland cutting. This situation accentuates the weakness of the colonies.
The work carried out in various field crop areas of the Gers department (south of France) questions farmers and beekeepers on the one hand on their relationship to bees and melliferous resources linked to tree elements in the agricultural environment and landscape diversification, and on the other hand on the evolution of agricultural and beekeeping practices and knowledge. It also questions the strengths and weaknesses of different types of agroforestry systems.
The analysis of the discourses highlights three important periods: before 1950, from 1950 to 1980 and since 1980, showing how landscapes and practices have changed from self-sufficient to highly specialized systems. The diachronic approach used highlights the diversity of perceptions and representations of farmers and beekeepers regarding the evolution of their activities and issues.

Keywords: Biodiversity production, pollinators, stakeholders perception, diachronic approach, ecosystem degradation.

References:

1. Guillerme S.et al., 2015, Quae Editions, pp.141-158.
2. AFSSA, 2009, Rapport Novembre 2008, 155p.
3. Backman J.P.C., Tiainen J., 2002, Agriculture, Ecosystems and Environment, 89, 53-68.
4. Gallai N., Salles J.M., Settele J., Vaissière B.V., 2009, Ecological Economics, 68(3), 810-821.
5. Varah A., Jones H., Smith J., Potts S.G., 2013, Journal of the Science of Food and Agriculture

L04.1_O.05

Plant diversity level does not affect cocoa productivity: The case of Colombian agroforestry systems

Jaramillo M. A.[1] (maria.jaramillo@unimilitar.edu.co), Nossa-Silva D.[1], Sánchez-Marroquín H.[1], Peña-Varón J.[1], Deheuvels O.[2]

[1] *Applied Biology, Universidad Miltiar Nueva Granada, Cajica, Colombia*; [2] *UMR SYSTEM, CIRAD, Lima, Peru*

Cacao is a major commodity crop that is mostly planted in small plots managed by family workforce in agroforestry systems (AFS). AFS are productive systems that combine a diverse canopy and provide opportunities for preserving biodiversity while sustaining rural livelihood. However, the role of the diversity and structure of the associated plant community on cocoa's productivity is still poorly assessed, especially in Colombian AFS. We selected fifteen cacao-based AFS in the upper Magdalena region of Colombia. In each one, we used a 1,000 m2 plot to characterize the diversity, structure and uses of the associated plant community. Additionally, we described the cocoa tree populations by measuring plantation density, age, and size of the cocoa trees. Finally, we characterized management practices by conducting farmers interviews to assess the frequency of pruning, application of fertilizer and manual pest control. AFS were ranked by multivariate analysis according to (i) management intensity, and (ii) plant functional groups based on the uses by humans. Four types of AFS differed on their management intensity and ranged from old plots planted at low density and based on traditional varieties to young plots planted at high densities of improved cacao varieties. Three types of AFS differed for their plant functional groups and included plantations where either fruit, timber or service trees predominated. Cocoa yield was in average low and although it widely varied among farms, differences were not significant among management or plant functional group types. As expected, cacao yield was positively affected by the proportion of improved cacao varieties and negatively affected by the proportion of unproductive cocoa trees. However, cacao yield was not affected by associated plant diversity. When most approaches to increase productivity are focused on replacing unproductive cacao trees with improved cacao varieties, we suggest that associated plant diversity should also be taken into account to diversify products and increase overall productivity, especially when the selected species do not affect cocoa yield. Better planning and management of associated plant species within cocoa-based AFS could provide further benefits to farmers such as provition or regulation ecosystem services. Research funded by UMNG Grant CIAS 2304.

References:

1. plant functional groups
2. Theobroma cacao
3. Colombia Peace Agreement
4. management intensity
5. plant species richness

L04.1_O.06

Ecological role of grassy and forest habitats in soil-related biodiversity in an intensive agricultural area

Kiss-Szigeti N. (szigeti.nora@uni-sopron.hu), Berki I., Vityi A., Winkler D.

University of Sopron, Sopron, Hungary

Intensive agricultural technics have different disadvantageous effects on the ecologic conditions of the land. The complex land use offers a wider range of benefits. The ecological importance of linear and insular uncropped habitats, including forest shelterbelts and patches, grass margins, has already been emphasized by numerous studies. In our research we investigated the impact of grassy and forest habitats on the biodiversity in an intensively managed agricultural area in the Little Hungarian Plain. We concentrated on the diversity of herbaceous plants and soil microarthropod communities, which sensitively indicate the effect of forest and grassy ecotones on ecological conditions. Surveys were carried out in five habitat types: cultivated arable field, grassland, forest, forest shelterbelts, grassy ecotones between the shelterbelts and cultivated fields, respectively. The vegetation was sampled by quadrat method, while soil core samples were taken for soil mesofauna analyses. To assess the biological quality of soil, the QBS-ar index was used. The number of herbaceous species were the highest in grassy quadrats, farther from the shelterbelts. Inside the tree plantations only a few forest specific species appeared. Among soil microarthropods, Acari and Collembola were by far the most abundant taxa in all habitats, while important groups like Pauropoda, Protura and Symphyla were only present in the forest and grassy habitats. These observations were also reflected by the higher values of the soil biological quality (QBS-ar) index in the mentioned habitats. Collembolan species richness and diversity peaked in the forest belts, while their values were the lowest in the samples taken from cultivated fields. Abundance of springtails showed high values also in grassy strips and occasionally in arable fields.

Keywords: silvoarable systems, forest shelterbelts, herbaceous plants, soil mesofauna, soil biological quality.

References:

1. Altieri 1999. Agric. Ecosyst. Environ. 74, 19–31. DOI: 10.1016/B978-0-444-50019-9.50005-4
2. Moreno et al. In: 3rd European Agroforestry Conference 2016, Book of Abstracts, Montpellier, 24–27
3. Parisi et al. 2005. Agric. Ecosyst. Environ. 105, 323–333. DOI: 10.1016/j.agee.2004.02.002
4. Torralba et al. 2016. Agric. Ecosyst. Environ. 230, 150–161. DOI: 10.1016/j.agee.2016.06.002

L04.1_O.07

Taxonomic and functional diversity of insects within a nettle-poplar plantation on a sediment landfill

Yung L. (loic.yung@edu.univ-fcomte.fr), Chalot M., Chiapusio G., Bertheau C.

UMR 6249, Lab. Chrono-environnement, Montbéliard, France

Phytomanagement, which combines techniques using plants to extract, contain or degrade pollutants, appears as efficient nature-based solutions for the rehabilitation of contaminated soils. The present study aimed at evaluating the entomological diversity and its beneficial aspect at a phytomanagement field trial, consisting of a mixed plantation of poplars and spontaneous stinging nettles (*Urtica dioïca*). In natural conditions, nettle hosts a large diversity of insects, including some auxiliary species (James et al., 2015), which could be involved in the bio-control of poplar pests. The entomological inventory was performed monthly during 2017 and 2018 using multidirectional window flight traps combined with active catching. In 2017, 1484 insects were collected and grouped on 154 taxa identified up to the genus level for 61%. Nine orders were represented with the coleopteran, hemipteran and dipteran accounting for 95% of the total abundance. The ratio of phytophageous / predatory was 23 ± 6 %. Diversity indexes showed a high taxonomic and functional diversity comparable to those observed in natural patches of nettles (Davis, 1989). We highlighted that nettles growing between poplars offers a natural reservoir of entomological biodiversity that seems beneficial to the whole agro-system. We also confirmed that the nettle-related insects were not directly implicated in the transfer of contaminants at the studied agro-forestry system.

Experimental agroforestry system based on a mixed plantation of poplars-stinging nettles, located on a sediment landfill

Keywords: Contamination, Insect diversity, Nettle, Phytomanagement, Poplar.

References:

1. James et al, 2015, Pan-Pac. Entomol. 91, 82–90.
2. Davis, 1989, Bolletino Zool. 56, 321–326

L04.1_O.08

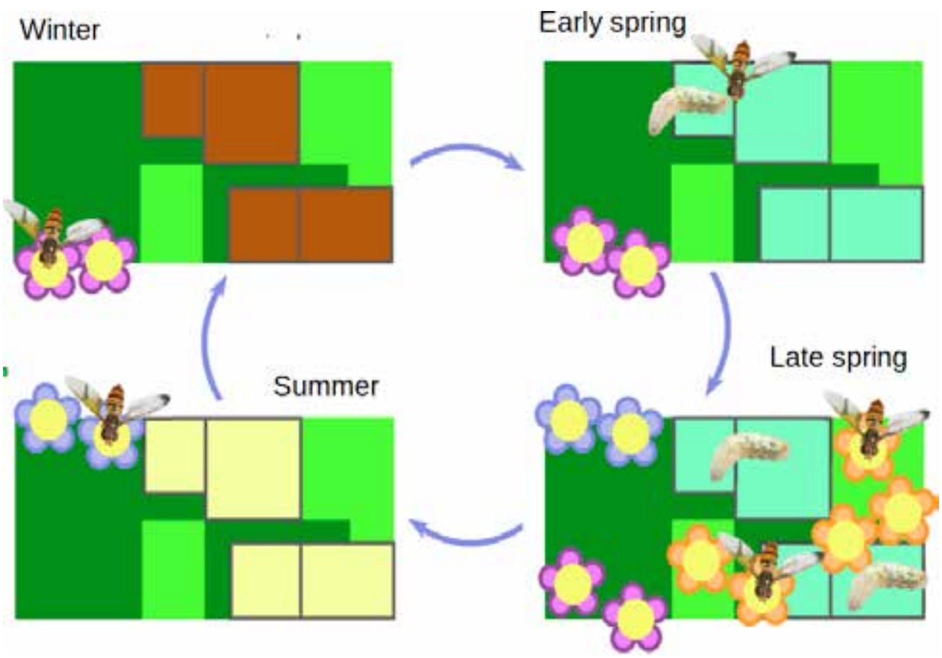
How trees in agricultural landscapes structure pollinator communities ?

Andrieu E.[1] (emilie.andrieu@inra.fr), Carrié R.[2], Villemey A.[3], Alignier A.[4], Vialatte A.[5], Ouin A.[5]

[1] *UMR1201 Dynafor, Inra, Castanet Tolosan, France*; [2] *Centre for Environmental and Climate Res, Lund, Sweden*; [3] *Irstea, Nogent sur Vernisson, France*; [4] *UMR 0980 BAGAP, Inra, Rennes, France*; [5] *UMR1201 Dynafor, INP Ensat-Inra, Castanet Tolosan, France*

Insect pollinators play a pivotal role in agricultural landscapes, supporting both biodiversity and food production. However, intensification of agricultural practices and the subsequent landscape simplification have threatened pollinator abundance and diversity via important losses and fragmentation of semi-natural habitats. These perennial elements are mainly permanent grasslands and rural forests, i.e. farm forests and trees outside forests like scattered trees or hedgerows, that compose agroforestry landscapes. They provide feeding resources but also overwintering and nesting sites for pollinators such as wild bees, butterflies and hoverflies.

We present here a synthesis of several studies we conducted on the effects of rural forests on pollinator abundance and diversity and how they structure pollinator communities and functional assemblages. We focus on their role on spatial and temporal resource complementation (wild bees and hoverflies) and their role on spatial connectivity (wild bees and butterflies). We also explore how the effect of rural forest on functional assemblage could buffer agricultural intensification. These studies highlight the need for a small-scale mosaic of crops, grasslands and rural forests to sustain pollinator biodiversity.



Temporal habitat complementarity for Episyrphus balteatus, a pollinator and aphid predator. Winter: females hoverwintering in woods feed on late flowering species occuring in south-facing edges. Early spring: females lay up eggs in crops surrounding woods, their aphidophagous larvae cause an early control of aphids. Late spring: flowers are available in semi-natural habitats and in some crops, adults scatter in the landscape and lay up eggs not only in the close proximity of woods. Summer: flowering resources are scarcer, adult feed on flowers in north-facing edges.

Keywords: landscape ecology, pollinators, farm forest, agricultural intensification, connectivity.

L04.1_O.09

The effect of land use types on insect diversity and composition in tropical agroforestry system

Rachmawati R.[1] (rina_rachmawati@yahoo.com), Rizali A.[1], Prayogo C.[2], Rowe R.[3], Suprayogo D.[2], Abadi A. L.[1], Hairiah K.[2]

[1] *Plant Protection, Brawijaya University, Malang, East Java, Indonesia*; [2] *Soil Science, Brawijaya University, Malang, East Java, Indonesia*; [3] *Center for Ecology and Hydrology, Lancaster, United Kingdom*

Land-use intensification is rapidly increasing in regions that harbor high levels of biodiversity, thus posing a serious threat to the stability and resilience of these ecosystems (Mumme et al, 2015). The expansion of monoculture crops has been directly linked to large-scale losses of biodiversity and ecosystem functioning (Barnes et al., 2014). Agroforestry has been proposed as an alternative to agriculture for smallholder farmers throughout the tropics in order to enhance ecosystem service supply and conserve biodiversity (Kearny et al. 2017). Insects are important bio-indicators of forest health. Each type of insect has an important role in ecosystem; therefore it is very important to maintain the existence of these species. Nevertheless, only a view studies has been reported regarding the response of several species of insects in tropical agroforestry system. In this report we bring together these four important insect taxa, namely ant, borer beetle, parasitoid wasp, and dung beetle to study for their response in terms of species richness, species abundance and their compositions from five land use types in agroforestry system in Indonesia. The method used was a field survey in UB Forest Malang, Indonesia. Types of land use in UB Forest being used as plots were pine intercropping with vegetables, pine intercropping with Coffee, mahogany intercropping with taro, mahogany intercropping with Coffee, and protected areas, with three repetition in each land use. Different types of insect traps were installed in the sub plot, depending on the insect taxa. All ant specimens were identified to the morphospecies level by referring to the book Identification Guide to Insect. The measurement of species diversity was calculated using the Shannon-Wienner diversity index formula (H'). Results between different land use were analyzed using variance analysis (ANOVA). Further tests on the similarity of the composition of the dung beetle community were calculated using Non-Metric Multi-Scaling (NMDS). All data processing was conducted using the vegan package from the R-Statistics software (R Development Core Team 2018). The results showed that all land use types significantly affected only species abundance, with various effect from negative to positive effect, with the exception for Hymenopteran parasitoid that was being affected both for species richness and abundance. Protected areas were the land uses that had highest abundance of woodborer and hymenoptera parasitic. As for the highest number of individuals for ants and dung beetle were found in pine intercropping with coffee. From this study it can be concluded that in general, different land use affected species abundance rather than species richness of the four species. Species compositions of the four insect taxa were significantly affected by land use type. Overall observations showed that protected areas has more species compositions rather than in any other four land use types.

Keywords: insect species richness, species abundance, ants, borer beetle, parasitoid.

References:

1. S. Mumme et al., 2015, Biological Conservation 191, 750–758.
2. L. Gibson et al., 2011, Nature 478, 378–381.
3. A.D. Barnes et al., 2014, Nat. Commun. 5, 5351.

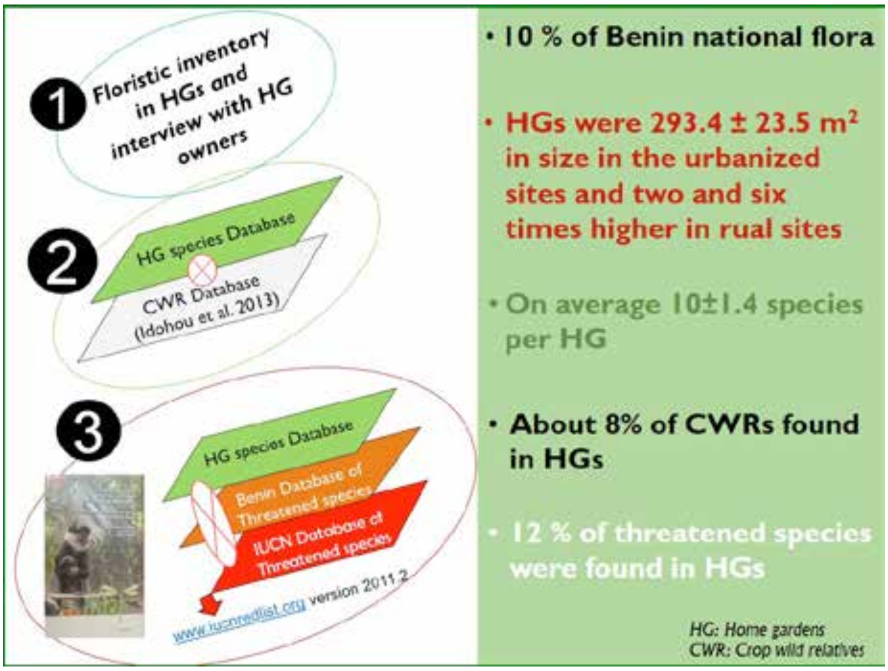
L04.1_O.10

Homegardens in Benin: countrywide flora and contribution to conservation of threatened species and crop wild relatives

Salako K. V. (salakovalere@gmail.com), Gbedomon C. R., Glèlè Kakaï R., Assogbadjo A. E.

Natural Resources Management, LABEF/FSA/UAC, Cotonou, Benin

Despite growing literature supporting the importance of home gardens (HG) as biodiversity hotspots, knowledge of patterns of their contribution to conservation of threatened species and crop wild relatives (CWR) across climate and culture in Africa is still limited. This investigation was conducted across three climatic zones to assess the floristic diversity of HG and the extent to which they contribute to conservation of threatened species and CWR. Overall, 240 HGs were sampled and their floristic diversity assessed. The ecological importance of recorded species was determined per climatic zone using the importance value index (IVI). A cluster analysis was performed to group the species according to their IVI-values and a principal component analysis helped to identify the most important species. 285 species were inventoried throughout the study area. Home garden species' diversity globally declined from the drier to the wetter zone but was highest in the transition zone. The average number of species found per HG was 10.1 ± 1.4 and varied weakly across zones. The most important HG species differed across zones but has similar uses. They were mainly vegetables and used as food and/or medicinal plant species. Twenty CWR and twelve threatened species were recorded and were also mainly used for food and medicinal purposes. Detailed studies are still needed to understand the HG socio-ecological system, its dynamics and effectiveness in conserving biodiversity.



Methodological approach and key results of a countrywide assessment of homegardens biodiversity and contribution to conservation of threatened species and crop wild relatives in Benin

Keywords: Conservation status, Climatic zones, Agroforestry, Floristic inventory, West Africa

L04.2_O.01

EARNEST: Examining the agroforestry landscape resilience in India to inform socioecological sustainability in the tropics

Kulkarni C.[1] (charuta.kulkarni@open.ac.uk), Bhagwat S. A.[1], Finsinger W.[2], Nogué S.[3], Anand P.[4], Willis K. J.[5]

[1] *Geography, The Open University, Milton Keynes, United Kingdom*; [2] *ISEM, Univ Montpellier, CNRS, EPHE, IRD, Montpellier, France*; [3] *Geography and Environment, University of Southampton, Southampton, United Kingdom*; [4] *Environment, Earth and Ecosystems, The Open University, Milton Keynes, United Kingdom*; [5] *Long-Term Ecology Laboratory, University of Oxford, Oxford, United Kingdom*

The effective management of human-dominated tropical forest landscapes is crucial in the wake of global climate change affecting biodiversity, ecosystem functions, and the livelihoods of billions. Among varied land management practices in the tropics, agroforestry remains one of the most promising, promoting deliberate maintenance of forest cover for productive agriculture, facilitating avenues for mitigating climate change and enhancing ecosystem functions. Considering these merits, the Indian Government launched the National Agroforestry Policy (NAP) in 2014, world's first, nationwide policy with a central idea of doubling the agroforestry area concurrent with expansion of national forest cover[1]. As the world's most populous country, yet its fastest growing economy, moving towards "Green India" would be a serious game-changer for this tropical country with positive global environmental implications. The effective implementation of this economically valuable policy falls on the shoulders of Indian Forest Departments (IFDs), who uphold a strict policy of preventing fires in and around forests. Fire is an integral part of forest ecosystem functioning and its strict prevention leads to accumulation of biomass load, causing more/severe fires[2]; this scientific evidence emerged from palaeoecology led other post-colonial countries towards adopting prescribed burning[3,4.] Such evidence is vital to age-old, human-dominated Indian agroforestry landscapes where people have traditionally used fires in shifting cultivation[5]. This disagreement in fire practices often instigate serious conflicts between local communities and IFDs, hampering implementation and the desired impact of the NAP and its associated socio-ecological benefits. In this context, using palaeoecology-driven innovative statistical modelling methods (e.g. pollen-based REVEALS modelling, rarefaction and multivariate ordination), we examine the resilience of Indian agroforestry landscapes in relation to past fire regimes and monsoonal variability, thereby analysing their capacity to sustain biodiversity across the Common Era. To explore its applicability to other parts of the tropics, we use the model system, Western Ghats of India, one of world's biodiversity hotspots supporting the highest population density through agroforestry. Moreover, these age-old agroforestry landscapes often coexist with community-based conservation in the form of sacred groves, thus comparing forest trajectories from these two eco-units provides an ideal opportunity to develop regional resilience scenarios against human and natural regimes at a 20-50 yr resolution. This resolution renders a tangible window for building policy implications for fire management practices in relation to assess sustenance of biodiversity in the light of NAP. Our work is part of project "EARNEST" that has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement no. 795557.

Keywords: Pollen-based land-cover, past landscape burning, impacts of changing monsoon, biodiversity changes in its tropical hotspot, Anthropocene.

References:

1. Government of India, 2014, National agroforestry policy.
2. Swetnam, et al., 2012, Ecol. Appl. 9, 1189–1206. 10.1016/j.palaeo.2009.09.014
3. Burrows, 2008, For. Ecol. Manage. 255, 2394–2406. 10.1016/j.foreco.2008.01.009
4. Keane, 2008, Int. J. Wildl. Fire 696–712.
5. Gadgil, et. al. 2013. 10.1093/acprof:oso/9780198077442.001.0001

L04.2_O.02

Farmers' contributions to the conservation of tree diversity in the Groundnut Basin, Senegal

Sambou A. (tonysambouegos@yahoo.fr)

Agroforestry, Assane Seck University of Ziguinchor, Ziguinchor, Ziguinchor, Senegal

Tree diversity in West Africa is threatened by intensified land uses and salinization, and farmers' role in conservation of tree species is unclear. We hypothesized that farmers contribute to conservation of tree diversity through protection of trees in their agroforestry landscapes and compared the diversity and structure of the tree vegetation across landscape classes. Inventories were carried out in three villages in the Groundnut Basin in Senegal, assessing tree diversity, density and crown cover. Tree diversity as assessed by species accumulation curves was high in forests, but cultivated landscapes had comparable or almost comparable diversity, especially in the cases where the forest was planted or was affected by charcoal production. However, the occurrence of exotic species was higher in cultivated parts of the landscape, and although many species were in common, ordination plots indicated that forests and cultivated landscapes to some degree had
different species composition. Salinity had a strong influence on vegetation, not only in the tans (salt marshes) but also across the other landscape classes. In conclusion, agroforestry landscapes in the three villages harbor considerable tree diversity, but insufficient to fully conserve the tree species. We argue that informing and including farmers in tree management in the region will contribute to overall conservation of tree genetic resources.

L04.2_O.03

Biodiversity conservation value of swidden agroforestry systems vs. RSPO oil palm in West Kalimantan, Indonesia

Simamora T. I.[1] (trifosaiin@gmail.com), Suriyanto I.[2], Dewo S.[2], Laumonier Y.[3]

[1] *Sustainable Landscapes and Food systems, CIFOR, Bogor Barat, Jawa Barat, Indonesia*; [2] *Forestry Faculty, Tanjungpura University, Pontianak, Indonesia*; [3] *UR 105 Forests and Societies, CIRAD, Montpellier, France*

The loss of biodiversity following forest conversion into monoculture plantations is well documented in SE Asia. The effectiveness of land sparing or integrating "wildlife-friendly" management into agricultural landscapes to maintain biodiversity is still a matter of debate. This study examines biodiversity conservation value of forest fragments in two types of land management: monoculture oil palm plantation under RSPO scheme, and agroforestry systems within swidden landscapes in the last forest frontier of West Kalimantan province. The area is a mixture of forested and agricultural lands dominated by swidden traditional practices, while oil palm plantations are expanding.

We studied three sites representing different intensities of forest fragmentation at various distances from the contiguous forest. We surveyed swidden landscapes featuring natural forest, old and young fallows, smallholder jungle rubber plantations and forest remnants patches (mixed dipterocarp, peat swamp, and Kerangas forests) in oil palm concession. At each site, trees, birds and soil arthropods were sampled. Plots were laid for tree measurements (60 plots; 20 m x 20 m), bird recorded using timed point-counts and mist nets (120 points; 2087 mist-net hour), and litter-soil sample (140 trays) collected for soil arthropods identification. We used ordination, indicator species analysis, and statistical tests to assess the biodiversity conservation value of forest fragments.

As expected, trees and birds species diversity were highest in natural and old secondary forest, but swidden agroforestry systems were also considerably biodiversity-rich largely outperforming oil palm forest fragments and rubber monocultures in terms of bird species richness. Natural forest and old fallows sustained a higher number of endangered bird species compared to young fallows and monoculture plantations. The species richness of soil arthropods -as ecosystem engineers- was also significantly highest in natural and old secondary forest, with Acari, Hymenoptera, Collembola, and Coleoptera being the most abundant.

Traditional agroforestry systems should be maintained and managed to support forest successional stages and high biodiversity at the landscape level. Agroforestry patches in swidden landscape significantly harbored more diverse species composition than forest fragment remnants in oil palm concession and were even comparable in term of species richness to natural forests. Oil palm concession in our study site still contained high conservation value forest patches, but these particular patches were considerably larger (c. 500-1000 ha) than the one ha blocks preconized by the RSPO scheme. The question remains if these forest patches will remain resilient in the long run since connectivity with the contiguous forest has been lost.

Keywords: Biodiversity, Swidden, Agroforestry, Oil palm, RSPO.

L04.2_O.04

Dynamic agroforestry, a systemic approach of farming in the tropics improving biodiversity, soil fertility and yields

Milz J.[1] (j.milz@ecotop-consult.de), Kazuya N.[2], Armengot L.[3], Soto V.[1], Schneider M.[3], Mamani B.[1], Jacobi J.[4]

[1] *ECOTOP, La Paz, Bolivia*; [2] *Instituto de Ecología, Universidad Mayor de San Andres, La Paz, Bolivia*; [3] *SysCom, Research Institute of Organic Agricultur, Frick, Switzerland*; [4] *Centre for Development and Environment, University of Bern, Bern, Switzerland*

Dynamic agroforestry systems DAF (also “syntropic farming”) feature multi-purpose and natural regeneration trees and many crops, based on natural succession dynamics: Crops and trees are grouped as pioneers (lifespan < 8 months), secondary (lifespan <80 years) or primary species (life span>80 years), to form a composition in which all storey (spatial) and all phases (temporal) are occupied, optimizing density and diversity. Where orange or cocoa is the main crop, a DAF can start with maize and rice in combination with manioc and pigeon pea, followed by banana and papaya, pineapple and Inga sp., providing shade for slowly growing primary forest species. Timber as a long-term investment dominates the system after 10–15 years, with cacao and oranges in full production. A most important experience is the benefit of land preparation without fire. The advantage of DAF can be seen already after a couple of months which helps to encourage farmers to extend the system step by step to the whole plantation.

Investigations carried out in an orange plantation converted in a DAF system in Alto Beni, Bolivia indicates less abundance of fruit flies (*Anastrepha spp*. and *Ceratitis captitata*) in oranges in dynamic agroforestry with significantly higher yields and the same sugar content, significantly more humus in soils and a deeper Ah-horizon than in comparable monocultures.

The plantation includes now more than 60 species of timber and fruit trees in different canopy layers below and above the citrus trees. More than 1.000 trees and palms are present per hectare, and soil fertility has increased in line with the development of the supporting flora within the plantation

The birds´ selection among five cocoa production systems and forest fallow, using a cafeteria experiment was carried out in the long-term System Comparison trial in the same region of Alto Beni, Bolivia. In this study, five different cacao production systems were assessed—full-sun monoculture and agroforestry systems under organic and conventional management, dynamic agroforestry system and a natural fallow. The birds were quantified by a modified point count during the dry season. 239 visits of 43 bird species belonging to 18 families were recorded. The number of visits was positively related to the complexity of vegetation structure and tree diversity, decreasing from fallow, dynamic agroforestry systems DAF, simple agroforestry systems and monoculture plantations. In the monocultures, the number of species was reduced to the half of that found in the fallow plots. The bird composition was similar between the DAF and the forest fallow, suggesting that the DAF, having a diverse vegetation structure, providing resources similar to the forest fallow. It is important to encourage complex agroforestry systems for bird conservation in agricultural landscapes.

A study on the economic viability of the same trial showed that agroforestry has a higher economic return on labour than mono-cropping.

Keywords: dynamic agroforestry, biodiversity, orange and cocoa, system comparison, birds.

References:

1. Milz, J., 2010, Ecología en Bolivia: 324-340
2. Armengot, L., 2016, Agron. Sustain. Dev.: 36:70
3. Kazuya, N., 2017, Ecología en Bolivia: 100-115
4. Götsch, E., 1994, ASPTA
5. Osterroth, M., 2002, Agroecologia hoje: 8-11

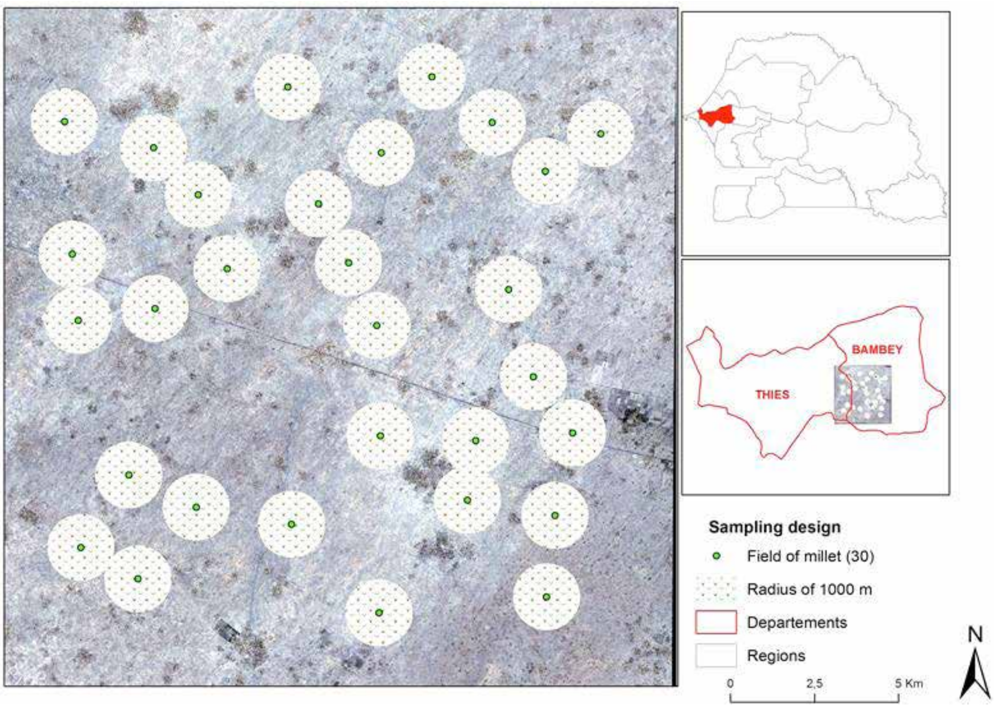
L04.2_O.05

Tree species effect on natural control of *H. albipunctella* de Joannis in a millet agroforestry system in Senegal

Thiaw I.[1] (thiawmy@gmail.com), Soti V.[2], Sow A.[3], Brevault T.[2], Diakhate M.[4]

[1] *Géographie, UGB, Saint Louis, UT, Sénégal*; [2] *PERSYST, CIRAD, Montpellier, France*; [3] *Biologie Animale, UCAD, Dakar, Senegal*; [4] *Géographie, UGB, Saint Louis, Senegal*

Association of several tree species in and around a plot can have a positive impact on ecosystem services. Thus, traditional agroforestry systems, characterized by a high plant diversity, constitute an ideal model of study to test if the natural tree vegetation provides both shelter and food resources for insects that could potentially improve biocontrol services. The main objective of this study was to test if tree species presence and diversity could enhance the natural regulation of the millet head miner *Heliocheilus albipunctella* (MHM) in agroforestry systems of the Senegalese Peanut Basin. To address our objective, we realized an inventory of tree species in a total of 30 millet fields surveyed in Bambey area, during 2013 and 2014 (Fig.1). These data were used to calculate indices related to the abundance and diversity of tree species. The natural regulation was estimated using the biocontrol service index (BSI) for each millet field. In addition, data on MHM egg and larval predation and parasitism rates were also collected to estimate biocontrol services. Statistical analysis of the effect of tree presence and diversity on natural regulation variables were tested using a linear regression. Surprisingly, we found that BSI decreased with tree diversity and that it increased with the presence of the tree species *Faidherbia albida*. Morever, the presence of *Anogeissus leiocarpus* enhanced MHM egg parasitism and the presence of *Azadirachta indica* favored MHM egg predation.



Bambey study area and the set of 30 millet field sites surveyed

Keywords: H. albipuntella, Tree species, natural regulation, Biodiversity conservation, Senegal.

L04.2_O.06

The richness of tree in agroforestry systems favors the diversity of soil macroarthropods in the humid tropics of Mexico

Villanueva-López G.[1] (gvillanueva@ecosur.mx), Casanova-Lugo F.[2], Aryal D. R.[3], Lara-Pérez L. A.[2], Oros-Ortega I.[2], Ramos-Reyes R.[4], Ramírez-Barajas P. J.[5]

[1] *Agroecología, El Colegio de la Frontera Sur, Villahermosa, Tabasco, Mexico*; [2] *División de Estudios de Posgrado e Inves, Instituto Tecnológico de la Zona Maya, Othón P. Blanco, Quintana Roo, Mexico*; [3] *Facultad de Ciencias Agronómicas, Villaflores, Chiapas, Mexico*; [4] *LAIGE, El Colegio de la Frontera Sur, Villahermosa, Tabasco, Mexico*; [5] *Instituto Tecnológico de la Zona Maya, Othón P. Blanco, Quintana Roo, Mexico*

The change in land use for livestock and agriculture is usually linked to a potentially devastating effect on flora and fauna communities. n the humid tropics of Mexico, Tabasco is one of the States with the highest rate of deforestation and, currently, more than 66% of its territory is destined to livestock. We evaluated the effect of different representative traditional agroforestry systems (AFS) on the diversity of terrestrial arthropods. The collection was carried out in 49 plots of 41 localities categorized by their structure and function in eight SAF. Ten pitfall traps were established in each plot during the dry season (March-May 2009). To compare the diversity of macroarthropods in the soil between the eight AFS, species accumulation curves and diversity indexes were made. A total of 42,270 individuals of arthropods belonging to 16 orders in the eight AFS were collected. The most abundant orders were Hymenoptera and Coleoptera, while the less abundant were Dermaptera and Haplotaxida. The greatest diversity of terrestrial arthropods estimated was recorded in the roza-tomb-burning system and family gardens, and the lowest diversity was for alley cropping and the taungya system. The results showed significant differences in the diversity of terrestrial arthropods in AFS with lower plant diversity compared to systems with greater diversity. The study suggests that AFS with greater botanical diversity are an important strategy to increase the productivity, diversity and conservation of arthropods.

Keywords: Agroforestry, Diversity of arthropods, Dry season, Conservation, Humid tropics.

L04.2_O.07

Vanilla boom in North-Eastern Madagascar: A chance for a sustainable land-use transformation?

Wurz A.[1] (annemarie.wurz@uni-goettingen.de), Martin D.[2], Osen K.[3], Andrianisaina F.[4], Fulgence T. R.[5], Hänke H.[6], März A.[3], Osewold J.[3], Rakotomalala A. A. N. A.[7], Raveloaritiana E.[8], Soazafy M. R.[9], Barkmann J.[6], Grass I.[1], Hölscher D.[3], Tscharntke T.[1], Kreft H.[2]

[1] *Agroecology, University of Goettingen, Goettingen, Germany*; [2] *Macroecology and Biogeography, University of Goettingen, Goettingen, Germany*; [3] *Tropical Silviculture and Forest Ecology, University of Goettingen, Goettingen, Germany*; [4] *Science Agronomy, University of Antananarivo, Antananarivo, Madagascar*; [5] *Zoology and Animal Biodiversity, University of Antananarivo, Antananarivo, Madagascar*; [6] *Environmental and Resource Economics, University of Goettingen, Goettingen, Germany*; [7] *Entomology, University of Antananarivo, Antananarivo, Madagascar*; [8] *Plant Biology and Ecology, University of Antananarivo, Antananarivo, Madagascar*; [9] *Natural Ecosystems, University of Mahajanga, Mahajanga, Madagascar*

Cash crops farmed in agroforestry systems can be an economically attractive opportunity for farmers while alleviating negative impacts on biodiversity and ecosystem functions. Whether such a win-win situation can be realized is, however, highly context-dependent. Here, we study the impacts of vanilla agroforestry in North-Eastern Madagascar - a biodiversity hotspot which loses forest cover at high rates to agriculture. This forest cover loss is mainly attributed to subsistence rice farming but the current vanilla boom driven by prices of up to 600€ per kilo may also lead to the encroachment of plantations into forests, thus reducing understory complexity and tree cover locally. However, vanilla plantations can also be established on open fallow land already highly disturbed by slash-and-burn practices ("tavy") leading to a potentially more sustainable land-use. The interdisciplinary project "Diversity Turn in Land Use Science" investigated on 216 vanilla plantation the relationship of crop productivity and biological diversity. We compared tree cover, biodiversity, and vanilla yields (a) of forest conversion plots vs. fallow conversion plots and (b) along a canopy cover gradient to investigate (i) how vanilla farming shapes canopy cover locally, (ii) how vanilla yields vary between plantation types and under different shade regimes, and (iii) how plantation type affects tree cover, biodiversity (avifauna, insects, plants, mammals, amphibians and reptiles) and associated ecosystem functions (i.a. predation, carbon storage, soil quality). We hypothesize that vanilla agroforestry negatively affects biodiversity inside primary forest, but that it may have positive effects if established on open fallow land leading to tree regeneration and thus an increase in tree cover. Yields are expected to peak at mid-canopy cover – potentially incentivizing tree clearance under high canopy cover and tree regeneration under low canopy cover. Thereby we investigate how the cultivation of the same cash crop might have very different outcomes for biodiversity and sustainable land-use depending on initial land-use. This knowledge is aimed to result in management advice or certification schemes that are sensitive to land-use prior to vanilla cultivation.

Keywords: biodiversity, canopy cover, Madagascar, vanilla agroforestry, yield.

L04.2_O.08

First typology of cacao agroforests in the Colombian Amazon, based on composition, structure and light availabililty

Suárez Salazar J. C.[1] (ju.suarez@udla.edu.co), Melgarejo L. M.[2], Di Rienzo J. A[3], Casanoves F.[4], Ngo Bieng M. A.[5]

[1] *Universidad de la Amazonia, Caqueta, Florencia, Colombia*; [2] *Universidad Nacional de Colombia, Bogota, Colombia*; [3] *Universidad Nacional de Cordoba, Cordoba, Argentina*; [4] *CATIE, Turrialba, Costa Rica*; [5] *CIRAD, UR Forêts et Sociétés, Turrialba, Costa Rica*

Background

The cultivation of cocoa in Colombia are of key social importance. Indeed cacao plays a prime role in post conflict resolution as it is the legal crop to replace illicit crops. In the current context of the need of combating climate change, cacao agroforests are also expected to be a sustainable practice, promoting forest-friendly land use. In that context, it is necessary to describe accurately these systems, and especially accounting for their potential in terms of biodiversity conservation.

Aim

In this work, we present a first a typology of cacao agroforest systems in Colombian Amazonia, systems that had yet to be described in the literature. This typology is based on tree species richness, canopy structure and light availability.

Material and Methods

We worked in 50 agroforest plots of 2000m² each, in the Bajo Caguán area of the department of Caquetá, in the Colombian Amazonia. In each plot, we measured variables of composition (diversity of plants associated with cacao trees) and variables of vertical and spatial structure (height layers, Diameter at Breast Height, basal area, shape and area of the crown, (x, y) positions of each individual plant in each plot. We also measured variables of radiation transmitted to cacao trees in the understorey: above the cacao canopy layer, we took hemispherical photographs and measured the intensity of Photosynthetically Active Radiation (PAR, in µmol m-2 s-1) using an AcuPAR LP-80 sensor. We included variables related to light availability to evaluate the amount of transmitted radiation to the cacao trees in each type, and its suitability for cacao ecophysiological development. We also use variables of spatial organization to model the distribution of light in each plot, using two models: Shademotion 4.0 to calculate the fraction of the average of shade hours and shade area in each agroforest plot and the Spatially individual-based Explicit Forest-Simulator to calculate the degree of canopy openness in each agroforest plot. We there used a cluster analysis to build a typology of cacao agroforest, based on 28 variables characterized in each plot, and related to diversity, composition, spatial structure and light availability for the cacao trees.

Major results and Conclusions

We identified 4 types of cacao agroforests. The typology was based on their differences in tree species diversity and the impact of canopy spatial structure on light availability for the cacao trees in the understorey. We also found 127 tree species in the dataset, with 3 out of the 4 types identified displayed an erosion of tree species diversity. This reduction in shade tree species may be linked to the desire to reduce shade, but we also found that all the types described were compatible with good ecophysiological development of the cacao trees. One challenging prospect will be to monitor and encourage the conservation of tree species diversity in cacao agroforest systems during the development of these cropping systems.

L04.2_O.09

Agroforestry as a restoration strategy: Motivations of farmers to plant more biodiverse systems in the Eastern Amazon

Coudel E.[1] (emilie.coudel@cirad.fr), Navegantes L.[2], Ferreira J.[3], Carneiro R.[2], Galvão L.[2], Almeida A.[2], Carvalho R.[2]

[1] *Cirad, Brasilia, Brazil*; [2] *UFPA, Belem, Brazil*; [3] *Embrapa, Belem, Brazil*

In Brazil, the forest legislation has opened up new options for forest restoration by smallholders, allowing in particular the use of agroforestry in conservation areas. This has triggered a vigorous national debate, involving social movements, scientists and policy makers: while these legislative changes may encourage farmers to engage in restoration, the provision of environmental services greatly varies according to the type of agroforestry system (AFS). However, few studies go beyond the technical aspects of restoration and studies assessing the social drivers are urgently needed.

To contribute to this debate, we analyzed restoration experiences of farmers in the Eastern Amazon, where there is a great diversity of AFS. Our objective was to understand why farmers had engaged in forest restoration and how these motivations influenced their management practices. Based on 136 questionnaires with farmers and in-depth analyses of their AFS, we elaborated a typology of different restoration systems based on the practices involved, in particular the number of species (see figure 1). 78% of farmers restore through AFS. Most of those who have pragmatical motivations (water, soil, products) have less diverse AFS. Those with broader environmental motivations (preoccupation with overall degradation and biodiversity loss) have more diverse systems. This points to the importance of building more awareness about the potential role of biodiversity in restoring environmental services.

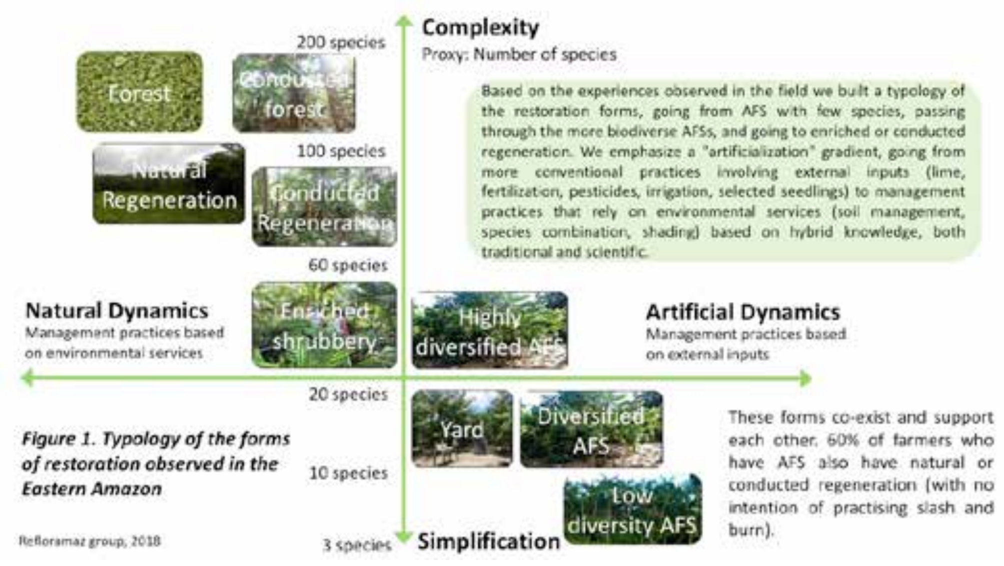


Figure 1. Typology of the forms of restoration observed in the Northeastern region of Pará

Keywords: restoration, motivations, biodiversity, family farmers, social drivers.

References:

1. Clewell & Aronson 2006. Motivations for the restoration of ecosystems. Conservation Biology, 20(2)

L04.2_O.10

Carbon stocks in agroforestry systems correlate with tree diversity

Sari R. R.[1] (rieqa_r@yahoo.co.id), Saputra D. D.[1], Hairiah K.[1], Roshetko J. M[2], Van Noordwijk M.[3]

[1] *Soil Science, Brawijaya University, Malang, East Java, Indonesia*; [2] *World Agroforestry Centre, Bogor, West Java, Indonesia*; [3] *Plant sciences, Wageningen University, Wageningen, Netherlands*

The degree to which maintenance of C stocks and tree diversity in practice can be jointly achieved in production landscapes is debated. Carbon stocks in forests decrease by logging before tree diversity is affected, while monoculture tree planting increases C stocks before diversity. Agroforestry can break this hysteresis pattern, relevant for policies in search of synergy. We compared five land use systems in Konawe District, Southeast Sulawesi, Indonesia: degraded forest (DF), complex cacao/fruit tree agroforests (CAF), simple shade-tree cacao agroforestry (SAF), monoculture cacao (CM), and annual crops (CR). Tree diversity (Shannon Index-H') and carbon stock were measured and estimated using the Rapid Carbon Stock Appraisal (RACSA) protocol. We added 48 data points from other studies which had similar methods of data collection. The data suggested intermediate positions for agroforestry systems, between forest decline and restoration responses (Fig1), with some medium-diverse low C stock, and medium- C stock low tree diversity points. Overall data indicate that maintaining agroforestry systems in the landscape allows the climate change control and biodiversity loss goals to be addressed simultaneously, in sustainable production systems.

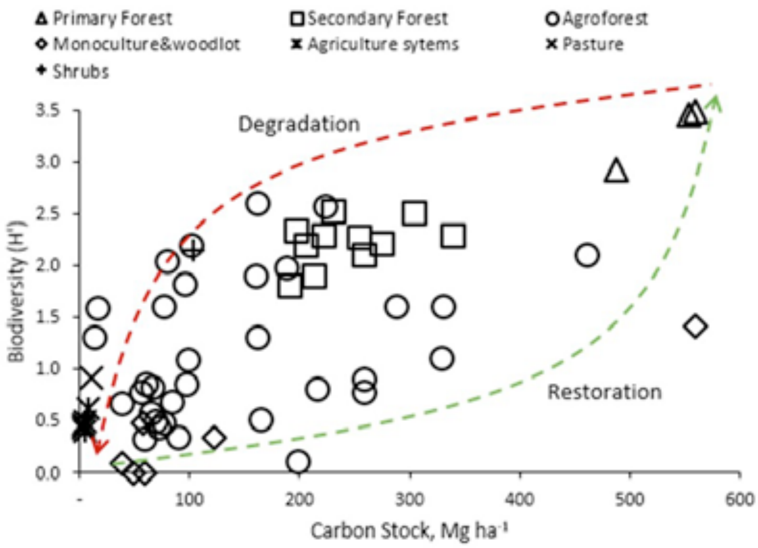


Figure 1. Carbon stock and biodiversity index (Shannon-wiener index) in different land use systems of Indonesia (Primary data from Konawe plus published data from Henry et al., 2009; Mandal et al., 2013; Markum et al., 2013; Kendom, 2013; Natalia et al., 2016; Kurniawan, 2018; Prayogo, 2018)

Keywords: Carbon stocks, Biodiversity, Agroforestry.

References:

1. Henry et al., 2009. Agric. Ecosyst. Environ. 129, 238–252.
2. Mandal et al., 2013. ISRN Botany, page 1-7.
3. Markum et al., 2015. Agrivita, page 207.
4. Natalia et al. 2017. Agrivita 39, 74–82.

L04.P.01

Species in agroforestry systems, Centre Côte d'Ivoire: contribution to ecosystem services and biodiversity conservation

Adou Yao C. Y.[1] (adouyaocy@gmail.com), Kpangui K. B.[2], Vroh B. T. A.[1], N'guessan K. E.[1]

[1] *UFR Biosciences, Université Félix Houphouët-Boigny, Abidjan, Côte d'Ivoire*; [2] *UFR Environnement, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire*

In Côte d'Ivoire, as in all West Africa, the cocoa farms from forests conversion results in drastic decline of forest biodiversity (Clough et al., 2011, *PNAS* 108 : 8311-8316.). Facing this unsustainable situation, agroforestry systems (AF) can offer a promising alternative, such as smallholders' plantations where trees have long been associated for diverse reasons. In a forest-savanna transitional zone, three AF have been defined (Kpangui et al., 2015, *IJAAR*, 36-47). Beyond the cocoa production of these AF, the peasants benefit from ecosystem services resulting from the species associated with the cocoa orchards. In order to assess these ecosystem services and analyze how the species contribute to biodiversity conservation, we conducted the present. We made botanical inventories to record the species associated with cocoa tree. Whereupon, we evaluated the provision of ecosystem services of the tree species, their biomass, and their contribution to biodiversity conservation (a special focus on the species with high conservation value).The study showed that most of the species are associated with cocoa trees to provide food and medicinal goods to local people. Tree biomass and rates of carbon sequestrated were important. The study has also showed that these three AF housed high conservation value species. The study suggested that agroforestry practices in center Côte d'Ivoire provide important ecosystem services as well as biodiversity conservation.

Figure 1: Aspect of a complex agroforest according to Kpangui et al. (2015) showing diverse trees in the high stratum above the cocoa canopy.

Keywords: Agroforestry systems, aboveground plant biomass, high conservation value of biodiversity, Côte d'Ivoire.

References:

1. Clough et al., 2011, PNAS 108 (20), 8311-8316
2. Kpangui et al., 2015, IJAAR 6 (3), 36-47

L04.P.02

Domestication of Wild Edible Mushrooms as an Agroforestry Crop for Biodiversity Conservation in Manipur, India

Apshahana K. (appibeck@gmail.com), Sharma A.K.

Silviculture and Forest Management, Forest Research Institute, Dehradun, Uttarakhand, India

The state of Manipur, India falls under the Indo-Burma global biodiversity hotspot and hosts a variety of species.Wild Edible Mushrooms (WEMs) are one of the key food sources of rural people and have a major dependence both for own consumption and for cash income.WEMs are known for its valuable dietary and medicinal properties worldwide.Some mushrooms are domesticated and grown for commercial use but many edible mushrooms are still wild in the forest. The study was conducted to document WEMs diversity which are consumed and traded by the Kuki and Naga tribes of Kangpokpi and Senapati districts. Seasonal markets survey were carried out during 2016-2018 to record the local names, sources of supplies and quantity traded.The survey recorded 8 edible macrofungi species, belonging to 7 families. Some of the widely traded WEMs are *Auricularia delicate*(Fr.)P.Henn., *Lentinula edodes*(Berk.) Pegler and *Schizophllum commune* Fr. These species were found to be associated with many promising agroforestry tree species such as *Alnus, Quercus*, *Castanopsis hystrix*, *Parkia roxburghii*, and *Phoebe hainesiana*. Therefore, promising agroforestry models can be developed incorporating these tree species, so that the availability of WEMs may be maintained thereby conserving its biodiversity and help in securing the livelihood of rural tribes by generating employment opportunities. Thus, this finding provides baseline data for future monitoring and establishing suitable agroforestry models in the region.

Fig: WEMs trading in the market (a) Lentinula edodes,(b) Schizophllum commune, (c) Auricularia delicate

Keywords: Wild edible mushrooms, Manipur, Biodiversity, Domestication, Employment opportunities for rural tribes.

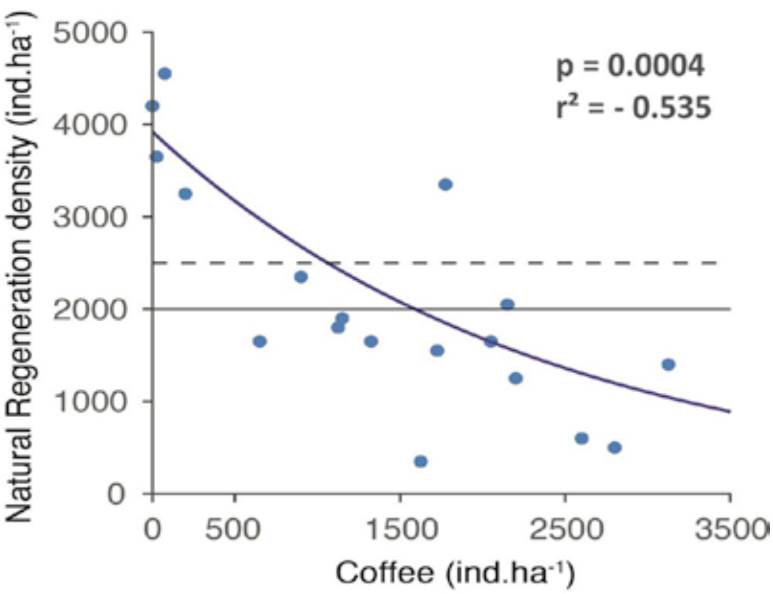
L04.P.03

Coffee agroforestry as an alternative for tropical forest restoration: compering with conventional restoration planting

Badari C. G.[1] (carolgbadari@yahoo.com.br), Bernardini L. E.[1], Viani R. A. G.[2]

[1] *Forest Sciences, ESALQ/USP, Piracicaba, SP, Brazil*; [2] *CCA/UFSCar, Araras, SP, Brazil*

Agroforestry systems (AFS) are among the most representative systems that integrate productive and ecological restoration goals. However, although AFS have been widely promoted as an eco-friendly land use, little is known about its potential for ecological restoration. Here, we compared the ecological outcomes of 12-15 years old coffee AFS (established with native shade-trees), conventional restoration plantations with similar age, and ecosystem reference (regional old-growth forests) within a forest and landscape restoration project at the Pontal do Paranapanema region, Atlantic Forest, Brazil. We compared the abundance, richness, and regenerating saplings among these forest types, and investigated the drivers of natural regeneration in coffee AFS. Reference forests had a much higher density of trees and saplings, yet at richness levels similar to coffee AFS. Although coffee AFS and plantations did not differ in their density of trees, coffee AFS had a higher density, richness, and proportion of animal-dispersed species of saplings and canopy cover than conventional plantations. However, the abundance of regenerating woody plants declined with coffee density, thus indicating that the restoration value of high coffee abundance AFS can be reduced, and a potential trade-off between ecological and productive outcomes. Despite that, the coffee AFS had greater ecological performance than the conventional restoration and can thus be an alternative for tropical forest restoration.



Negative binomial generalized linear model between the spontaneous regeneration abundance and the coffee abundance in coffee agroforestry systems at Pontal do Paranapanema landscape, São Paulo, Brazil. Values above the dotted line are considered adequate, and below the continuous line are considered critical according to the legal ecological standards of São Paulo State to attest forest restoration compliance.

Keywords: Forest and Landscape Restoration, Coffee arabica L., Ecological indicators, Tropical forest restoration, Coffee agroforestry.

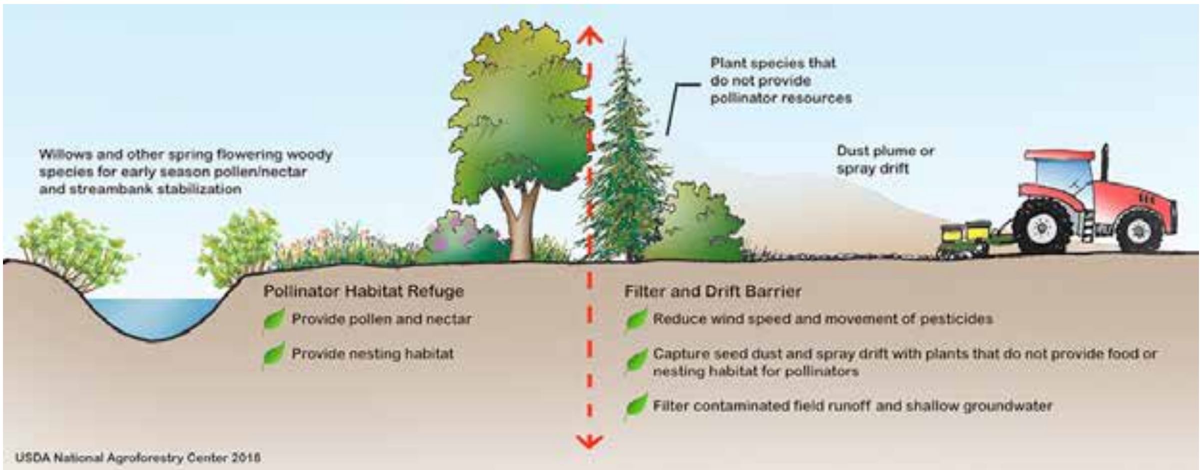
L04.P.04

Supporting pollinator conservation in the United States with agroforestry

Bentrup G.[1] (gbentrup@fs.fed.us), Stein S.[2], Adamson N.[3], Hopwood J.[4], Powers R.[5], Vaughan M.[6]

[1] *USDA National Agroforestry Center, U.S. Forest Service, Lincoln, NE, United States*; [2] *USDA National Agroforestry Center, U.S. Forest Service, Washington, DC, United States*; [3] *Xerces Society for Invertebrate Cons., Greensboro, NC, United States*; [4] *Xerces Society for Invertebrate Cons., Omaha, NE, United States*; [5] *Xerces Society for Invertebrate Cons., Lincoln, NE, United States*; [6] *Xerces Society for Invertebrate Cons., Portland, OR, United States*

Pollinators, especially bees, are facing many threats, from loss of habitat to pesticide exposure. Agroforestry can play a central role in the creation and management of critical pollinator services, especially in organic, specialty, and small-scale agricultural and forest systems. With proper selection of species and design criteria, agroforestry practices can provide pollinator services in addition to other ecosystem goods and services. This presentation summarizes the scientific literature on the benefits and potential issues of using agroforestry to support pollinator conservation and services within temperate regions of the United States. Agroforestry can offer sources of pollen and nectar, resin for honey bees to form propolis, and stable nesting and larval habitat in frequently-disturbed agricultural landscapes. Windbreaks and other practices can reduce windspeeds in fields, minimizing the desiccation of floral resources while also allowing pollinators to forage during high wind events that would normally reduce or prohibit foraging. These practices may provide adequate local scale habitats to support short distance foragers and increase crop pollination. When appropriately designed, these practices can help reduce pesticide drift and exposure to pollinators. Emerging research suggests that agroforestry practices might offer more resilient habitats needed to cope with climate change and may enhance landscape connectivity to facilitate pollinator range shifts.



Keywords: pollinators, agroforestry, pollination services, bees, insects.

L04.P.05

Traditional cocoa base agroforets in mid-west COTE D'IVOIRE: floristic diversity and conservation value for biodiversity

Cisse A.[1] (abdoulayeciss@rocketmail.com), Vroh B. T. A.[2], Adou Y. C. Y.[2], N'Guessan K. E.[2]

[1] *Botanique, Université Felix Houphouët-Boigny, Abidjan, Abidjan, Côte d'Ivoire*; [2] *Botanique, Université Félix Houphouët-Boigny, Abidjan, Abidjan, Côte d'Ivoire*

In the current context of deforestation, farming practices constitute a loss of forest biodiversity in tropical countries (Jagoret, 2011). In Côte d'Ivoire, in particular, cocoa cultivation has long been considered one of the main causes of forest biodiversity loss. However, several studies have shown that these agroforestry systems contain a greater diversity of species (Kpangui et al., 2015) than monocultures. In order to examine the impact of this cultural practice on biodiversity, we analyzed and compared the ligneous flora of different cocoa based system. During this work, ethnobotanical surveys were conducted among 223 cocoa farmers. The data from these surveys were supplemented by botanical inventories on 115 plots of 625 m^2 . The analyses show that, at the floristic level, 176 species of plants have been identified in cocoa plantations. The analyses also show that these plantations contain a high proportion of endemic species, rare and endangered species listed on the 2016 IUCN Red List, which gives them exceptional and patrimonial values for biodiversity conservation. Surveys confirmed that beyond the production of cocoa beans, the practices of local populations show that women used these tree species for food and medicinal purposes. All of these contribute to the preservation and conservation of biodiversity.

Cocoa-based agroforest in west-central Côte d'Ivoire (Lakota)

Keywords: Biodiversity, Conservation values, Agroforestry systems, cultural practices, Côte d'Ivoire.

References:

1. Jagoret, 2011. doctoral dissertation, Montpellier, SupAgro p.5
2. Kpangui et al., 2015 IJAAR, 6 (3): p.36-47

L04.P.06

Soil-litter edaphic macrofauna in an agroforestry system with oil palm tree and monoculture in Amazonia

Costa N.[1] (nailamartins@yahoo.com.br), Coimbra L.[1], Vasconcelos S.[2], Castellani D.[3]

[1] *Lab. de Análises de Sistemas Sustentávei, EMBRAPA Amazônia Oriental, Belém, Pará, Brazil*; [2] *Lab. de Análises de Sist. Sustentáveis, EMBRAPA Amazônia Oriental, Belém, Pará, Brazil*; [3] *Tec. de prod. vegetal e manejo da biodiv, Natura Inovação, Cajamar, São Paulo, Brazil*

The edaphic macrofauna gathers invertebrates whose action optimizes nutrients cycling and are sensitive to changes in vegetation cover (Lavelle, 2001). Oligochaeta, Blattodea and Hymenoptera form the group called “soil engineers”, because they modify it with their mechanical action. In view of the expansion of the oil palm culture in the Amazon, we conducted a study of the macrofauna community to understand how this culture impacts these organisms. We selected an organic biodiverse Agroforestry System (AGS) with 10 (ten) years old oil palm tree, and a traditional monoculture management in Tomé-Açu, Pará, Brasil. We adapted the method of Anderson et al. (1994) and removed in each system 9 (nine) blocks of soil (25x25x10cm) with the associated litter, divided in three transects of 18m. We used the software PAST (Hammer et al, 2001) for diversity-analysis.

The community of AGS macrofauna is more diverse and is well distributed among the taxon (Figure 1). The high density (1004,4 ind.m-2) in monoculture is the result of Blattodea highest frequency, confirmed by dominance. The frequency of the predator Hymenoptera in the AGS reflects a structured food web. Monoculture presented only 8% of Oligochaeta, this group is directly linked to the maintenance of the soil structure (Marichal, 2017).

The AGS soil-litter system offered better conditions for the establishment of soil macrofauna.

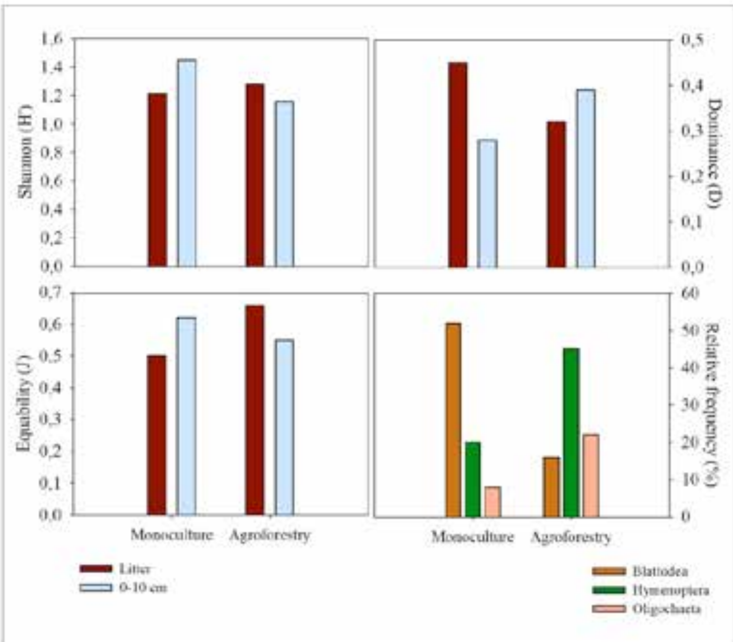


Figure 1: Systems diversity indexes and relative frequency of soil engineers.

Keywords: soil engineers, Agroforestry, Oil palm, Diversity.

References:

1. ANDERSON, In: Tropical soil biological and fertility: A Handbook of methods, 1994, Wallingford: C.A.
2. HAMMER et al. 2001, Palaentologia Electronica, 9pp.
3. LAVELLE, In: Soil Ecology, 2001, Springer Science & Business Media, 667.
4. MARICHAL et al. 2017, European J. of S. Biology, 43-51p.

L04.P.07

Bird abundance and richness in ten Mediterranean agroforestry systems

da Silveira Bueno R.[1] (rafael.dasilveirabueno@unipa.it), Cangarato R.[2], Cusimano C.[1], La Mantia T.[3], Lo Duca R.[1], Lo Verde G.[3], Massa B.[3], Pulido F.[4]

[1] *STEBICEF, University of Palermo, Palermo, Italy*; [2] *ADPM, Mértola, Portugal*; [3] *SAAF, University of Palermo, Palermo, Italy*; [4] *INDEHESA, University of Extremadura, Plasencia, Spain*

Since the last century agriculture is strongly promoting the simplification of the landscape. The LIFE Desert Adapt project is been developed across 1000 hectares in Italy, Spain, Portugal and has the objective of implementing integrative agroforestry-based land use planning and management, and one of the indicators to evaluate the project effectiveness is birds richness and abundance. Here we present the results of the first assessment and explore the relationships with the main vegetation cover types. We established 68 sampling points where we recorded bird abundance and richness. In total we registered 57 bird species, sampling points surrounded by woodlands presented 50 species, while shrublands presented 45 and herbaceous cover presented 32 species. The agroforestry practices that will take place inside the LIFE project are expected to increase the vegetation complexity inside the farms and consequently enhance bird diversity and abundance, as well as will provide useful information to compare the influence of different management decisions for bird communities. However, the species of birds threatened at the Mediterranean level are those linked to open agricultural systems (such as the alaudidae) and to areas with sparse tree cover (e.g. laniidae). The project will then evaluate the effects of agroforestry practices on bird communities in qualitative terms to also determine which of these do not have a negative effect on avifaunistic communities.

Keywords: bioindicators, desertification, land use change, shrublands, woodlands.

References:

1. Blondel, J., Ferry, C., Frochot, B., 1970. Alauda 38, 55–71.

L04.P.09

Traditional agroforestry systems in Northeast India

Deb S. (sdeb@tripurauniv.in)

Forestry and Biodiversity Department, Tripura University, Agartala, Tripura, India

Traditional agroforestry systems have been widely practiced by the people of Northeast India since time immemorial. A study has been conducted in different states of Northeast India to understand the structure, biodiversity value and management of traditional agroforestry systems. The study revealed that the systems have potential to preserve biodiversity in the region. Different plant species grown in these multistoried systems are confounded by the livelihood requirements and traditional knowledge. Deb etal (2014) reported 93 species from traditional agroforestry systems. The stratification in agroforestry is based on light requirement of plants, soil qualities and also by seeing the commercial value of the particular species. The farmers of the traditional agroforests can categorize the plants indigenously on the basis of light requirement. The most prevalent agroforestry systems in the region are Agri-horti-silvi-pisciculture, Agri-horti-silviculture and Horti-silvi-pastoral systems. It was observed that the plants have been distributed contagiously in most of the systems. Overall, the intimate mixture of diversified agricultural crops and multipurpose tree species fulfills most of the basic needs of the local inhabitants while the multistoried configuration and high species diversity of the agroforestry system helps to reduce the environmental hazards that is commonly associated with monoculture production system.

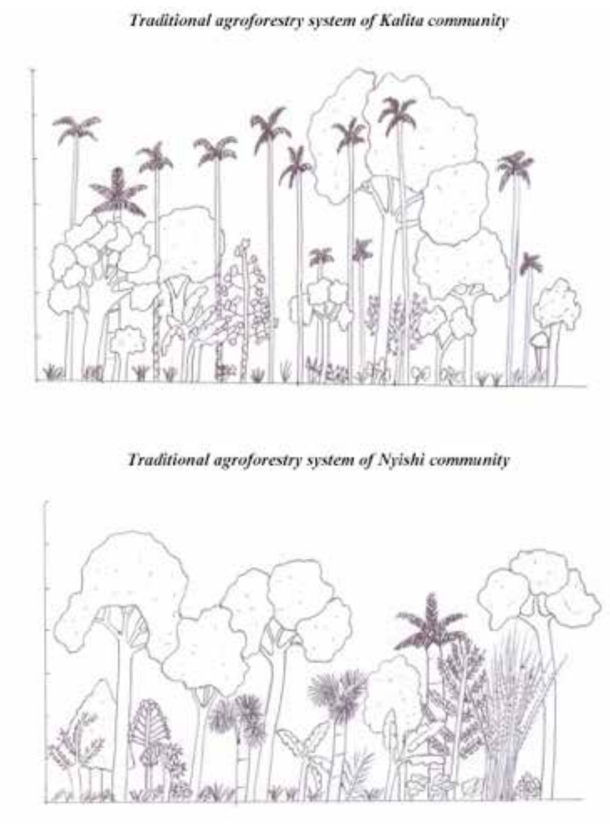


Fig: The structure of multistoried traditional agroforestry systems

Keywords: Traditional, Northeast India, multipurpose, diversity.

References:

1. Deb et al, 2014, J Biodivers Manage Forestry, 3:3, http://dx.doi.org/10.4172/2327-4417.1000129

L04.P.10

Contribution of buffer zone agroforestry to the conservation of tree diversity of protected areas

Djiongo Boukeng J. E.[1] (jose-elvire.djiongo-boukeng.1@ulaval.ca), Avana Tientcheu M. L.[2], Zapfack L.[3], Desrochers A.[1], Maaku Dzo I. G.[3], Khasa D.[1]

[1] *Department of Wood and Forest Sciences, Laval University, Québec, QC, Canada*; [2] *Department of Forestry, FASA, Dschang, Ouest, Cameroon*; [3] *Department of Plant Biology, University of Yaounde, Yaounde, Centre, Cameroon*

Protected areas in the Sudano-Sahelian zones are increasingly subject to threats related to climate change and human activities. To reduce these threats, an often-recommended approach is the intensification of agroforestry systems (AFS) in areas adjacent to protected areas (PA) (McNeely et al, 2006; Dudley, 2008). The present study focused on the characterization of agroforestry systems around the Bouba Ndjidda National Park (BNNP) in terms of woody plant diversity, structure and uses, in order to evaluate their contribution to the conservation of tree diversity. The methodological approach combined the inventory using the quadrats method associated with tree height and diameter measurements, and ethnobotanical surveys to document products, services and usage of trees by local people in the surrounding of the BNNP. Hedgerows (6%), fallows (72%), home gardens (83%) and scattered plantations (98%) were the four types of AFS identified around the BNNP. The overall average woody plant richness was 50 species belonging to 23 families. The most dominant family was Fabaceae with a species richness, family value of importance (FVI) and relative abundance of 12, 148.97%, and 62.38%, respectively. The tree density in AFS ranged from 29 stems / ha to 180 stems / ha for home gardens and hedgerows, respectively. The most predominant species was *Acacia polyacantha* with the highest value index (IV) (88.65), basal area (7.52 m2 / ha). Farmers use woody plants species of the AFS around BNNP for several reasons (fuelwood, food, fertilizer, fodder, medicine, shading, lumber, fence, and ornament), but mostly for fuelwood (66.49%) and food (63.69). The use of woody plants also vary according to the type of AFS. In fallows and hedgerows, trees are used primarily for fuelwood (78.49%) and (98.33%), respectively, while in scattered plantations and home gardens, shade for both livestock and humans is a priority with 91.94% and 78.26% of respondents, respectively. These use of AFS trees reduced the need of exploiting the woody plants of the Park. The plants of the Fabaceae family were the most cited as being used and contributing mainly for charcoal and fuelwood provision to local population. *Vitellaria paradoxa* recorded the highest used value (VU) (4.36); *Anacardium occidentale* and *Acacia polyacantha* the highest cultural indices (CI) of (1.00) and (0.98), respectively. Two endangered species, listed in the International Union for Nature Conservation's Red List were found in BNNP buffer zone namely *Khaya senegalensis* and *Vitellaria paradoxa*. The results of this study highlight the need to strengthen strategies to promote AFS around Sudano-Sahelian protected areas, as they contribute to improving farmers' livelihoods, creating an enabling environment for the conservation of useful and endangered woody plant species.

Keywords: Agroforestry systems, ethnobotanical knowledge, tree resources conservation, Bouba Ndjidda National Park, woody plant diversity.

References:

1. Dudley Nigel (Ed), 2008,Guidelines for applying protected area management, UICN, Gland, Suisse, 116p
2. McNeely et al, 2006, Biodiversity & Conservation, pp 549–554

L04.P.11

Ongoing cocoa intensification policy is driving outbreaks of belowground pests in cocoa agroforestry systems of Cameroon

Djuideu Tchouamou C.[1] (djuideuchristian@gmail.com), Ambele Chaba F.[2], Bisseleua Daghela H.[3], Kekeunou S.[4]

[1] *Animal biology and physiology, University of Yaounde I, Yaounde, center region, Cameroon*; [2] *ICIPE, Nairobi, Kenya*; [3] *World cocoa foundation, Accra, Ghana*; [4] *Animal biology and physiology, University of Yaounde I, Yaounde, Cameroon*

Cocoa agroforestry system (AFS) is increasingly recognized as a biodiversity repository for many plants and animal species and it ensures a natural biocontrol of pests and diseases. However, In Cameroon, this biodiversity “hotspot” is gradually destroyed by ongoing cocoa intensification policies to incraese cocoa yield in the short term. The on-going intensification policies is already having negative impacts on the natural mangement of subeterraneans animal species such as termites generally recognized as bioindicators in cocoa AFS. We sampled termites in 20 cocoa farms in five localities in the Centre region of Cameroon, ranging from rustic to full sun agroforestry systems to assess the impact of shade trees removal and aging of cocoa farms on termite communities’ composition and infestation of cocoa trees. We showed that implementation of on-going cocoa intensification policies toward shade trees removal has reduced the diversity and richness of termite with many of them feeding on newly planted seedlings and mature cocoa trees. We found that termites feeding damages were significantly lower in shaded rustic cocoa systems than full sun. We also observed that under full sun systems some species (*Microtermes* spp., *Ancistrotermes* sp., and *Pseudacanthotermes militaris*) have shifted their behavior from leaf-litter decomposer to above-ground pests building their galleries on cocoa trunk around flowers cushion. These species increase their abundance in cocoa farms in relation to shade trees removal to induce damages to cocoa trees. We also discovered a termite species (*Amalotermes phaeocephalus*) recognized as soil feeder which attacked cocoa trees by building galleries on the trunk. This emphasizes the impact of cocoa intensification in the drastical change in behavior of some key environmental species towards invasiveness. In addition, most of the control methods applied by farmers is not working against this new emerging pests but farm rehabilitation and renovation seems to affect termites infestation in farm. This study emphasizes the need to wild-friendly and sustainable cocoa cultivation by promoting agroforestry and favoring farm rehabilitation strategies to prevent termites outbreaks.

Keywords: Cocoa cultivation, pest outbreaks, termites, shade destruction, farm rehabilitation.

L04.P.12

Farmers as guardians of biodiversity preservation and landscapes

Fromageot C. (claude.fromageot@yrnet.com)

Yves Rocher Foundation, Issy les Moulineaux, France

The Anthropocene crisis is a reality, it is apparent to anyone. Where we live, we see the transformations of our environment: we note the scarcity of fish, the disappearance of trees and hedges, the scarcity of snow, the shrinkage of glaciers, the appearance of new species sometimes invasive. We have never been so informed by scientific relays and medias about climate change, desertification and biodiversity loss. Our politicians deal with these issues and attempt in their action to influence the way in which our societies are going to organize their «live together». Thus, today, every citizen, as long as he is in the circuits of public information, is sensitized to the questions of the human relation to climate, biodiversity, water, soil, agriculture, to questions related to the Earth. In short, the commons emerge as a source of debate, discussion and collective awareness.
At the same time, however, there is a kind of dissociation between this understanding and the reality of our lifestyles. Transdisciplinary researchers like Peter Kahn, Cynthia Fleury and Anne Caroline Prévot are studying this «generational environmental amnesia». They try to better understand what is «the experience of nature», in the sense of : if we multiplied our personal relationship to the natural world and if it is early in our growth, if it is linked to happy moments, we are more able to put coherence between the messages heard about environment and our practices of consumption in order to make them compatible with the preservation of biodiversity.
The reconnection of human being to a natural local territory is fundamental to invent new modes of society. To that end, trees can be a mediator.
This article claims to identify some levers, from the experience of the Yves Rocher Foundation launching. Created in 1991 the YR Foundation focuses today on actions of preservation of the biodiversity which participate to raise awareness of the public. Since 2007, Yves Rocher Foundation is committed in tree plantation: ninety million trees have already been planted in 35 countries throughout the world. Agroforestry projects are being implemented in Europe: in France with the largest program of plantation of country trees on the territory (3.5 million), in the Netherlands but also in Africa, Latin America and India. These actions show the importance of trees in the essential relation of the human being to their natural environment: the «experience of nature» in the sense of a satisfactory re-anchoring on their territory. The action of planting contributes to the transformation of minds, therefore to the very possibility of changing individual and collective behavior for human societies. It is a tiny instrument, but we want to emphasize its strength. Whether we are in Europe, Asia, Africa or the Americas: Plant for the Planet program is a testament to the universality of trees. It re-anchors us to make us more able to protect biodiversity.

Keywords: Agroforestry, Biodiversity, Plant For the Planet, Hedges, 100 millions.

References:

1. Claude Fromageot, Yves Rocher Foundation – Institut de France Director, 2018

L04.P.13

Conservation by use: the management of the Araucarian forest in the *caívas* areas in the southern Brazil

Hanisch A.[1] (analucia@epagri.sc.gov.br), Pinotti L. C.A.[2], Vogt G. A.[1], Negrelle R. R.B.[2]

[1] *Canoinhas Experimental Station, EPAGRI, Canoinhas, Santa Catarina, Brazil*; [2] *Agricultural Sciences Sector, UFPR, Curitiba, Paraná, Brazil*

Part of forest remnants in southern Brazil are used as traditional agroforestry systems, denominated *caívas*. In these, the arboreal canopy maintenance of the Araucarian Forest is combined with the extraction of yerba mate and animal husbandry. These systems have existed for over a century being important cultural, landscape and historical references for the region. However, the effect of livestock on forest regeneration is poorly understood. In order to contribute to a better understanding of the effect of grazing on the regeneration of the Araucaria Forest, was carried out experiment in eight *caívas* in the North Plateau region of Santa Catarina State over the years 2014 to 2017 (Figure 1). Regardless of the management used in the pasture, the regeneration of the tree species is a dynamic, present and continuous process in the evaluated *caívas*. There are abundance of native species in regeneration, including many typical advanced stages species of Araucarian Forest. The results have confirmed that these systems present high resilience with respect to biodiversity conservation, despite its use with animal grazing for a long period.

Participatory evaluation of forest regeneration in caívas areas in Southern Brazil.

Keywords: silvopastoral system, biodiversity, livestock, Ilex paraguariensis St. Hil., forest regeneration.

L04.P.14

Sowing legume-rich pastures in Iberian dehesas: effects on biodiversity and carbon sequestration are smoothed by trees

Hernández-Esteban A A. (anaherest@unex.es), Rolo V., López-Diaz M. L., Moreno G.

Universidad de Extremadura, Plasencia, Cáceres, Spain

Sowing legume-rich pastures is becoming increasingly important in Mediterranean grasslands, because it improves forage production and quality for years, as showed by Hernández-Esteban et al (2018) in Iberian dehesas. While this is claimed by dehesa owners as a priority to increase the economic resilience of their farms (Moreno et al 2016), the high nature value of Iberian dehesas, categorized as habitat of community interest in then UE (Council Directive 92/43/EE), introduces some environmental concerns against the artificialization of their natural pastures (Moreno et al 2018).

In this work we study the consequences at mid-term (10-15 years) of sowing biodiverse legume-rich pastures on soil carbon sequestration rate and plant biodiversity. Additionally, we assess if the presence of trees (cover 20-30%) modulates the response of the system to the sowing. The study was carried out in seven dehesa farms of CW Spain (Extremadura region) that followed a chronosequence of sown pastures, from 1 to 16 years since sowing. Each farm included three to five sown plots together with a control un-sown plot. Plant diversity was monitored with the point-transect method in the spring of 2016 and 2017, sampling 208 plants per plot (age) and farm, one half beneath the tree canopies and the other out of the canopy. Soil carbon was measured in four samples per habitat (beneath and out of the canopy), plot and farm in 2016. Each sample was composed of three samples taken with an auger of 8 cm of diameter and 15 cm depth.

Results at the plot level show an initial decrease of plant species richness in the first year after sowing, increasing gradually until the years 6-7 up to values above the control plot. However, after that, species richness decreases again and by the year 15, we found a loss of roughly 20% of the species richness in the sown plots. This loss was more moderate beneath trees than out of the trees. The plant community dissimilarity among sown and control plots decreased with age beneath the tree canopy but increased out of the canopy. In accordance with the high dissimilarity among sown and control plots, our result show that having multiple legume-rich plots of different ages within a farm have a positive effect onthe total species richness . This, together with the progressive increase of soil carbon after sowing, quite above the targeted 4‰ (14.3 and 27.8‰ respect to the soil C content beneath and out of the canopy, respectively), indicates some positive environmental consequences of sowing legume rich pastures in Iberian dehesas

Keywords: plant diversity, soil carbon, tree canopy, chronosequence, legume-rich pastures.

References:

1. Hernández-Esteban et al 2018. Agroforest Syst, doi.org/10.1007/s10457-018-0307-6
2. Moreno et al. 2016. Silvopastoral systems in a changing world, Evora, Portugal
3. Moreno et al. 2018. Agroforest Syst 92:877–891

L04.P.15

Composition and diversity of tree species in agroforestry homegardens in Harare, Zimbabwe

Jimu L.[1] (jimaldino@yahoo.com), Mupamhadzi U.[1], Nyakudya I.[2], Mujuru L.[1]

[1] *Natural Resources, Bindura University of Science Education, Bindura, Zimbabwe*; [2] *Crop Science, Bindura University of Science Education, Bindura, Zimbabwe*

Trees in agroforestry systems contribute to provision of wood and non-wood products, and help in *circa-situm* conservation of species. Agroforestry homegardens provide opportunities for plant biodiversity conservation. The objective of this study was to assess variation in tree species composition and diversity across urban, peri-urban and rural areas of Harare, Zimbabwe. The urban stratum was subdivided into High, Medium and Low density suburbs. Random sampling was used to select households within each stratum where forty respondents were sampled from each stratum. The Shannon-Weiner Index was used to determine species diversity. A total of 81 tree species were recorded in all homegardens across strata. More than 90% of the tree species found in homegardens were fruit trees while ornamental plants were prominent in medium density, low density and peri-urban areas. The highest species diversity was observed in the low density (3.09) and peri-urban (2.93) areas whilst the least diversity was recorded in high density (2.12) areas. *Mangifera indica* (83% of all homesteads) and *Persea americana* (71%) were the most dominant species across all strata. The high tree species compositions and diversities (2.12-3.09) recorded across all strata in Harare shows that urban areas play an important role in species conservation and should not be excluded in agroforestry extension strategies.

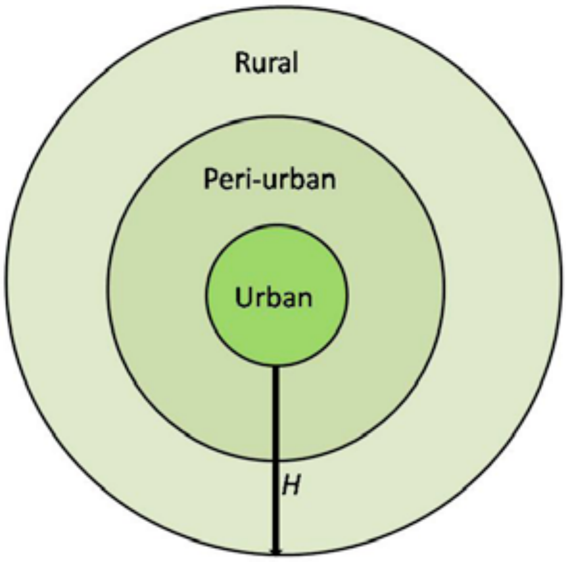


Figure 1: Study design and the hypothesis that species diversity (H) decreased from urban to rural areas.

Keywords: Agroforestry, Exotic tree species, Fruit trees, Ornamental trees.

References:

1. Maroyi A, 2009, International Journal of Sustainable Development & World Ecology, 1-8

L04.P.16

Prospects of homegarden agroforestry in conservation of biodiversity and increasing of carbon stock in Jaffna District

Karthigesu J.[1] (kjvanan@gmail.com), Pushpakumara G.[2], Sivachandiran S.[3], Weerahewa J.[4], Sivananthawerl T.[2]

[1] *Department of Agronomy, University of Jaffna, Kilinochchi, Northern Province, Sri Lanka*; [2] *Department of Crop Science, University of Peradeniya, Kandy, Central Province, Sri Lanka*; [3] *Department of Agronomy, University of Jaffna, Jaffna, Northern Province, Sri Lanka*; [4] *Department of Agricultural Economics and, University of Peradeniya, Kandy, Central Province, Sri Lanka*

Jaffna is a heavily urbanized district of Sri Lanka with a natural forest cover of 0.03% of total land area. This study was carried out in Jaffna district to assess the biodiversity and carbon stock of homegarden agroforestry which contribute to 33% of land total area of the district[1]. Data were collected from a field survey of randomly selected homegardens. A total of 5,920 individual flora from 58 families and 135 species were assessed. Mean value of Shannon diversity index (H), Simpson diversity index (D) and evenness (E) for the floristic component were 1.72±0.04, 0.78±0.12 and 0.81±0.01, respectively and revealed that the floral diversity of the homegardens was equally distributed with medium species diversity. A total of 825 individual domestic fauna from 19 species and 12 families were identified. Mean value of H, D and E for domestic fauna were 0.21±0.03, 0.16 ±0.03 and 0.22±0.03, respectively and revealed that faunal diversity was not equally distributed and had low species diversity. Mean above ground carbon stock was 41±4 Mg C per ha. Small sized homegardens had a significant positive correlation with above ground carbon stock due to high number of trees. Age of the homegardens did not influence the carbon stock and number of tree species. In addition to the floral component, there were 11 live fence tree species identified in the homegardens[2]. Prevalence of palm crops, fruit crops and live fenced species were high[3,4]. About 53% of the homegardeners had involved in rearing of domestic faunal species. Future perspective of the homegardens should focus to enrich the genetic diversity and increasing the carbon stock in the yard for resilience to climate change[1,5]. Based on the above results, it can be concluded that Jaffna homegardens were a versatile multi-functional system designed for beneficiaries in the district.

Keywords: Agroforestry, Biodiversity, Carbon stock, Dry zone homegarden, Sri Lanka.

References:

1. Pushpakumara et al., 2012. Journal of Tropical Agriculturist, 160: 55-123.
2. Jeyavanan et al., 2014. Tropical agriculturist: an international Journal of Sri Lanka, 162:25-49.
3. Pokhrel et al., 2015. Journal of Institute of science and technology, 20 (1): 87-96.
4. Albrecht, A. and Kandji, S.T. 2003. Agric. Ecosyst. Environ., 99:15–27. doi:10.1016/S0167-8809(03)00
5. Nair et al., 2009. J. Soil Sci. Plant Nutr., 172:10–23. doi:10.1007/978-94-007-1630-8

L04.P.17

Prioritisation of woody plants for conservation in traditional agroforestry systems along Ouémé catchment in Benin

Lokonon E. B.[1] (brunolokonon@gmail.com), Tchandao Mangamana E.[2], Glèlè Kakaï R.[2], Sinsin B.[1]

[1] *Dep. of natural resources management, Laboratory of Applied Ecology, Cotonou, Benin*; [2] *Dep. of natural resources management, Laboratory of Biomathematics and Forest, Cotonou, Benin*

Background
Due to their socio-economic values in Ouémé catchment, useful woody plants are preserved in agroforestry systems (See photo). However, to date, this catchment experiments increasing degradation of its resources due to human pressures and climate change. Thus, most of species as well as knowledge related to them are facing a very high risk of extinction. Surprisingly, no study had assessed the values of these species to local people.
Objectives
To fill in this gap, this study aimed to (1) assess woody plants diversity and their knowledge and usage by local people; (2) rank these species according to their priority for conservation and (3) inventory local strategies for their conservation.
Methods
An ethnobotanical survey was done with 411 selected households followed by a field survey in 69 plots. Ethnobotanical and ecological parameters were computed and analysed. These parameters were combined to construct a conservation priority index per species adapting the formula of Oliveira et al. (2007).
Results
46 species were recorded. Significant differences in plants knowledge between women and men, but also between ethnic groups were found. Six species were classified as having highest priority for conservation in this area.The local conservation strategies most used were: seedlings protection in farms and apiculture practice favouring pollination.
Conclusion
These six species could be involved in landscape restoration initiatives that are being promoted in Benin.

Photo showing woody plants species preserved in field by local people of Ouémé catchment.

Keywords: conservation priorities, Traditional agroforestry systems, local knowledge, useful plants, Ouémé catchment.

References:

1. Assogbadjo, et al. (2012). Forest Policy and Economics, 14, 41–49.
2. Ayantunde, et al. (2008). Human Ecology, 36, 881–889.
3. Lokonon, et al. (2013). Agronomie Africaine, 25(2), 121–131.
4. Oliveira, et al. (2007). Environmental Monitoring and Assessment, 132, 189–206.
5. Sop, et al. (2012). Environment, Development and Sustainability, 14, 627–649.

L04.P.18

Increasing connectivity and biodiversity conservation in livestock dominated landscapes: the BioPaSOS project

Martínez-Salinas A.[1] (amartinez@catie.ac.cr), Jiménez-Trujillo J. A.[2], Messa Arboleda H. F.[3], Pérez E.[4], Sepúlveda L. C. J.[1]

[1] *Agriculture, livestock and agroforestry, CATIE, Turrialba, Cartago, Costa Rica*; [2] *Agriculture, livestock and agroforestry, CATIE, Tuxtla Gutiérrez, Chiapas, Mexico*; [3] *Agriculture, livestock and agroforestry, CATIE, Autlán de Navarro, Jalisco, Mexico*; [4] *Agriculture, livestock and agroforestry, CATIE, Campeche, Campeche, Mexico*

Increasing habitat connectivity in livestock dominated landscapes is critical to secure wildlife populations viability in the long-term. The project *Scaling up biodiversity conservation through climate-smart agrosilvopastoral practices in landscapes dominated by cattle-raising systems in three regions of Mexico* known as BioPaSOS, aims at improving biodiversity conservation through the promotion of agroforestry practices, such as live fences and trees in pastures, that increase connectivity while improving habitat quality for wildlife and farm productivity. BioPaSOS is implementing actions in three intervention territories in the Mexican states of Jalisco, Chiapas and Campeche, considered hotspots for biodiversity conservation and where livestock production is dominant. BioPaSOS is working closely with over 1200 cattle rancher families to build capacity in themes related to biodiversity conservation and agroforestry practices that contribute to increase connectivity, habitat quality and farm productivity. Additionally, BioPaSOS works in collaboration with multiple local partners from government and non-government organizations including state and federal government agencies, cattle rancher associations, research-oriented organizations [Universities and Research Institutes] and the private sector, all to promote agroforestry practices that can help increase the biodiversity conservation value of these livestock dominated landscapes.

Livestock using the shade of a live fence to shield themselves from the sun. Campeche, México. Proyecto BioPaSOS.

Keywords: Livestock, biodiversity, Mexico, agroforestry, connectivity.

L04.P.19

Agroforestry systems for development and protection of wildlife species

Mihaila E.[1] (lilianmihaila@yahoo.co.uk), Popovici L.[2], Costăchescu C.[1], Constandache C.[2]

[1] *Silvotehnics, INCDS "Marin Dracea", Voluntari, Romania*; [2] *Silvotehnics, INCDS "Marin Dracea", Focșani, Romania*

In the north-eastern extremity of the Romanian Plain, near Namoloasa, Galati County within a 6,000-hectare hunting fund, a type of agroforestry system adapted to hunting requirements (to grow, develop and harvest hunting) was realized in autumn 2016. The agroforestry system consists of mixed belts of forest and agricultural vegetation for the growth of game species (pheasants, partridges and rabbits) and protected wild species (bustard). The width of this belt is about 40 m and consists of 5 rows of forest species (black pine, black locust, sweet locust, oleaster, mahaleb cherry, cherry plum), a strip of fodder species (maize, sunflower, clover, alfalfa), species producing seeds (in, mustard, chicory, millet etc.) and again 5 rows of forest species (Figure 1). These belts have been installed on less productive marginal lands. It has been proposed to analyze this type of agroforestry system in terms of influence on wild species, on agricultural production and environmental factors. Because the system is recently created, relevant observations could only be obtained on the influence on wild species. Thus, the number of pheasants harvested in 2017 was 65 % more than in the other hunting funds. This is an idea by which using agricultural and forestry species on less productive agricultural land increase the productivity of the land used. At the same time, a legal and stable framework is created for the protection and development of wild species including the endangered species.

Figure 1: Forest belts for growth and development of wild species and for protection of agricultural crops

Keywords: agroforestry systems, belts of forest and agricultural vegetation, game species, wild species, growth and development.

L04.P.20

Does agroforestry carbon project can contribute to biodiversity conservation and poverty reduction in western Africa ?

Niang Diop F. (faniangdiop@live.fr), Sambou B., Goudiaby A., Diop M., Sall O., Dieng S. D., Cissé L.

Institut des Sciences de l'Environnement, Dakar, Senegal

The loss of forest and tree cover is weakening biological diversity and contributing to soil degradation. Soil degradation is one of the most serious and pervasive ecological problems in rural West Africa. It is reducing agricultural productivity, increasing the frequency and magnitude of crop failures and undermining food security among already impoverished communities.

There is an urgent need to work with smallholders to develop sustainable land management plans that integrate trees more into agricultural practices and increase their presence in the landscape. Since most of the land in the area is under cultivation, devoting more land to trees would mean that, in the estimation of local communities, the economic and other benefits of trees would need to compete with the value of harvested crops. That's why, there is a pressing need for financial and other resources, technical assistance, capacity strengthening measures, and a supportive institutional framework to enable local inhabitants to plant and maintain trees.

Agroforestry carbon project offers the right sort of institutional framework for a properly financed and structured approach to supporting local communities and smallholders to cultivate and manage trees in their landscape.

ARLOMOM provides a local frame of reference that is meaningful and inspiring for biodiversity conservation and local communities empowerement. It provides information about the sorts of methods and processes that can succeed, or why they fail. It can be a good reference for agroforestry carbon project in western Africa and can be efficiently replicated and expanded.

Keywords: Carbon project, Agroforestry, Senegal, ARLOMOM, Patako.

References:

1. Van Noordwijk M. and Ong C.K. (1999). Can the ecosystem mimic hypotheses be applied to farms in Afri
2. Christensen S.N. (2010 in prep). Socio-economic and ecological determinants of local scale tree dist
3. Montagnini F. and Nair P.K.R. (2004). Carbon sequestration: An underexploited environmental benefit
4. UNEP – United Nations Environment Programme (1999). Global Environment Outlook 2000. UNEP, Nairobi,
5. Chikanda A (2009). Environmental degradation in sub-Saharan Africa. In: Luginaah I.N. and Yanful E.K

L04.P.21

Effects of human disturbance and climate change on the African Baobab (*Adansonia digitata* L.) populations in Ethiopia

Noulekoun F.[1] (florentnoulekoun@yahoo.fr), Birhane E.[2], Asgedom K. T.[2], Tadesse T.[3], Hishe H.[2], Abrha H.[4]

[1] *Div. Environmental Science, Korea University, Seoul, South Korea*; [2] *LRMEP, Mekelle University, Mekelle, Ethiopia*; [3] *NREM, Mekelle University, Mekelle, Ethiopia*; [4] *Institute of Climate and Society (ICS), Mekelle University, Mekelle, Ethiopia*

The recently reported demise of most of the oldest and largest African baobabs (*Adansonia digitata* L.) raises concerns about the sustainable management and conservation of the remaining population of this important and iconic tree species in the face of the current climate change. Given the multipurpose nature of the species and the important role of human disturbance and climate in shaping species population, we hypothesized that integrating ecological assessments with modeling tools and socio-economic surveys would improve the understanding of the species ecology and biology, which in turn, can enhance the overall effectiveness of management efforts and community awareness. We established thirty-eight strip transects of 5 ha (i.e., 50 m x 1 km) each, systematically distributed across three land-use types (grazing lands, riverine areas and natural forests) in two districts of Western Tigray to characterize the structure of the species population and identify its future suitable niche using the Maximum Entropy (MAXENT) model. We administered semi-structured questionnaires to 120 households to assess local knowledge on the importance and management of the species. Baobab stands were denser with larger-sized and taller individual trees in riverine areas and natural forests compared to grazing lands, suggesting an adverse effect of human disturbance on its populations. Size-class distributions were positively skewed with negative slopes in all the land-use types, indicating a low recruitment of juvenile trees to adult stage. Climate change would lead to a significant reduction in baobab suitable habitats. Moreover, climate-induced range shifts resulting in a local extinction of the baobab was predicted under 2070-RCP 8.5. The decreasing baobab population indicated by local communities, in combination with the lack of conservation practices and risk of extinction due to climate change constitute serious threats for the viability of the species in the western Tigray and necessitate immediate interventions.

Keywords: Size-class distribution, Maximum Entropy (MAXENT), Consensus value, Northern Ethiopia.

L04.P.22

Effects of agroforestry on farming diversity in northern Thailand

Onprom S.[1] (fforsro@ku.ac.th), Kladwang P.[2]

[1] *Forest Management, Kasetsart University, Muang, Thailand*; [2] *Forest Management, Kasetsart University, Bangkok, Thailand*

In rural Thailand, trees on farm have played critical role in supporting local livelihoods. This study looks at the effects of agroforestry on farm biodiversity. More specifically, it looks at diversity of edible tree species in agroforestry system in Mae Tha community, which is located in Mae Tha sub-district, Mae-on district of Chiang Mai province. The sub-district consists of 7 villages. The majority of villagers are farmers. Traditionally, they have been practicing rice paddy for domestic consumption. They generated income from cash cropping, livestock and forest products. Like other forest communities in northern Thailand, farmers of Mae Tha community in Chiang Mai province have been traditionally depending on tree and forest resources from natural forests for household consumption and income generation. Three decades ago, organic farming and agroforestry practices were introduced to the village by local NGO. The study found that, at present, there are 59 households (5.6% of total population), who practiced agroforestry systems. The total area of agroforestry system was 42.27 ha (264.2 rai), at average 0.66 ha/household (4.13 rai/household). Regarding the diversity of plant species, the study revealed 144 woody perennial tree species found in agroforestry system including 77 species of tree, 26 species of orchard tree, 27 species of shrub, 7 species of palm and rattan and 7 species of bamboo. Diversity index of woody perennial tree species was 2.99. Interestingly, number of species and diversity index are varied between small (less than 5 rai) and medium (5-10 rai) and large plot (more than 10 rai).

Keywords: diversity, agroforestry, Thailand.

L04.P.23

Plants with alternative uses in a valonia oak silvopastoral system

Papadopoulos A. (ampapadopoulos1@gmail.com), Fotiadis G., Pantera A.

Forestry & NEM, TEI Stereas Elladas, Karpenissi, Greece

Valonia oak forms traditional silvopastoral systems with distinctive ecological and socio–economic interest. Many native species from the valonia oak silvopastoral systems flora were used in the past and are still used today for their apicultural, aromatic and medicinal properties. In this study, the native species of valonia oak forests with medicinal or other properties were identified in order to contribute to their preservation by emphasizing their value and add to our knowledge on past traditional practices and alternative uses. Initially a list was formed based on existing bibliography in order to collect and identify the medicinal and other species with alternative uses. An inventory followed to local stakeholders based on which information was obtained on their knowledge of medicinal and plants with alternative uses. The results were further substantiated by field observations. Based on the results, at least 89 species are present in the region with alternative properties. Almost 60% of the recorded plants are used or can be used as medicinal followed by the edible (18%), the flavoring (5%) and the dyeing ones (4%). Usually the whole plant and leaves are used followed by the roots (15%), shoots (10%) and flowers (9%). The species most commonly used, in the area, are *Origanum vulgare*, *Matricaria chamomilla* and *Salvia officinalis*. This work was funded by the FP7 AGFORWARD project (Grant Agreement N° 613520) and co-funded by the GSRT, Hellenic Ministry of Education.

Valonia oak silvopastoral system holds a high number of plant diversity

Keywords: medicinal, aromatic, ethnobotany, traditional uses, plant conservation.

L04.P.24

Environmental monitoring report of 'Guáimaro and sustainable cattle raising' project

Patentreger B.[1] (bpatentreger@envol-vert.org), Domínguez-Haydar Y[2], Arenas Y[3], Morelo L[3], Nova J.[3], Pájaro Y[3], Suarez N[3]

[1] *Envol Vert, Paris, France*; [2] *Teacher Universidad Del Atlantico, Puerto Colombia, Colombia*; [3] *Student Universidad Del Atlántico, Puerto Colombia, Colombia*

Agroforestry systems are favorable scenarios for the revegetation of native species and the recovery of natural capital. In order to assess the impact of the Guáimaro and the sustainable Cattle Raising program on the recovery of biodiversity, the composition of groups of ants, reptiles, amphibians and birds have been studied in three areas: five plots of land with agroforestry systems, a remainder of forest and an area in regeneration. For the sampling of reptiles, amphibians and birds, direct observation was made in a transect of 2 km x 100 m, as for ants, Pitfall traps and manual capture were used. The findings show that the plots of land with the highest vegetation cover (CV) (57 and 52%) and heterogeneity in their crops exhibited the greatest wealth of ants (19), reptiles and amphibians (18) and avifauna (18). The plots of lands with the highest vegetation cover were also more similar to forests and rehabilitation areas in their species composition. The plots of land with a lower species richness presented percentages of CV between 21-25% and low diversity in their crops. These systems have a high potential for the conservation of species, more even when the area is contiguous with a protected area. That is why some recommendations regarding revegetation with endemic species and empowerment by the community must be done to ensure the sustainability of the project.

Location of the «Guáimaro and sustainable cattle raising» project areas.

Keywords: agroforestry, native species, Guáimaro, recovery of biodiversity.

References:

1. jiménez, f., & muschler, r. (1999). conceptos básicos de agroforesteria
2. corporación suna hisca. (2003). componente biofísico. fauna-anfibios y reptiles
3. gregory, r. (2006). birds as biodiversity indicators for europe. significance, 3(3), 106-110. jour
4. underwood, e. c. & fisher, b. l. (2006). the role of ants in conservation monitoring

L04.P.25

Cloud forest plant endemism persistence within crop–fallow systems in a Mesoamerican hotspot area

Pérez-García O. (osperegrow@gmail.com)

IPN-CIIDIR-Oaxaca, Instituto Politécnico Nacional (IPN), Santa Cruz Xoxocotlán, Oaxaca, Mexico

Tropical montane cloud forests (TMCF) under natural disturbance events have shown high endemism in early successional vegetation. However, little is known about the relationship between anthropogenic disturbance and plant endemism in TMCF under ancient agricultural management. In this sense, I assessed the number of species, abundance, and frequency of endemic vascular plants in temporary plots of cultivated and young fallow areas from two maize-based systems: *milpa* shifting cultivation (MS) and semi-permanent cropping (SP) in Oaxaca, México. Overall both agricultural stages and systems harbored endemic species, seven in total, but most of such species were found in the fallow stage than in the cropping stage, and in the MS system than in the SP system. A single Asteraceae herbaceous endemic species (*Melampodium mimulifolium*) was commonly recorded in cultivated fields, but almost exclusive to the SP cropping system. Seven species were recorded in fallows, where the narrow-range endemic tree species *Clethra integerrima* (Clethraceae) was the most abundant and frequent, but almost exclusive to the MS cropping system. In more permanent and intensified agricultural systems within biodiversity hotspots, only ruderal endemic herbaceous species can persist. In contrast, in low intensity managed agricultural systems, like ancient agroforestry, not only can endemic tree species prosper, but also restricted endemic trees can be found.

Endemic species	Life form[a]	Abundance (number of individuals)				Frequency (% of plots in which the species were present)			
		Cultivated fields[b]		Fallows[c]		Cultivated fields		Fallows	
		MS (n = 15)	SP (n = 15)	MS (n = 19)	SP (n = 19)	MS	SP	MS	SP
Melampodium mimulifolium (Asteraceae)	H	2	45	0	2	6.7	46.7	0	5.3
Roldana oaxacana (Asteraceae)	S	0	0	31	6	0	0	42.1	15.8
Clethra integerrima (Clethraceae)	T	0	0	138	3	0	0	89.5	15.8
Clethra kenoyeri (Clethraceae)	T	0	0	2	0	0	0	5.3	0
Inga latibracteata (Fabaceae)	T	0	0	1	0	0	0	5.3	0
Magnolia dealbata (Magnoliaceae)	T	0	0	4	3	0	0	15.8	10.5
Pinus chiapensis (Pinaceae)[d]	T	0	0	13	31	0	0	31.6	52.6

[a] *Definitions: H, herb; S, shrub and T, tree.*
[b, c] *Acronyms of cropping systems: MS, milpa shifting cultivation and SP, semi-permanent system.*
[d] *Endemic to Mexico and western Guatemala.*

Table 1. Country-level endemic plant species and their abundance and frequency recorded in Juquila Vijanos, Oaxaca, Mexico

Keywords: Cloud forest regeneration, Maize monoculture, Milpa shifting cultivation, Narrow-range species.

References:

1. González-Villarreal, 2006, Ibugana, 13:11–25
2. Kessler, in: The tropical mountain forest: Patterns and processes... 2008, Gradstein et al. 35-50
3. Pérez-García, 2016, Agric. Ecosyst. Environ., 228:30–37
4. Pérez-García, 2017, Agric. Ecosyst. Environ. 248:162–174
5. Villaseñor, 2016, Rev. Mex. Biodivers., 87:559–902

L04.P.26

Contribution of coffee agroforestry to land-use heterogeneity in Chiapas, Mexico

Prado Lopez M.[1] (miguel.prado@unicach.mx), Estrada Macal R. M.[2], Perez Aguilar B. J.[1], Alvarado Jose A. C.[1]

[1] *Facultad de Ingeniería, Universidad de Ciencias y Artes de Chiap, Tuxtla Gutierrez, Chiapas, Mexico*; [2] *Universidad de Ciencias y Artes de Chiap, Universidad de Ciencias y Artes de Chiap, Tuxtla Gutierrez, Chiapas, Mexico*

Coffee agroforestry is an important element in the agroecosystems matrix because promote habitat heterogeneity and connection between protected areas. Far from affecting diversity, coffee plantations are critical for management and conservation of the biodiversity in tropical agroecosystems. However, understanding patterns of biodiversity remains unclear so it is necessary to deepen in the knowledge of it to improve the conservation-production strategies. We designed a two-phase research where during the first phase we assess diversity and composition of bats and soil fauna on three different land-use systems (agricultural, natural forest and Coffee agroforestry). The second phase is still ongoing and consists of determining the relationship between diversity and ecosystem functioning as control of pest arthropods by bats and decomposition by soil fauna. Here we present the results of the first phase research. To assess soil fauna we used the standard tropical soil biology method in dry and wet season and to assess bats richness, abundance and composition we use capture mist-netting. In general, the abundance of soil fauna had no differences between sites but is significantly higher in the wet season. During dryness, the three main orders of soil fauna were hymenoptera, Oligochaeta and Lepidoptera (larvae) and during wet season were Oligochaeta, Isoptera and Hymenoptera. Forest is the site with more diversity (H´=2.5), and also is the site with more abundance of predators. Only agricultural sites are the one with significant differences in diversity between seasons.
Regard bats, we recorded 648 individuals belonging to 20 species and three families. Frugivorous are the functional group more abundant (11 species; n=545), insectivores (5 species; n=57), Hematophagous (*Desmodus rotundus*; n=40). Forest is the site with more species (17), agriculture (13 spp) and coffee (12 spp).
Both in the assessment of bats and soil fauna, the forest is the site with more abundance and more diversity. But the importance of coffee agroforestry and agricultural spaces is because they promote niche heterogeneity and the presence of specific groups that assure the complexity of the community interactions. We conclude that coffee farms have an overall positive, but context dependent effect and are important for the mobility of bats among the agroecosystems landscape.

Keywords: Bats, Coffee plantations, Forest fragmentation, Soil fauna, Wildlife conservation.

L04.P.28

Value of vanilla agroforestry for ant conservation in the Sava Region, Northeastern Madagascar

Rakotomalala A. A. N. A.[1] (andrynyaina001@gmail.com), Wurz A.[2], Martin D.[3], Osen K.[4], Andrianisaina F.[5], Fulgence T. R.[6], Hänke H.[7], März A.[4], Osewold J.[4], Raveloaritiana E.[8], Soazafy M. R.[9], Barkmann J.[7], Grass I.[2], Hölscher D.[4], Tscharntke T.[2], Kreft H.[3], Raveloson Ravaomanarivo L. H.[1]

[1] *Entomology, University of Antananarivo, Antananarivo, Madagascar*; [2] *Agroecology, University of Goettingen, Goettingen, Germany*; [3] *Macroecology and Biogeography, University of Goettingen, Goettingen, Germany*; [4] *Tropical Silviculture and Forest Ecology, University of Goettingen, Goettingen, Germany*; [5] *Science Agronomy, University of Antananarivo, Antananarivo, Madagascar*; [6] *Zoology and Animal Biodiversity, University of Antananarivo, Antananarivo, Madagascar*; [7] *Environmental and Resource Economics, University of Goettingen, Goettingen, Germany*; [8] *Plant Biology and Ecology Department, University of Antananarivo, Antananarivo, Madagascar*; [9] *Natural Ecosystems, University of Mahajanga, Mahajanga, Madagascar*

Madagascar's unique biodiversity is threatened by anthropogenic forces such as deforestation. However, protected areas are not sufficient to halt biodiversity loss. This suggests that sustainable land use practices are needed to minimize negative impacts on biodiversity. It has been demonstrated that agroforestry and forest fragments can play an important role in nature conservation in the tropics, but the contribution of agricultural landscapes for biodiversity conservation in Madagascar remains poorly studied. Here, we investigate the value of vanilla agroforestry for ant diversity in the Sava Region, Northeastern Madagascar. We compared ant diversity in vanilla plantations to other land use types (primary forest, forest fragments, fallows, rice paddies). In addition, we analyzed (a) how habitat complexity within vanilla plantations affects ant diversity, and (b) how vanilla cultivation management affects ant diversity. We hypothesize that (i) vanilla plantations have greater ant diversity than less shaded land use types, and thus also share more species with forest fragments and primary forest, (ii) increased canopy cover and tree species richness positively affect ant species richness, and (iii) ant diversity is reduced by management intensification. Our research may contribute to establishing win-win situations for both biodiversity conservation and vanilla production, and contribute important knowledge to ant conservation and distribution in Madagascar.

Keywords: agroforestry, ant, conservation, Madagascar, vanilla cultivation.

L04.P.29

Can shifting cultivation agricultural system maintain biodiversity?

Ribeiro G. S.[1] (gabibisribeiro@gmail.com), Pereira M. F. C. S.[2], Righi C. A.[1], Couto H. T. Z.[1], Ribeiro C. O.[1]

[1] *Dept. of Forest Science, University of São Paulo, Piracicaba, SP, Brazil*; [2] *Campus Laranjeiras do Sul, Federal University of Fronteira Sul, Laranjeiras do Sul, PR, Brazil*

Shifiting cultivation systems (SAIs in Portuguese) are characterized by the alternance of agricultural plots and forest fragments which are slashed and burned after a fallow period. Due to fire use, there are questions on SAIs capacity to maintain original vegetation and its biodiversity. We aim to characterize the evolution of floristic composition among areas with different stages of fallow compared to a primary forest fragment. We stablished chronosequences in SAIs managed by two families (F1 and F2) on Cananéia municipality, Sourthern Brazil. Once the plots were localized and their respective fallow periods were determined, the floristic survey was carried out and the most abundant tree species were identified by successional groups. We calculated richness (S) and Shannon-Winner (H') diversity indexes to characterize the biodiversity. We also measured diameter at breast high (DBH) to obtain class size distribution and verify the evolution of the regenerated areas. In the F1 areas we found similar richness indexes between the areas with 4 and 10 years of fallow compared to primary forest (S = 19; 18 and 20, respectively). As for diversity we found H' = 2.2880 and 2.0030 (4 and 10 years fallow respectively), compared to H' = 2.1800 in the primary forest. As for the F2 areas the calculated richness indexes where S = 29; 16; 8 and 19 (15, 30 and 42 years of fallow and primary forest, respectively). Therefore, diversity varied considerably (H' = 2.7040; 1.9820; 1.5910 and 2.4040) due to high variation on edaphic conditions. In the area with 4 years of fallow, there was a predominance of pioneer's trees of smaller DBH classes (91.38% of individuals). The 10 years-fallow area presented a similar distribution to the primary forest on F1, containing 7 DBH classes (5 to 30 cm) and predominance of early secondary species. As for the F2 areas, we found a higher presence of small DBH trees (5 to 9 cm) in all the areas, which is typical of sand coastal plain vegetation. In the 30 years-fallow area we also observed the most homogeneous distribution of DBH classes. We noticed an evolution of vegetation through the different fallow periods, finding predominantly pioneer species in the 15 year-fallow area and early secondary species in the older areas. Considering this, we suppose that there is a maintenance of biodiversity in all the fallow areas, since the diversity indexes and classes of DBH resemble the primary forest in both families. This can only be affirmed with complementary studies on soil conditions, nutrient stocks and forest structure.

Keywords: slash and burn agriculture, Restinga forest, forest regeneration.

L04.P.30

Agroforest of pineapple: ethnoagroforestal system of biological importance for conservation in western Mexico

Rosales-Adame J. J. (jesusr@cucsur.udg.mx), Cevallos-Espinosa J., Vázquez-López J. M., Hernández-Vázquez F.

Depto. Ecología y Recursos Naturales, Universidad de Guadalajara, Autlán de la Grana, Jalisco, Mexico

Mexico houses an agroforestry system managed by indigenous and mestizo farmers recognized as *Agroforest*, where the Creole pineapple (*Ananas comosus*) is the most important product. It is located in the states of Jalisco and Nayarit. However, it is estimated that it exists in marginal areas of other regions of the country. We present information on composition, structure, biological diversity and *Agroforest* management, by sampling 33 plots of 1,000 m^2, in 8 locations and interviews with owners. Sea level is recorded at 800 m altitude, is extensive, uses little technology and local knowledge. An age of almost three centuries is recognized, but a pre-Hispanic presence is considered. Agroecologically maintains rustic management, traditional productive gardens and simple polycultures that diversify the production of the agroecosystem, all contrasting with the conventional crop model. More than 75 woody species make up the vertical and horizontal structure mostly native (80-90%), being the legumes the most abundant, a small percentage are fruit trees introduced from Europe and Asia. The canopy reaches up to 30 m height, covers of 75-85% and densities of up to 800 ind/ha. Wildlife is abundant (birds and mammals) and it is as diverse or more diverse than native ecosystems and shade agroecosystems (coffee and cocoa). Its temporal continuity shows its ecological resilience and represents an alternative to biocultural conservation for adaptation and mitigation to global climate change.

Agroforest of pineapple, Villa Purificación, Jalisco, México

Keywords: Agroforestry System, Ananas comosus, pre-Hispanic, Biodiversity, Agroecosystems.

References:

1. Rosales-Adame, J.J. et al., 2014. Tropical and Subtropical Agroecosystems. 1-18
2. Rosales-Adame, J.J. et al., in Etnoagroforestería en México. 2016. UNAM. 44-65

L04.P.31

Tree diversity and use in Western Himalayan foothills of Jammu and Kashmir, India

Sehgal S. (sehgals1@yahoo.com), Abidi R. A.

Agroforestry, SKUAST-Jammu, Jammu, J&K, India

Agroforestry plays a vital role in the livelihood of rural community and farmers have a long tradition of raising food crops, trees and animals together. The present study was aimed to have an exploratory view on the farming system in district Samba, situated in the Western Himalayan foothills of Jammu and Kashmir, India. It lies between 32°34′ N and 75°07′ E and has an average elevation of 384 m above mean sea level. The local farming systems rely heavily on forest and trees for their livelihood as trees are the single most important source of fodder, food and fuel wood for the inhabitants. The study was conducted with the objectives to identify the trees planted/retained on the farmland, the purpose of their planting/retaining as well as their spatial arrangement. A household survey was conducted in the study area, for which a total of one hundred eighty respondents were interviewed through a pre-structured interview schedule in person. Results indicate that farmers are retaining/planting trees on their field and have been accruing diversified uses and services from these trees which include both indigenous and exotic tree species. Overall, there were 33 tree species belonging to 16 families present on the farmers' field, out of which more than 50 per cent were fruit trees. The farmers' inclination for fruit trees may be due to their contribution towards nutritional security as well as income generation capability. The results impress upon developing tree based farming systems with preferred tree species as an essential component.

Keywords: Western Himalayas, Trees on farms, Biodiversity, Agroforestry.

L04.P.32

Conservation need of Globally Significant Himalayan Indigenous Farming Systems with reference to bird diversity

Sharma G.[1] (banstolag@gmail.com), Acharya B. K.[2]

[1] *The Mountain Institute India, Tadong Daragaon, Gangtok, Sikkim, India*; [2] *Department of Zoology, Sikkim University, Gangtok, Sikkim, India*

Human-managed indigenous farming systems (IFS) in Eastern Himalayas—a part of globally significant biodiversity hotspot, provide unique ecosystem services and house rich biodiversity. Recent infrastructure development (hydropower projects, Pharmaceutical companies, etc.) has resulted into land-use transformation leading to habitat and biodiversity loss. IFS managed through traditional knowledge of small-holders serve as habitats for birds, butterflies and other biodiversity elements. We assessed bird diversity during 2014-2017 covering Mandarin orange-based (MA), Farm-based (FA) and Large cardamom-based agroforestry (LA), and in Forest ecosystems (FE) in Sikkim, Eastern Himalayas, India following point count method (1900 counts) spread across 24 different transects. We recorded 18,086 individuals, 42 families and 220 species of birds contributing 38.2% of total bird species (576) reported from Sikkim Himalayas. Species richness was highest in LA and FA (157 each) followed by FE (137) and least in MA (130) representing 71.2% each in LA and FA, 62.3% in FE and 59.1% in MA of the total species.IFS also support rich diversity of birds across feeding guilds, forest specialization, stratum and migratory status; house two endemic, three IUCN Red listed species, and 12 species listed in CITES appendices. Paradoxically, in addition to production of food the IFS are crucial ecosystems and need conservation priorities under framework of science, policy and practice.

Farm-based agroforestry systems in the Eastern Himalayas

Keywords: Eastern Himalayas, Traditional Agroforestry, Indigenous Farming Systems, Species Diversity, Biodiversity.

References:

1. Sharma and Sharma (2017) In: Agroforestry: Anecdotal to Modern Science. doi.org/10.1007/978-981-10-
2. Sharma G, Honsdorfur Ben, Singh KK (2016) Tropical Ecology, 57(4): 751-764
3. Sharma, et al (2016) ICIMOD Working Paper 2016/5 Kathmandu: ICIMOD.
4. Sharma and Acharya (2013) Agriculture Systems and Management Diversity. Gazetteer of Sikkim, India

L04.P.33

Agroforestry in Poland - first practices

Świderska P.[1] (paulina_swiderska@sggw.pl), Baj Wójtowicz B.[2], Borek R.[3]

[1] *Faculty of Horticulture, Biotechnology, Warsaw University of Life Sciences, Warsaw, Poland*; [2] *Oxford University, Oxford, United Kingdom*; [3] *The Institute of Soil Science and Plant, Puławy, Poland*

Agroforestry in Poland is still a niche subject. The poster will present few good practices developed so far. In the past silvopastoralism, shelterbelts and scattered trees on farmlands were very common in Poland replaced next by agricultural plots consolidation and monocultures. Silvopastoral agroforestry systems has been recognized recently as very beneficial and curently is being reintroduced to the farming in Poland. The first agroforestry practice in herbs cultivation present mutual benefits for farmers, for the environment benefiting from the intentional combination of agriculture and forestry that increases biodiversity and reduces erosion as well as for the consumers. Chłapowski Landscape Park is another good practice in agroforestry. Chłapowski's method relies on implementing a network of forest stands and windbreaks between fields to fortify the landscape and increase crop yields.

Keywords: silvopastoralism, agroforestry practice in herbs cultivation, a network of forest stands and windbreaks.

L04.P.34

Beneficial effects of hedges and scattered woody areas on soil properties in organic agriculture

Szalai Z.[1] (szalai.zita@kertk.szie.hu), Tóth E.[1], Biró B.[2], Pusztai P.[1]

[1] *Ecological and Sustainable Production S, Szent István University, Budapest, Hungary*; [2] *Soilscience and Watermanagement, Szent István University, Budapest, Hungary*

Hedgerows were established in 1998-2001 by Department of Ecological farming and sustainable Production System to utilise beneficial effects of hedges through balanced microclimat to soil strcutural and biological properties.
Soil properties especially soil biodiversity (SFW) of different land use system was examined at Experiment Field of Szent István University Soroksár, Ecological Farming Unit. The soil-physical-chemical parameters, the nutrient content, the humus quantity and quality was measured. Enzyme activities and qualitative Soil Food Web assessment (Soil Food Web Inc.) was used. Results of FDA enzyme activities show significantly positive correlation with increasing humus content (R=0,861) in the samples. According to the different land use and cultivation practices SFW responded differently - e.g. highest number of fungi was found in scattered woody area, and in hedgerow.
Our study shows, that the application of different land use and cultivation practices influences the biological activity of the soil of cultivated plots. We can assume that the soil of hedgerows, and scattered fruit orchards show significantly the highest biological activity, and humus content compared to intensive tillage areas (cereal field) and recultivation areas. Further samples collected from cultivated areas from different distance of the hedgerows are under procession.

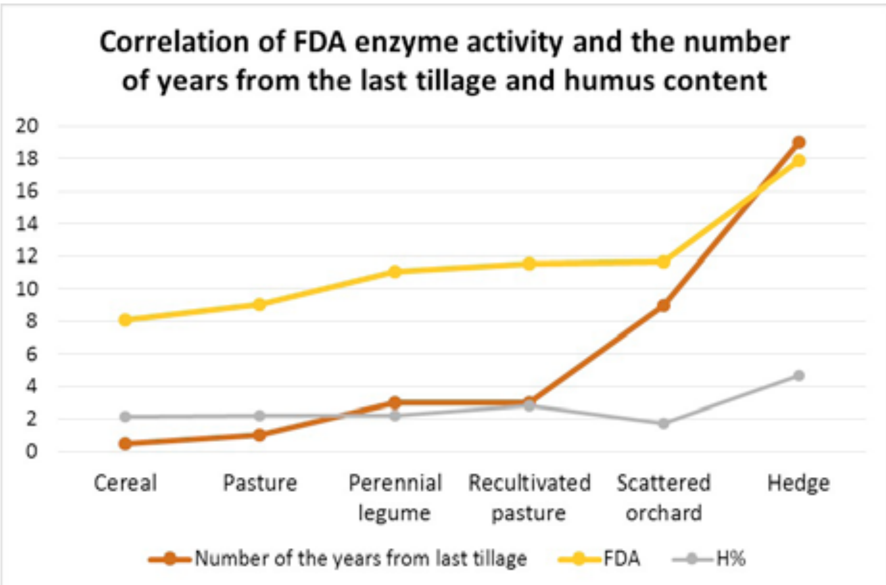


Figure 1. Correlation of FDA enzyme activity and the number of years from the last tillage and humus content

Keywords: hedges, soil biodiversity, soil biological activity, beneficial effect, soil food web.

References:

1. Barrios, E. (2007). Ecological economics, 64(2), 269-28
2. Domonkos, M., Madarász, B., Biró, B. 2015.Környezetkímélő művelési rendszerek Magyarországon. MTA
3. Wittwer, R., et al (2018) In EGU General Assembly Conference Abstracts (Vol. 20, p. 17002)
4. Cooper, J. (2016) Agronomy for sustainable development, 36(1), 22.

L04.P.35

Shifting cultivation in Mizoram, Northeast India: problems and prospects

Tripathi S. K. (sk_tripathi@rediffmail.com)

Forestry, Mizoram University, Aizawl, Mizoram, India

In Mizoram, northeast India majority of the population (~60%) depends on agricultural products from shifting cultivation carried out on steep slopes, and half of the total land area of the state is having 40-100% slopes. During this practice, farmers slashed a piece of forest land and burn the vegetation *in situ* after drying followed by cropping for one or two years, and then abandoned the land to restore soil fertility and moved to other forest areas for cultivation. Earlier the system was adequately productive, economically feasible and ecologically balanced because of prolonged fallow period (~20-30 years) but in recent years as a result of exponential expansion of human population, fallow periods have been drastically reduced (~<5 years) which has led to substantial decrease is soil fertility, crop diversity and productivity (Grogan et al 2012). This has led to widespread concern of Government and Non-government organizations about the sustainability of this system and thus the Government has implemented various policies with aim to improve the livelihood options for the majority of poor people.
Shifting cultivation in Mizoram is a unique agro-ecosystem with distinct biodiversity adapted on steep slopes of hilly terrain which includes variety of crops like cereals, vegetables, legumes, oil seeds, culinary spices and herbs, even flowers and medicinal plants within a small piece of land in comparison to other farming system (Tripathi et al 2017). Shifting cultivators generally belongs to a poor background who could not easily meet their daily need from market, and therefore they grow almost all crops that they need in a small land area through the well preserved seeds of the previous year crops using traditional conservation practices. These small farms support 30-60 different species of tree, fruits, vegetables, weeds. Diversity of crops depends on the fallow age, for example, shorter fallow support less diversity than the longer fallow. Diversity and the functioning of microbes in the rhizosphere of early regenerating plants showed a reverse trend that appears to boost up the nutrient cycling and growth of plants more rapidly in the short fallow land. Conversion of shifting cultivation to plantations like Oil palm, Rubber etc lead to decrease the diversity of plants and soil microbes in the system. Earlier *Jhumias* were using local varieties of the species with wide genetic diversity but nowadays some farmers use high yielding hybrid varieties that accelerates the erosion of endemic biodiversity of the region. Sustainability of shifting cultivation can be achieved by scientific interventions through integrated nutrient management using moderate fallow period and conserving the indigenous diversity of crops and microbes.

Keywords: Shifting cultivation, Biodiversity conservation, Soil fertility, Microbial diversity, sustainability.

References:

1. Grogan P., Lalnunmawia F. and Tripathi S.K. (2012). Agroforestry Systems 84: 163-177.
2. Tripathi SK, in: Shifting cultivation policies: Balancing environmental and social sustainability, 2

L04.P.36

Effect of landscape connectivity provided by wooded and cultivated elements on weeds: a response-effect trait framework

Uroy L.[1] (lea.uroy@univ-rennes1.fr), Mony C.[2], Ernoult A.[2], Alignier A.[3]

[1] *UMR CNRS 6553 Ecobio & UMR INRA 0980 Bagap, University of Rennes & INRA of Rennes, Rennes, France*; [2] *UMR CNRS 6553 Ecobio, University of Rennes, Rennes, France*; [3] *UMR INRA 0980 Bagap, INRA of Rennes, Rennes, France*

Higher landscape connectivity should facilitate plant dispersal and increase plant diversity. In agroforestry landscapes, wooded elements but also grasslands and croplands may provide connectivity. Several studies demonstrated that connectivity acts as a filter on dispersal and establishment traits values (*response trait*). These traits values should, in turn, shape plant diversity (*effect trait*).

Weeds play a dual role in agroforestry landscape. They support important ecosystem functions (*e.g.* pollination, limitation of soil erosion) but also represent a major problem for farmers through the competition with the crop. Assessing the effect of landscape connectivity on weed diversity represent a promising avenue toward a better understanding of mechanisms behind weed assembly.

Here, we investigated how connectivity impacts i) five dispersal and establishment trait values and ii) weed diversity as a proxy of their colonization ability. We sampled 27 cereal fields in the LSTER-ZA Armorique. We assessed the connectivity provided by wooded, grassland and cropland using habitat reachability metrics based on circuit theory.

Our preliminary results showed that connectivity provided by both wooded and cultivated elements impacts functional traits and diversity of weeds. This study emphasizes that using the response-effect trait framework provides i) a better understanding of weed assembly rules and ii) a key to combine the maintenance of weeds without jeopardizing crop production.

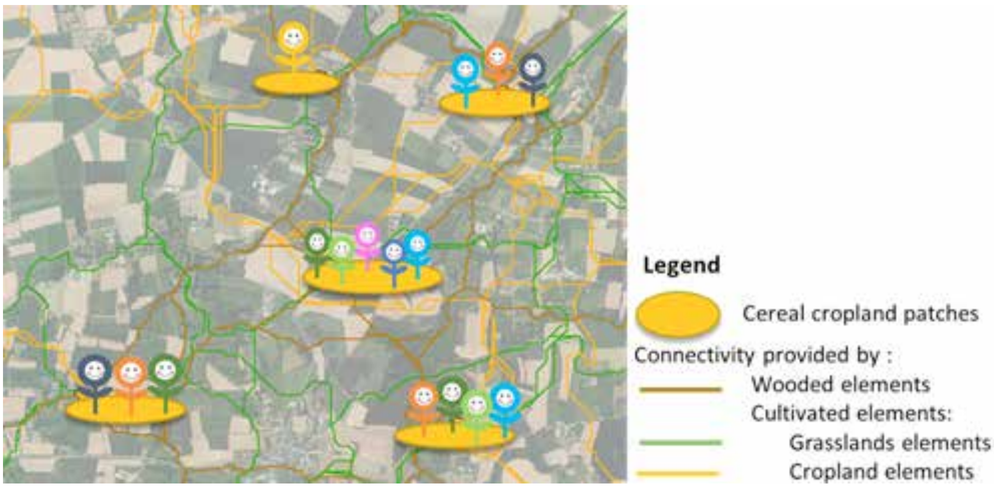


Illustration of landscape connectivity provided by wooded, grassland and cropland elements and weed diversity in cereal cropland patches

Keywords: agroforestry landscapes, circuit theory, weed diversity, dispersal traits, establishment traits.

ABSTRACTS

Agroforestry and world challenges

Agroforestry: riding to the world's rescue

- L5 -

Agroforestry for water quality and watershed restoration

Getting springs to gush the zen way: the agroforestry water works

Agroforestry practices offer the potential to improve environmental, economic, ecological and social benefits for landowners globally. These practices have enhanced tree-cover on agricultural lands, close to 1 billion ha, world-wide. Integration of perennial trees in any given agricultural watershed could / might result in e.g., biodiversity enhancement (plants, animals, birds and microorganisms), increased economic returns influenced by enhanced biodiversity, increased soil health and fertility, positive influence on stream geomorphology, increased energy capture at different trophic levels at the landscape / watershed level, improved water quality, soil erosion control, reduction of non-point source pollutants entering water sources, watershed-level carbon (C) sequestration, and the reduction of greenhouse gas (GHG) emissions (CO2, CH4 and N2O) from the terrestrial and aquatic ecosystems. However, especially in areas close to streams and rivers, where modern intensive agricultural operations are ongoing, riparian filter strips with woody plants are lacking. These sites therefore might highly benefit from the establishment of riparian buffer strips or filter strips. Riparian buffer strips / filter strips are perennial vegetation (trees, shrubs, perennial grasses) along the banks of waterways found in both forested and agricultural areas, or as constant vegetation barriers integrated in sensitive areas of the crop field itself. They can be artificially established or can also occur naturally. Although they represent only a minor component of the landscape, they are highly productive systems that exert a disproportionate regulatory influence over many important ecological processes at many scales.

L05_O.01

A Paired Watershed Evaluation of Agroforestry and Bioenergy Effects on Water Quality on a Corn/Soybean Rotation

Udawatta R. (UdawattaR@missouri.edu), Jose S., Rankoth L.

The Center for Agroforestry, SNR, University of Missouri, Columbia, MO, United States

Rigorous long-term scientific studies confirming environmental benefits from the use of agroforestry (AF) practices are limited and thus restricts the adoption of AF practices. The objective was to examine the effects of AF and bioenergy crops on nonpoint source pollution (NPSP) on row-crop watersheds. Three watersheds in a paired watershed design were established in 1991 at the Greenley Research Center of University of Missouri, USA (Fig. 1). Treatments of oak trees+grass buffers on AF and grass buffers (GB only) on GB were established in 1997. Bioenergy crops (grass and legume) were established in between buffers of AF and GB watersheds in 2012. Water samples were analyzed for sediment, total nitrogen (TN) and total phosphorus (TP). Results indicated that treatments reduced the number of runoff events, runoff volume, sediment, TN, and TP on AF and GB watersheds compared to the row crop watershed. During 2012-2018, treatment watersheds generated two runoff events and row crop watershed generated four events annually. Average sediment loss for row crop and treatment watersheds were 11 and 5 kg ha-1 yr-1. Treatment watersheds reduced sediment, TN, and TP losses by 54, 42, and 46% compared to the row crop watershed. Results suggest that establishment of AF, GB, and bioenergy crops help reduce NPSP to water bodies. These treatments could be established on contours and strategic locations of row crop watersheds to improve economic benefits, land value and environmental quality.

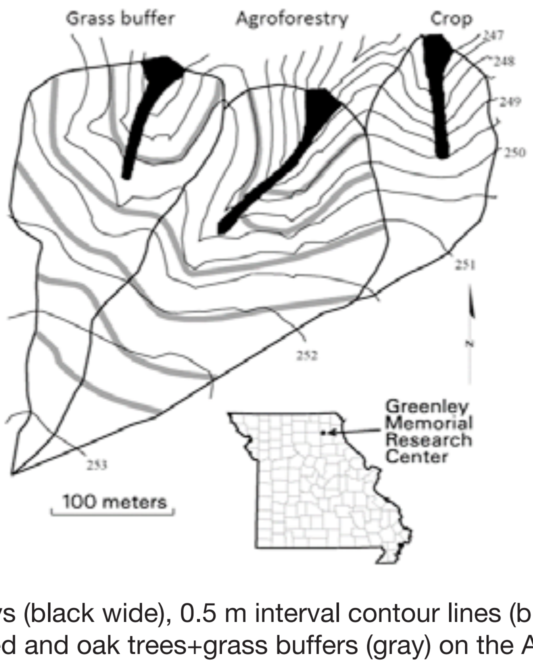


Figure 1. Grass waterways (black wide), 0.5 m interval contour lines (black thin), and grass buffers (gray) on the GB watershed and oak trees+grass buffers (gray) on the AF watershed. The inset map shows approximate location of the Greenley Memorial Research Center in Missouri.

Keywords: Nitrogen, Phosphorus, Runoff, Sediment.

L05_O.02

Mitigation of macronutrient leaching by agroforestry system of hybrid aspen and perennial grasses

Bardule A. (arta.bardule@silava.lv), Lazdina D., Bardulis A.

Latvian State Forest Research Institute, Salaspils, Latvia

Empirical data on leaching of macronutrients from agricultural land in the Baltic Sea region is of particular interest due to two reasons: 1) eutrophication of surface waters resulting in unfavourable ecological status of the Baltic Sea; 2) increasing risk of depleting the soil nutrient stocks by intensified harvest of agricultural yield and biomass. The objective of this study was to evaluate the mitigation effect of fertilized agroforestry system on macronutrient (NO_3-N, PO_4-P, K) leaching. The studied agroforestry system consists of juvenile hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) plantation and four cultivars of legume and perennial grass (fodder galega (*Galega orientalis* Lam.), poor-alkoloid lupine (*Lupinus polyphyllus* L.), reed canary grass (*Phalaris arundinacea* L.) and festulolium (× *Festulolium pabulare*)) sown for seed production.
The agroforestry system, size of 16 ha, was established in agricultural land in central part of Latvia in spring 2011. Wastewater sludge (10 t_{DM} ha^{-1}), stabilized wood ash (6 t_{DM} ha^{-1}) and digestate (30 t ha^{-1}) were applied as nutrient compensatory fertilizers to improve soil quality. Above-ground biomass was harvested in November 2015. Results derived from the monitoring of soil solution chemical content generally show a decrease of annual macronutrient leaching over time after the establishment of plantation in agricultural land in response not only to meteorological conditions, but also to the type of fertilizer used.

Macronutrient, mg L^{-1}	Year after establishment of plantation	Without fertilization	Wood ash	Digestate	Sewage sludge
NO_3-N	1st (2011)	15.9±2.4	10.8±1.7	10.9±5.2	8.1±4.1
	5th (2015)	0.15±0.05	0.06±0.02*	0.06±0.03*	0.06±0.03
	7th (2017)	0.02±0.01	0.01±0.01	0.02±0.01	0.04±0.02
	7th (2017, harvested plot)	0.17±0.09	<0.01	0.01±0.01	0.02±0.01
PO_4-P	1st (2011)	0.03±0.01	0.03±0.02	0.04±0.03	0.07±0.02
	5th (2015)	0.01±0.01	0.04±0.01*	0.01±0.01	0.14±0.01*
	7th (2017)	0.01±0.01	0.06±0.01*	0.01±0.01	0.16±0.01*
	7th (2017, harvested plot)	0.01±0.01	0.08±0.01*	0.01±0.01	0.03±0.01**
K	1st (2011)	3.4±2.1	8.8±0.4*	3.6±0.7	4.1±1.5
	5th (2015)	1.6±0.1	5.1±0.5*	1.8±0.1	2.6±0.3*
	7th (2017)	1.3±0.4	4.1±0.8*	2.1±0.3*	2.2±0.4*
	7th (2017, harvested plot)	1.9±0.2	3.6±0.8*	3.6±0.3*	1.9±0.1

* Statistically significant difference ($p < 0.05$) between mean annual nutrient content in soil solution in fertilized plots and in control plots (without fertilization) within year.
** Statistically significant difference ($p < 0.05$) between mean annual nutrient content in soil solution in harvested and unharvested plots in 2017.

Table 1: The mean (±S.E.) annual macronutrient concentration in soil solution (at 60 cm depth). Grey gradient highlights decrease or increase of concentrations within treatment.

Keywords: macronutrient leaching, fertilized agroforestry system, hybrid aspen, perennial grasses.

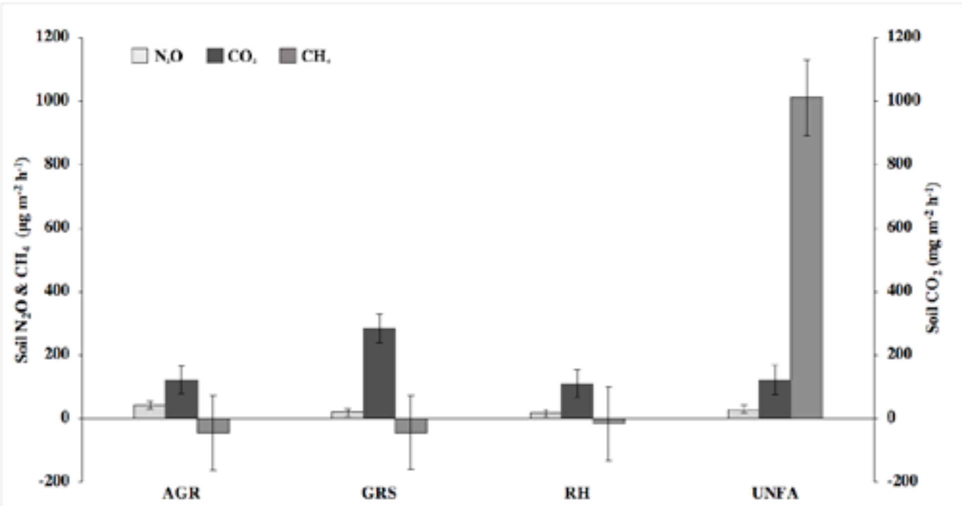
L05_O.03

Land-use comparison of temporal greenhouse gas emissions of riparian systems in Southern Ontario, Canada

Baskerville M.[1] (mabaskerville@uwaterloo.ca), Oelbermann M.[1], Thevathasan N.[2]

[1] *Environment, University of Waterloo, Waterloo, Canada*; [2] *Environmental Sciences, University of Guelph, Guelph, Canada*

Forested riparian buffers (RBs) located downslope of agricultural areas have high water tables, increased N due to surface runoff, and high C inputs from vegetation, creating a potential hot spot for soil greenhouse gas (GHG) emissions (Bradley et al., 2011). However, there are few comparative analyses of GHG emissions from different riparian land-use systems in temperate regions. The goal of the study is to determine and compare soil GHG (CO_2, CH_4, N_2O) emissions between a grassed buffer (GRS), an undisturbed natural forest (UNFA), a forested riparian buffer (RH), and an agricultural field (AGR) found along Washington Creek, Ontario. Four permanent GHG sampling chambers were placed in each land-use, and gas samples were collected bi-weekly to quantify GHG emissions. Emissions were measured from June 2017 to November 2018, excluding the winter season. Soil characteristics were measured next to chambers, and soil samples were collected to analyze ammonium/nitrate concentration in the lab. Highest average annual CO_2 emissions were seen in the GRS site and highest average annual N_2O emissions were found at the AGR site. Neither were found to be statistically significant. The UNFA site had significantly ($p<0.001$) higher average annual CH_4 emissions than all other land-uses. Thus, initial results indicate the RH did not significantly emit more GHGs than the other land-uses, and forested RBs are an acceptable best management practice to protect both water and air quality.



Soil N2O (µg m-2 h-1), CO2 (mg m-2 h-1), and CH4(µg m-2 h-1) emissions as LS means calculated from a linear mixed model for each land-use type from June 2017 to June 2018 (excluding winter emissions) at Washington Creek, Ontario, Canada. Vertical bars represent standard error.

Keywords: Greenhouse gas, Riparian buffer, Carbon dioxide, Nitrous oxide, Methane.

References:

1. Bradley et al., 2011, Appl Soil Ecol, 6-13. doi: 10.1016/j.apsoil.2010.11.007

L05_O.04

Shifts in N- cycling microbial communities associated with riparian buffers in Southern Ontario agricultural systems

Mafa-Attoye T.[1] (tmafaatt@uoguelph.ca), Thevathasan N.[1], Baskerville M.[2], Oelbermann M.[2], Dunfield K.[1]

[1] *School of Environmental Science, University of Guelph, Guelph, ON, Canada*; [2] *School of Environment, Resources and Sus, University of Waterloo, Waterloo, ON, Canada*

Riparian buffers (RB) intercept soil nitrogen (N) leaching and surface runoff from agricultural lands into aquatic ecosystems and can be hotspots for nitrous oxide (N_2O) emissions (1). N-cycling microorganisms are crucial for the production and consumption of N_2O in soils; however, they can be influenced by plant-microbe interactions (2). The goal of our study was to assess land-use changes related to RB on nitrogen-fixing, nitrifying and denitrifying bacterial communities and N_2O emissions. The Washington Creek long-term experiment was established over 25 years ago and consists of grass buffer (GRB), grassland (GRL), undisturbed natural forest (UNF), rehabilitated site (RH), and agricultural land (AGR) (3). Soil was sampled in the summer of 2017 and 2018, DNA and RNA were extracted and used to target key N-cycling genes for N-fixation (*nifH*), nitrification (*amoA* and *crenamoA*), and denitrification (*nirS*, *nirK, and nosZ*) via quantitative PCR (4). High throughput sequencing of 16S via Illumina MiSeq and Non-metric multidimensional scaling (NMDS) indicated statistical differences in bacterial communities between AGR, UNF, and other riparian land-use types (Fig. 1a). The abundance of the *nosZ* gene was highest in RH and GRB relating to low N_2O measured at these sites (Fig. 1b). Our results suggest N-cycling microbial community dynamics in RB differ according to land-use, this may be impacting potential N_2O fluxes in the sites investigated.

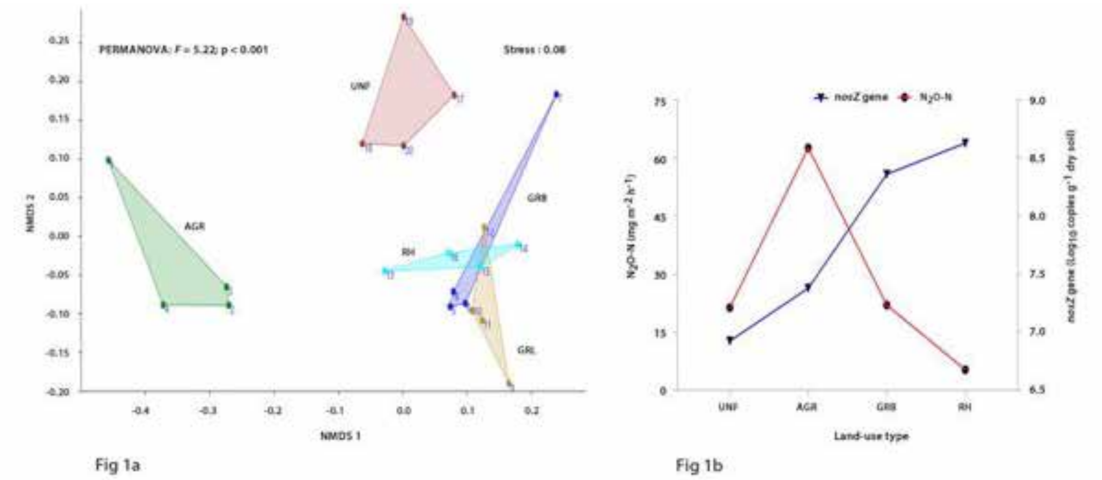


Fig 1 (a). Non-metric multidimensional scaling (NMDS) ordination plots (2D) of taxonomic dissimilarity (Bray–Curtis) at the level of genus for bacterial communities. Results of PERMANOVA on Bray–Curtis distance (based on 9999 permutations) is shown. Fig1(b). Comparison of nosZ gene abundance and nitrous oxide emission in riparian land-use types in Washington creek, summer 2017 (n=4).

Keywords: Denitrification, Illumina sequencing, Land-use type, Nitrification, Nitrous oxide.

References:

1. Zhao et al., (2018), Science of The Total Environment, 642, 1090-1099
2. Butterbach-Bahl et al., (2013), Phil. Trans. R. Soc. B, 368 (1621), 20130122.
3. Oelbermann et al., (2015), Environmental management, 55 (2), 496-507
4. Thompson et al., (2016), Soil Biology and Biochemistry, 103, 262-273

L05_O.05

Can we design forested riparian buffer strips to minimize soil greenhouse gas emissions as affected by earthworms?

Cameron A.[1] (ashley.cameron@usherbrooke.ca), Bradley R.[1], Benetková P.[2], Thevathasan N.[3], Whalen J.[4], Šimek M.[5], Boilard G.[1], Józefowska A.[6]

[1] *Département de biologie, Université de Sherbrooke, Sherbrooke, Quebec, Canada*; [2] *Faculty of Science, Charles University, Prague 2, Czech Republic*; [3] *School of Environmental Sciences, University of Guelph, Guelph, Ontario, Canada*; [4] *Department of Natural Resource Sciences, Macdonald College of McGill University, Sainte-Anne-de-Bellevue, Quebec, Canada*; [5] *Institute of Soil Biology, České Budějovice, Czech Republic*; [6] *Department of Soil Science, University of Agriculture in Krakow, Kraków, Poland*

Forested riparian buffer strips (FRBS) are common in temperate agroecosystems due to their ability to sequester nutrients from agricultural runoff. The full environmental benefits of FRBS can only be evaluated, however, by accounting for a wide range of criteria that go beyond stream water quality. For example, it is important to determine the net greenhouse gas (GHG) balance of FRBS relative to adjacent agricultural fields. It is also important to identify the factors controlling these GHG emissions in order to propose optimal FRBS designs that maximize their environmental benefits. One such factors is the presence of earthworms (EW), whose burrowing activities may modify soil emission rates of CO_2, N_2O and CH_4. We hypothesised that FRBS are a refuge for EW in agricultural landscapes due to higher moisture and litter inputs, and fewer physical disturbances. A field survey was conducted, in 2017 and 2018, to quantify EW species abundances in FRBS and adjacent agricultural fields in Eastern Canada and Central Europe. At 77 sites, we collected and identified EW, noted the tree species and understory vegetation in the FRBS, type of crop in the adjacent agricultural field, soil drainage class as well as five soil physicochemical variables (texture, pH, total C, total N and % organic matter). EW abundance was significantly higher in FRBS than in adjacent fields. Distance-based redundancy analysis (dbRDA) revealed that EW abundance is positively correlated with soil moisture, organic matter, clay content and deciduous trees, and negatively correlated with coniferous trees and sand content. To test the effects of EW on GHG emissions, microcosm studies were conducted using a replicated factorial design comprising of 3 soil origins (deciduous FRBS, coniferous FRBS, agricultural field) x 2 soil textures (field conditions, high clay) x 3 EW life habits (anecic, endogeic, no EW). Anecic EW had a positive effect on soil CO_2 and N_2O emissions, which decreased after a few weeks. Increasing soil clay content had a negative effect on the emission of these two GHGs. We are currently using an isotope dilution protocol for testing the effects of soil origin, soil texture and EW life habit on potential gross rates of CH_4 production and oxidation. Collectively, our data will be used to assess environmental trade-offs between stream water quality, soil C sequestration and soil GHG emissions in FRBS of different designs.

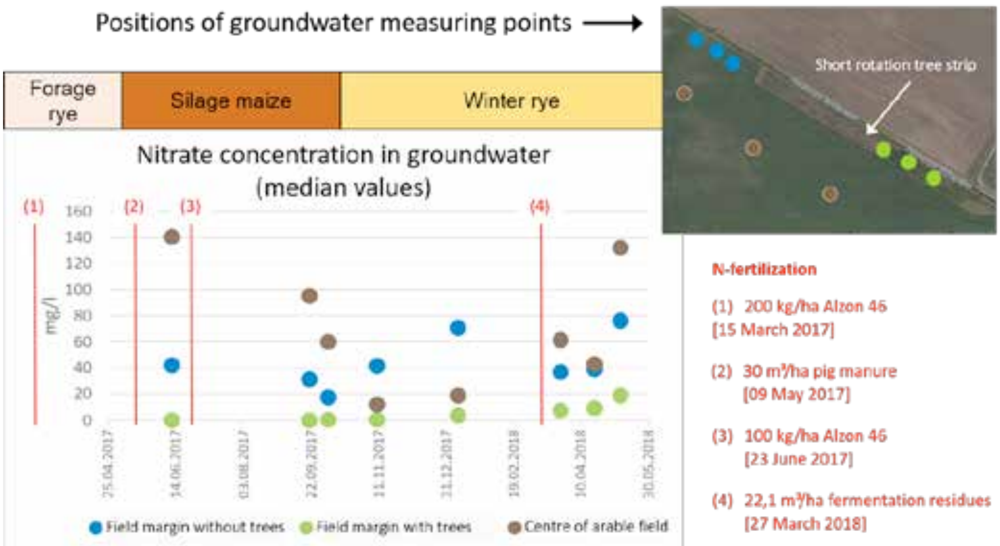
L05_O.06

Short rotation riparian strips as an option to protect surface water quality in Germany

Böhm C. (boehmc@b-tu.de)

BTU Cottbus-Senftenberg, Cottbus, Germany

In Germany the anthropogenic input of nutrients such as N and P into surface waters adjacent to agricultural land is high, which leads to eutrophication of ditches and lakes. In order to examine to what extent a short rotation riparian strip prevents N discharge to water bodies, an experiment was conducted in an agricultural site, located in southern Brandenburg (about 150 km south of Berlin). The groundwater table at this site varies between 1 and 1.5 m over the year. A 24 m wide short rotation woody strip of poplars (*Populus* spp.) was planted along an existing ditch, while part of the area near the ditch was further managed in arable rotation and used as a reference area. Two years after establishment of the woody plants, measurements of nitrate concentration in groundwater took place by using groundwater wells in the center of the field and near the ditch, both inside the woody strip (about 12 m away from the ditch edge) and in the same distance to the ditch in the reference area. The nitrate concentration in the groundwater varied greatly depending on fertilization and weather conditions (especially precipitation). During the entire measurement period significantly lower nitrate concentrations were determined within the poplar strip as compared to the reference area and the center of the field (Fig. 1). Hence, planting short-rotation woody strips along ditches can contribute effectively to reducing nitrogen discharge to surface water after only a short period of time.



Keywords: riparian buffer, nitrate, groundwater, poplar, short rotation agroforestry.

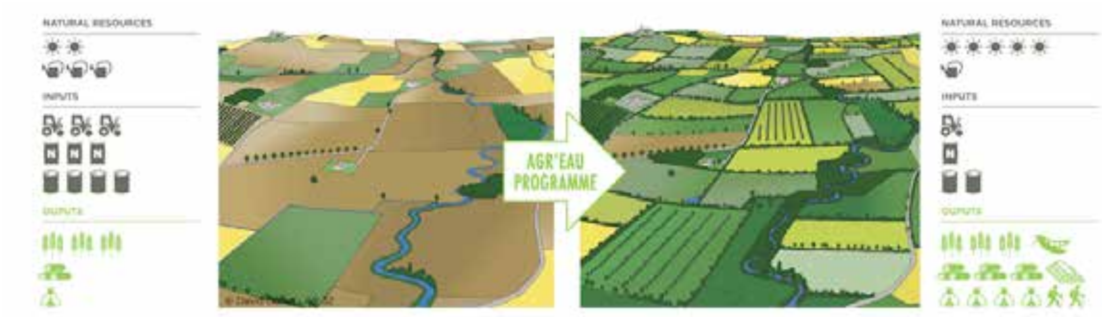
L05_O.07

The Agr'eau initiative - Main results and perspectives after 6 years of implementation

Charton A. (aurelie.charton@agroforesterie.fr), Balaguer F.

French Agroforestry Association, Auch, France

Mechanised, high chemical input intensive agriculture in the Adour-Garonne water catchment as in other parts of Europe has led to important land erosion, soil degradation, desertification, biodiversity loss and water pollution. This has increased floods and droughts, and other constraints on the agricultural production. In this large water catchment of nearly 5 Mha of agricultural area and a wide diversity of pedo-climatic contexts (average rainfall 700 mm), local farmer organizations and other landscape stakeholders have been developing agroforestry systems over the last 20 years to address these challenges. Since 2013, a network of more than 300 farms of all types and sizes across the region, organized in the Agr'eau programme and supported by researchers and local and national organizations, has built on this experience to develop and validate resilient climate-smart agriculture approaches that combine agroforestry with minimum-tillage, cover crop and mulching practices. The aim of the Agr'eau network was to come to collaborative development of farming practices that allow for sustainable soil and water management (landscape approach), intensification and optimization of farming systems, in short producing more with less resources, while protecting the environment. The result today is a multi-level form of agriculture that maximizes plant cover (both spatially and temporally), yields and ecosystem benefits, applicable on all sorts of farms.



From a degraded landscape to resilient climate-smart agriculture

Keywords: agroforestry, vegetation cover, water management, soil degradation, grassroots innovation.

L05_O.08

Quantifying aquatic carbon and nitrogen dynamics and greenhouse gas mitigation potential of riparian agroforestry zones

Hundal H.[1] (kiratkhundal@gmail.com), Oelbermann D.. M.[1], Thevathasan D. N.[2]

[1] *Environment, Resources & Sustainability, University of Waterloo, Waterloo, Ontario, Canada*; [2] *Environmental Sciences, University of Guelph, Guelph, Ontario, Canada*

Riparian areas can be defined as vegetation strips bordering a water body (1). Agricultural intensification in Canada has led to a loss of riparian areas, which has resulted in the degradation of freshwater aquatic ecosystems (2) due to an increasing amount of fertilizer and nutrients runoff from the upland vegetation (1). Nutrient pollution causes eutrophication of water bodies, thereby lowering the water quality (1) and the health of the aquatic ecosystems (3). And rehabilitation/restoration of the riparian areas has been shown to minimize these effects (2,4). Additionally, riparian zones have the potential to mitigate climate change through carbon (C) sequestration in vegetation biomass and soil (5). These two services of riparian zones guide my research. While, there is a lot of information regarding the adverse effects of the nutrient runoff on water quality (3), information on greenhouse gas (GHG) emissions from riparian zones is limited. Therefore, the objective of this research project is to study the carbon (C) and nitrogen (N) dynamics in the aquatic component of the Riparian Agroforestry Systems (RAFS). RAFS are formed when the practice of agroforestry, tree plantation in farmland, is implemented to create a riparian area on the edges of a water body. RAFS being monitored include: an undisturbed natural forest riparian area, unaltered for over 150 years; a rehabilitated forest riparian area, restored over 25 years ago; and a grassland riparian area.

Table 1: The following tables records the mean seasonal Carbon dioxide (CO_2-C) emissions (g/L); Nitrous oxide (N_2O-N) emissions (g/L); Methane (CH_4-C) emission (g/L); Nitrate (NO_3^-) (in mg/L); and Ammonium (NH_4^+) (in mg/L) for a rehabilitated forest buffer (RH) stream site, undisturbed natural forest (UNF) stream site, grassland (GRS) stream site. The stream sampled was Washington Creek, located in southern Ontario during the year 2017. Sampling will continue for the year 2018.

	Season	RH	UNF	GRS
CO_2-C (g/L)	Summer	0.068	**0.072**	0.052
	Fall	0.070	**0.077**	0.057
N_2O-N (g/L)	Summer	9.47E-07	**9.60E-07**	6.35E-07
	Fall	9.68E-07	**1.19E-06**	7.48E-07
CH_4-C (g/L)	Summer	2.66E-06	1.64E-06	**3.41E-06**
	Fall	1.82E-06	1.24E-06	**2.51E-06**
NO_3^- (mg/L)	Summer	0.065	**0.071**	0.054
	Fall	0.068	0.075	**0.080**
NH_4^+ (mg/L)	Summer	**10.23**	10.14	10.06
	Fall	10.59	10.58	**14.16**

Keywords: Agroforestry, Riparian Zones, Water, GHG emissions.

References:

1. Hilliard, et al., 2014, Agriculture and Agri-food Canada.
2. Fortier, et al., 2010, Agr Ecosyst Environ, Issue 137, 276–287.
3. Dodds In : Freshwater ecology: concepts and environmental applications, 2002, 449-470.
4. Verhoeven, et al., 2017, Trends Ecol Evol, Issue 21, 96–103.
5. Capon, et al., 2013, Ecosystems, Issue 16, 359–381

L05_O.09

Agroforestry and Phosphorus Credit Trading in the U.S.A.'s Chesapeake Bay Watershed

Munsell J. (jfmunsel@vt.edu), Addlestone B., Cobourn K., Strahm B., Trozzo K., Scott S., Beck A.

Virginia Tech University, Blacksburg, VA, United States

The Chesapeake Bay is the largest estuary in the U.S.A. Governmental agencies and other stakeholders incentivize riparian forest buffers and other tree-based conservation measures to reduce farm pollutants entering watershed creeks and streams. Many landowners hesitate to use conservation measures because they compete with agricultural production. One strategy for overcoming this barrier is the use of low-density multifunctional riparian agroforestry and upland contour plantings. A public/private partnership in Virginia, U.S.A. is studying the potential for agroforestry to generate phosphorus credits in the state's lucrative nutrient trading market (average price per pound of phosphorus = $15,000 USD on over 80 existing trading facilities). The current approach is to retire farming by planting conifer trees at high density, but agroforestry provides pathways for balancing tree planting and agricultural production. Conservation Credit for Agroforestry Production (C-CAP) includes several funded initiatives to: 1) demonstrate and study riparian and upland agroforestry plantings on two Virginia farms; 2) model the relationship between Total Maximum Daily Loads (TMDL) goals and simulated rates and types of agroforestry adoption; and 3) study tradeoffs between agroforestry farming returns and water quality benefits using a production possibilities frontier. Field-based plantings allow for empirical studies of tree-tube effectiveness, site preparation strategies, plant-water relations on contour, and nitrogen fixer intercropping. Plantings also help document financial costs for economic analysis. A set of hypothetical property-level projects representing agroforestry conversions across a large parcel sample frame are modeled using tools that depict the impacts of BMP adoption at the sub-basin scale. Integration of economic and biophysical models in simulations helps project production frontiers that study tradeoffs between various rates of tree plantings for trading and conventional agricultural production. This presentation covers C-CAP initiatives and early findings.

Keywords: Nutrient Trading, Environmental Services.

L05_O.10

A review of the literature on the relationships between trees, land use, and hydrological processes in the Andes

Mathez-Stiefel S.-L.[1] (sarah-lan.stiefel@cde.unibe.ch), Cerrón-Macha J.[2], del Castillo J. D.[2], Bonnesoeur V.[3], Peralvo M.[4]

[1] *ICRAF & CDE, Univ. Bern, Bern, Switzerland*; [2] *World Agroforestry (ICRAF), Lima, Peru*; [3] *CONDESAN, Lima, Peru*; [4] *CONDESAN, Quito, Ecuador*

In the Andean region, interest is growing in the use of trees to restore degraded areas through afforestation, reforestation or agroforestry. In addition to the economic benefits that these interventions can generate, particularly in the case of commercial plantations with exotic trees, one of the main arguments used to support these actions has been their purportedly positive effects on the recovery of the water provision and regulation functions of ecosystems. However, the relationship between tree cover and water is complex and may have positive or negative effects on the ecological functions of watersheds, depending on diverse factors.
In this study, we compiled and synthetized the literature on the relationships between woody plants, land use and hydrologic processes in the Andes. The results showed that there is very limited and fragmented knowledge, with significant gaps in specific areas. While most studies focus on native forests and on agricultural land uses, there is very little research on paramos (Andean moorlands) or on agroforestry, the latter limited to coffee agroforestry. Furthermore, the results from different studies are often not comparable and are sometimes contradictory because of varying research design and methods.
Our qualitative review highlighted the importance of montane cloud forests in water provision, in particular through the interception of horizontal precipitation. In addition, native forests play an important role in water regulation in comparison with crop and pasture lands, as they reduce runoff and store more water. Our results also showed that paramos provide higher water regulation than forested areas with exotic species and other land covers by maintaining base flows. Plantations with exotic taxa, such as pines and eucalypts, provide overall lower water provision than other land uses. However, their effect on water regulation defies simple comparisons with other uses: they have lower base flow and higher peak flow than other uses, and lower infiltration and water storage than forests and paramos, but perform better in these respects than natural pastures. The reviewed studies indicated that water provisioning from coffee agroforestry systems is lower than in coffee systems without shade, but that these levels vary according to the tree species. The tree species, and in particular the management practices, influence the water regulatory role of coffee agroforestry systems with shade as compared to systems without shade: while run-off is higher in systems with exotic taxa (e.g. pine, eucalypts), the level of infiltration varies according to management and leaf characteristics.
Even though there remain important knowledge gaps on the role of forests and trees in the hydrology of Andean watersheds, especially regarding the combined impacts of land use and land cover change, our review results can help inform degraded land restoration practices and policies in the Andean region.

L05.P.01

Effects of conservation management practices on soil quality parameters compared to row crop management

Alagele S.[1] (smaz22@mail.missouri.edu), Anderson S.[1], Udawatta R.[1], Veum K.[2], Rankoth L.[1]

[1] *School of Natural Resources, University of Missouri-Columbia, Columbia, MO, United States*; [2] *Cropping Systems and Water Quality Res., USDA-ARS, Columbia, MO, United States*

Restoration of degraded lands for watershed conservation and the adoption of recommended management practices on agricultural landscapes can rehabilitate watersheds and lead to enhance soil and water quality. The objective of this study was to assess the effects of grass buffers (GB), biofuel crops (BC), grass waterways (GWW), agroforestry buffers (AB), distance from trees, and row crop (RC) on soil quality. Soils were sampled by 10 cm depth increments for up to 30 cm with three replications. Samples were also collected from 50- and 150-cm from trees of AB (AB50 and AB150). Soil enzyme activities (SEAs) of β-Glucosidase, β-Glucosaminidase, Fluorescein diacetate (FDA) hydrolase, dehydrogenase as well as active carbon (AC), water stable aggregates (WSA), soil organic carbon (SOC), and total nitrogen (TN) were measured. Results showed that SEAs, AC, WSA, and TN values were significantly greater ($P<0.01$) for the GB, BC, GWW, and AB than the RC treatment. GB, BC, GWW, AB50, AB150 had 16%, 23%, 49%, 29%, and 21% higher SOC respectively than RC. The GWW had the highest soil quality values among all treatments. The 50-cm distance of AB treatment had higher values than the 150-cm distance for all measured soil quality parameters. Results of this study show that conservation management practices have enhanced soil quality by improving soil microbial activity and organic matter accumulation, thereby contribute significantly to watershed restoration and enhancing water quality.

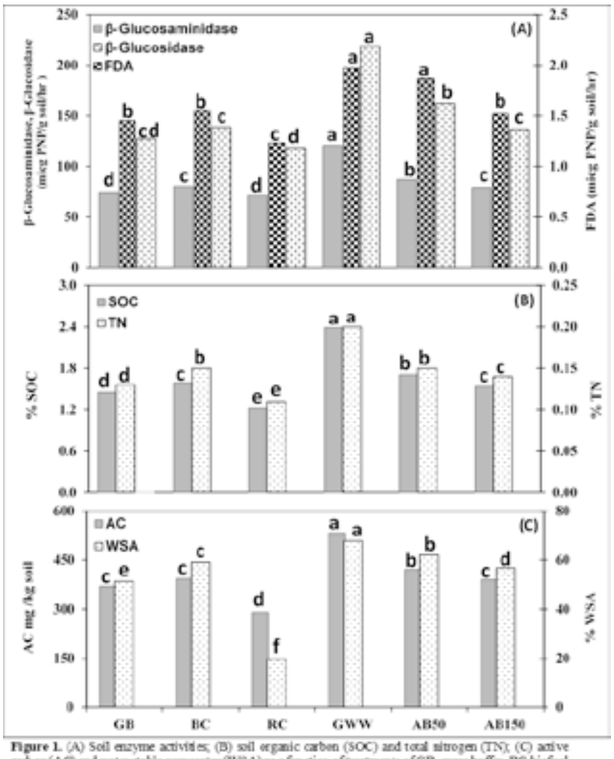


Figure 1. (A) Soil enzyme activities; (B) soil organic carbon (SOC) and total nitrogen (TN); (C) active carbon(AC) and water stable aggregates (WSA) as a function of treatments of GB- grass buffer, BC-biofuel crop, RC-row crop, GWW-grass waterway, AG50-agroforestry buffer at 50 cm, and AG150-agroforestry buffer at 150 cm distance.

Keywords: Watershed restoration, Soil quality, Soil enzyme activities, Soil organic carbon, water stable aggregates.

L05.P.02

Humic substances from chestnut forest for mineral waters valorisation: isolation and characterization in Fiuggi waters

Allevato E. (eallevato@unitus.it)

DIBAF, Tuscia University, VITERBO, Italy

At the beginning of the XXI Century United Nations published the Millennium ecosystem Assessment (UN, 2006): for each ecosystem it is possible to distinguish two components: a) the natural capital, which constitutes the matrix and B) the ecosystem services that represent the flow of benefits that contribute to define the level of human well-being. Natural capital preservation is now an imperative objective to guarantee continuity, quality and quantity of the ecosystem services.

In the 6th Goal of the Sustainable Development Goals 2015-2030 highlighting that water scarcity, poor water quality and inadequate sanitation have negative impact on food security (UN2015).Forests are a key component to ensure the purification and the sustainable supply of water.

Fiuggi chestnut forest (Lazio Region, Italy) provides an «unconventional» ecosystem service produced by the complex «water-chestnut forest-litter and soil».Fulvic acids in soil are water soluble in a wide range of pH (3-8): rain water flows through soil with the effect to move fulvic acid in the ground water (1).

Previous studies (2-3) highlighted Fiuggi's water therapeutic properties: it prevents the stones formation and/or facilitates their expulsion. The hypothesis is that this mechanism is activated at the renal level: fulvic acid prevents formation and promote the degradation of calcium oxalate and phosphate crystals through the formation of soluble calcium complexes.

The aim of this study is to verify the structural similarity of fulvic acids extracted both from water and chestnut forest soil. To this end has been performed a chemical identification/ characterization.

Soil sampling was performed on the basis of a randomized block design, taking 4 soil samples for each site. Soil samples were studied for their content in humic substances and these divided in to the different constituent fractions (FA,HA), according to the standardized method by the International Humic Substances Society (IHSS).

In order to isolate and purify the fulvic fraction in water, 280 liters of mineral water taken at the Fiuggi settlement, were subjected to: concentration with resin DAX8, acidification with amberlite, freeze-drying. Fulvic fraction, isolated and purified from soil samples,and mineral water (550µgl-1),were subjected to pyrolysis-GC-MS and FT-IR characterization. The fulvic acids from the water and the chestnut soil show spectral similarities and qualitative analogies of pyrolystic profiles.

The highlighted similarities allow to affirm that the fulvic acids isolated from the water come from chestnuts'stems and litter. The enrichment that chestnut forest gives to waters' quality, is an important information to define water enhancement strategies, establish soil management and designate sustainable forest management.

Keywords: Fulvic acid, water quality, chestnut forest, ecosystem service, mineral water.

References:

1. Calace, N., 1999. Nephron 81, 93–97.
2. Fraioli, A., 2001. La Clinica terapeutica. 152. 347-51.
3. Lin, Y., 2005. Environ. Sci. Technol. 39, 1–10.

L05.P.03

Provisioning of ecosystem services within temperate riparian agroforestry systems

Buchanan S. W.[1] (serrawillow.buchanan@mail.utoronto.ca), Baskerville M.[2], Isaac M. E[1]

[1] *Physical and Environmental Science, University of Toronto Scarborough, Scarborough, Ontario, Canada*;
[2] *Department of Environment, University of Waterloo, Waterloo, Ontario, Canada*

Riparian agroforestry systems, composed of herbaceous and woody species, are known to contribute to watershed health, however, little is known on how riparian plant species diversity contributes to soil processes/ function. By measuring plant functional trait diversity (FD), we are able to categorize how communities will acquire/conserve soil resources. It is generally hypothesized that higher resource use efficiency is positively related to higher levels of FD. To date, little to no research has investigated the FD of riparian agroforestry systems and what this means for ecosystem processes, especially in the large tracks of riparian buffer zones in southern Ontario. We measured plant FD within i) grassland (GRB) ii) undisturbed old-growth (UNF) forest and iii) restored agroforest (RHF) riparian buffer communities, as well as soil ecosystem processes, namely soil nitrogen (N) mineralization, carbon dioxide (CO2) efflux and nitrous oxide (N2O) emissions. Functional plant traits (leaf and root) were used to calculate common FD metrics within each plant community, using community weighed means (CWM) and trait value distribution. Our results indicate relationships between soil processes and community weighted trait means, with clear differences between the agroforest (RHF/UNF) and GRB buffers (Figure 1). Identifying plant communities in riparian agroforestry systems based on functional trait diversity provides key insights into controlling and managing important soil processes.

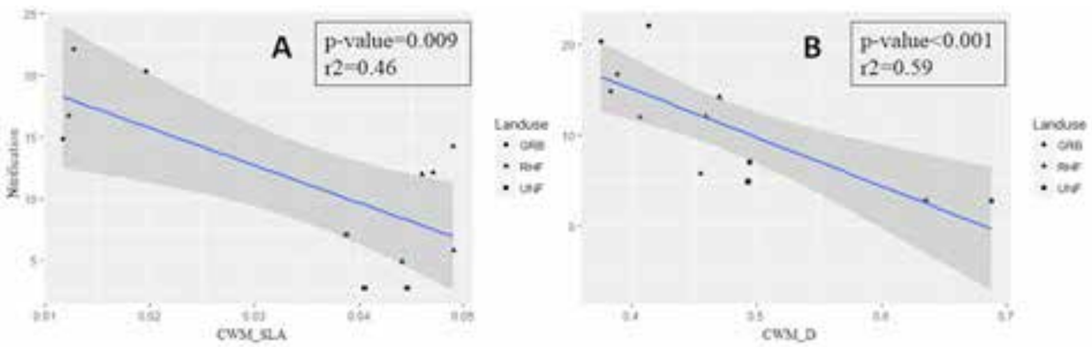


Figure 1: Significant linear regression between rates of nitrification and (A) community weighted mean specific leaf area (CWM_SLA) and (B) community weighted mean average root diameter (CWM_D) across three riparian land use types (grassland, rehabilitated and remnant forest buffers), including coefficients of determination (r^2) and significance (p-value).

Keywords: riparian, agroforest, functional trait, functional diversity, greenhouse gases.

References:

1. Cadotte et al, 2011, Journal of Applied Ecology, 1079–1087.
2. Pérez-Harguindeguy et al, 2013, Australian Journal of Botony, 167-234.
3. Mouchet et al, 2010, Functional Ecology, 867-876.
4. Diaz et al, 2007, PNAS, 20684–20689.
5. Cardinale et al, 2006, Nature, 989–992.

L05.P.04

What drives communities to conserve forest? Lessons learned from the management of a West Sumatran Village Forest

Chandra A.[1] (adelinachandra@outlook.com), Khatimah F. H.[2], Fauzi D.[2], Wicaksono S. A.[2]

[1] *LUCSUS, Lund University and WRI Indonesia, Lund, Sweden*; [2] *World Resources Institute Indonesia, Jakarta, DKI Jakarta, Indonesia*

Alam Pauh Duo village forest (HN Simancuang) holds a critical position as the village's primary water catchment area. Since its inception as a village forest in 2012, local communities have been working to protect it from potential threats, such as illegal logging and land conversion. We compare temporal tree cover loss in two different types of forest within Simancuang, one community-managed village forest and one watershed protection forest. Our spatial analysis shows that after HN permit was granted, forest cover loss rate in HN Simancuang became 25% lower than that of a nearby watershed protection forest. This trend indicates that the communal arrangement to protect the forests and agroforestry practice have been relatively effective in conserving the forest.

We conducted a random survey of 113 households in two sub-villages within HN Simancuang. The survey was designed to assess community's conservation behavior, income level, and environmental services they receive from HN Simancuang. Based on our analyses, although forest-based income did not significantly contribute to the total income of the community, HN Simancuang's environmental services to reduce disaster risk, support community livelihoods, and provide water needs did drive the community to conserve forest. Our study indicates that identifying common grounds among communities could be the first step in implementing successful community-based forest management and achieving village-level sustainable development.

Figure 1. Ordinal Regression Results on Conservation Behavior

Conservation Behavior	Coefficient	Standard Error	Odds Ratio
Flood experience	1.679695***	.4870362	5.363919***
Landslide experience	.8676769***	.3191981	2.381372***
Water consumption	.9023735**	.4033474	2.465448**
Food consumption	-.0014084	.000912	.9985926
Environmental motivation	1.01732*	.6148186	2.765772*
Subjective wellbeing	1.264288**	.6431606	3.54057**
Education level	-.5753987**	.247909	.5624806**
Migration reason	.4115126	.4811091	1.509099
Facilitation	.8149082**	.399693	2.258968**
Constant 1	10.72391	2.74724	
Constant 2	12.39147	2.829708	

*/**/*** denotes significance at 10%/5%/1% level

This figure depicts the relationship between one's conservation behavior and HN Simancuang's ecosystem services. We employ ordinal logistic regression model to analyse the collected data, with */**/*** denotes significance at 10%/5%/1%.level.

Keywords: village forest, social forestry, environmental services, conservation behavior, community-based forest management.

References:

1. Agrawal, 2003, Annual review of anthropology, 32(1) 243-262.
2. Hansen, 2013, Science, 850-53
3. Margono, 2014, Nature Climate Change, 730-735
4. Groot, 2002, Ecological Economics, 393-408
5. Siscawati, 2017, CIFOR Working Paper no. 223

L05.P.05

Multitier agroforestry system for resource conservation on sloping uplands of Eastern Ghats region of India

Jakhar P.[1] (icarpraveen@gmail.com), Dass A.[2], Sudhishri S.[2], Naik B. S.[3], Gowda H. C. H.[4], Adhikary P. P.[1], Madhu M.[1], Lenka N. K.[5], Chaudhary P. R.[6], Panda R. K.[7]

[1] *Dept. of agri. res. and educ., MoA&FW, ICAR IISWC RC, Sunabeda, Odisha, India*; [2] *Dept. of agri. res. and educ., MoA&FW, ICAR IARI New Delhi, New delhi, Delhi, India*; [3] *Dept. of agri. res. and educ., MoA&FW, ICAR IISWC RC, Bellary, Karnatka, India*; [4] *Dept. of agri. res. and educ., MoA&FW, ICAR IISWC RC, Ooty, Tamil nadu, India*; [5] *Dept. of agri. res. and educ., MoA&FW, ICAR IISS, Bhopal, MP, India*; [6] *independent consultant, OFSDP, bhubaneswar, Odisha, India*; [7] *Dept. of agri. res. and educ., MoA&FW, ICAR IIWM, bhubaneswar, Odisha, India*

Conservation of soil and water along with crop productivity improvement is indispensable for sustainable development of rainfed areas. The system of raising multi-height plant species with agricultural crops known as multitier agroforestry system was assessed (2007-10) for resource conservation and production potential in rainfed conditions of Eastern Ghats region in India. Thirty experimental plots, each of 18 m × 12m dimension with 2% slope having different multitier agroforestry treatments were assessed for soil erosion, nutrient loss and crop yield. Results revealed that multitier plantation of drumstick (*Moringa oleifera*) with *Gliricidia sepium* hedgerow and ginger (*Zingiber officinale*)+ pigeonpea (*Cajanus cajan*) under 8:2 row intercropping enumerated minimum mean runoff (8.26 %) and soil loss (3.45 Mg ha-1). This treatment saved 74 % more soil organic carbon, 64 % more phosphorus and 66 % more potassium, respectively than broadcasted finger millet cultivation (traditional farmers' practice). An increase of 24-27% drumstick fruit yield was observed in *Gliricidia* hedgerow based agroforestry systems over non-*Gliricidia* systems. Results from the experiment establish that, scientifically attuned combination of tree, hedgerows with compatible intercrops are effective in decreasing runoff-soil loss, building soil fertility and enhancing yields. The benefits of the system in resource conservation and production makes it a suitable intervention in the fragile ecologies.

Treatment	Runoff (%)	Soil loss (Mg ha^{-1})	Sediment assisted nutrient loss (kg ha^{-1})			Ginger/ Finger millet yield (Mg ha^{-1})	Pigeon pea yield (Mg ha^{-1})
			Organic carbon	Available Phosphorus	Available Potassium		
Gliricidia + Drumstick + Ginger+ PP(8:2)	8.26	3.45	23.20	0.39	0.37	11.3	0.24
Gliricidia + Drumstick + FM+PP(6:2)	9.83	4.91	31.44	0.51	0.55	1.44	0.67
Drumstick + Ginger+ PP(8:2)	8.90	4.45	31.49	0.45	0.48	10.7	0.24
Drumstick + FM+PP(6:2)	9.85	5.13	37.17	0.56	0.55	1.47	0.46
Gliricidia + Ginger+ PP(8:2)	12.82	6.87	43.06	0.69	0.73	10.0	0.26
Gliricidia + FM+PP(6:2)	14.47	7.29	48.37	0.73	0.80	1.45	0.72
Ginger+ PP(8:2)	16.01	6.73	49.67	0.68	0.76	9.4	0.27
FM+PP(6:2)	17.90	7.70	56.12	0.79	0.87	1.30	0.52
FM broadcasting (FP)	22.78	9.50	88.46	1.11	1.10	0.33	--
Fallow	27.36	11.84	87.28	1.30	1.38	--	--
LSD (0.05%)	1.38	0.96	11.81	NS	0.96	--	--

FM- Finger millet, PP- Pigeonpea, FP- Farmers' practice

Table: Values of different parameters ensuing from respective multitier agroforestry systems

Keywords: Multitier, Runoff, Soil loss, Green leaf manuring.

L05.P.06

Impact of integrated watershed management programme on agroforestry and sustainable development in Jharkhand (India)

Kumar S. (sanjeevkumar201@gmail.com)

Regional Chief Conservator of Forests, Department of Forests,Environment&CC, Hazaribagh, Jharkhand, India

With the objective of conservation and sustainable management of natural resources, Integrated Watershed Management Programme was initiated in watersheds of Jharkhand. It also intends to enhance agriculture productivity, improve livelihood options and restore ecological balance in degraded and fragile rainfed ecosystem. A Study was conducted in twenty five villages in different watersheds of North Chotanagpur and Singbhum area (Hazaribagh, Giridih, Chatra , East Singbhum , West Singbhum districts) of Jharkhand to assess the results of projects under IWMP. The major methods employed were household survey and meetings with watershed committees, Village Forest & Management Committees and Self Help Groups (SHGs). Secondary data were collected from literature and interpretation in GIS Cell. The paper aims to examine various aspects of activities and results of IWMP based on this study. The study revealed that the communities actively participated in planning and implementation of the activities. Overall technical and financial support has been provided by Forest and other government departments. Construction of earthen and loose boulder check dams, terracing, contour trenching, construction and renovation of ponds and wells are some of the measures adopted for soil and water conservation. For promoting agroforestry, plantations of Cashew nut (*Anacardium occidentale*), Mango (*Mangifera indica*). Gambhar (*Gmelina arborea*). Bamboo (*Dendrocalamus strictus*), Teak (*Tectona grandis*), Jackfruit (*Artocarpus heterophyllus*) etc. have also been taken up. Organic farming was also encouraged. For capacity building, SHGs, User Groups, villagers and members of Watershed committees were imparted training. Health and literacy camp have also been organized. In most of these watershed areas encouraging results have been registered with regard to silvi-pasture practices and production of different agricultural crops. There has been increase in biomass production and improvement in soil and water conservation. These results have positive impact not only on environment and livelihood of the people, but also on their social and cultural domain.

Keywords: IWMP, Jharkhand, Moisture Conservation, Soil Conservation, Sustainable Development.

L05.P.08

The original and effective hydric functionning of agro-forestry parkland of the Sahel

Valet S.[1] (valet.serge2@wanadoo.fr), Motelica-Heino M.[2]

[1] *Hydropédology & Agroecology, Association PASSERELLES, Lyon, France*; [2] *ISTO UMR 7327, CNRS-Université d'Orléans, Orléans, France*

The available water content of Sahelian agro-ecosystems controls their development and sustainibility. In fact there is a strong relationship between the availability ofwater and its use by plant associations. The presence of trees is related to the anthropic history of the local environment. Agroforestry parkland trees have two 'natural' habitats: in the lowland hydromorphic area and also in the area associated with farmers' activities developped on accessible groundwater. The expansion of these habitats is increasing. Our study therefore concerns the relationship between climate change, hydric and hydrodynamic properties of the soil under the crown and the effects of the tree-crop association on the regulation of soil water functioning. This regulation is very dependent on the free Eco-Systemic Services essential to human well-being of this zone such as:

1) Supporting services

- Sequestration of C and OM accumulation in soils: lower bulk density and higher total porosity due to macropores that facilitate infiltration of water in the top 40 cm of soils;
- Soil water availability improved both under and outside the canopy up to 175% of the canopy radius;
- N fixation: increased soil covering;
- Reduced leaching;
- Available water content higher under crown than outside.

2) Regulating services

- Limitation of runoff: protection against erosion;
- Climate regulation: i.e. higher relative humidity and lower air and ground temperature; decrease in direct evaporation and greatest efficiency of water use;
- Increased water quantity at the beginning and end of the crop cycle ; little competition for water between trees and crown plants thanks to pivoting roots that plunge into the water table;
- Intercropping under the crown decreases the ETR by 20%.

Conclusion

The Sahelian agroforestry parkland is a agro-ecosystem that provides a number of free Eco-Systemic Services that create specific local physical, hydric and climatic conditions favorable to a particular ecological entity. Each tree is a «green oasis» that resists climate change with a local agro-climatic effect on the entire field. Because these free Eco-Systemic Services ensure the improvement of physical properties of soils, they explain the improved water functioning and supply for crops. Its tolerance to extreme drought and its resilience at the edge of the desert is also positively affected.

Keywords: hydrologic and hydrodynamic, climate regulation, free Eco-Systemic Services, agroforestry parkland, Sahel.

References:

1. Valet S., H. Ozier-Lafontaine, 2013. Ecosystem services of multispecific and multistratified croppi
2. Valet S., H. Ozier-Lafontaine, 2013. Use the Ecosystemic services of intercropping to maximise the W
3. Ozier-Lafontaine H., S. Valet , M. Motélica-Heino, 2012. Modeling multi-stratified mixed cropping:
4. Valet, S., Motelica-Heino, M., 2018. Mixed/intercropping systems as a new paradigm for soil resilien
5. Valet S., M. Motelica-Heino, P.S. Sarr and Ph. Le Coustumer, 2010. Main ecologic services supply by

ABSTRACTS

Agroforestry and world challenges

Agroforestry: riding to the world's rescue

- L6 -

Social issues in Agroforestry systems (gender, migration)

The day our young men came home: agroforestry for a secure future

Agroforestry can be practiced in several contexts, including in forest-agricultural frontiers, when forest is converted to fields. It can provide a diversity of products, critical to the self-sufficiency, food security, and income of rural dwellers living in remote areas. Agroforestry is frequently practiced in savannahs, to address dryness or labour constraints, allowing farmers to work larger surfaces of land. It plays an important role in increasing the resilience of production systems to climate events, and contributes to climate change mitigation and to restoration of degraded landscapes. Hence, its potential to decrease outmigration and seasonal migration has been demonstrated. Finally, planting trees is often a way to demarcate land and secure recognition of ownership. Women and men commonly experience the benefits and constraints of agroforestry systems differently, and have different perspectives on the provision of ecosystem services and their relative importance to their livelihoods. Experiential and perceptual differences also occur along other social axes, such as residence (migrants and autochthons), ethnicity or socio-economic status.

This session will bring together papers examining the importance of such social differences in shaping outcomes from agroforestry initiatives and enhancing women's empowerment. It will also consider the two-way relationship between migration and agroforestry – that is, how migration affects land use and agroforestry, and how the practice of agroforestry can influence migration decisions. Papers focus on the diversity of cultivated species women and men from different social groups manage in agroforestry systems to improve food security, enhance their financial autonomy, or adapt to labour or water constraints. Others demonstrate the large strides needed to achieve gender equality in households, and the consequences that failing to consider women's interests can have on the landscapes they inhabit and manage. Several papers demonstrate that complementarities among women's and men's knowledge, roles and priorities should be valued rather than ignored, to enhance the impact and equity of agroforestry initiatives. With presentations from West and East Africa, Asia and Latin America, this panel proposes an exciting world tour of social issues in agroforestry systems.

L06_O.01

wadi: a agroforestry model for transforming lives and livelihoods

Sawant Y.[1] (ygsawant77@gmail.com), Mori J.[2], Bagul M.[2], Patel A.[3]

[1] *Agriculture, BAIF Development Research Foundation, Pune, Maharashtra, India*; [2] *Agriculture, BAIF Development Research Foundation, Vadodara, Gujarat, India*; [3] *Administration, BAIF Development Research Foundation, Vadodara, Gujarat, India*

The tribal people constitute 8% of India's population and are among the poorest and disadvantaged members of the society. Traditionally they depended on forest resources for food and livelihoods. The depleting forest resources and subsistence agriculture has challenged their struggle for survival. Majority of them, after harvest of rainfed crop sought to distress seasonal migration in search of livelihoods. Migration is associated with exploitative labor, poor living conditions and interrupted education of children. Several initiatives are made to reduce distress migration among tribal communities.

One such initiative was made by BAIF through the "wadi programme" in the tribal regions of south Gujarat, India. The wadi programme is based on the agroforestry approach. It aims at curbing distress migration by creating sustainable livelihood opportunities for the participating families within their villages. The families were supported to transform 0.4 ha. of their underutilized/ degraded lands to productive asset by planting and nurturing of 50 fruit plants and 300 forestry plants. Various legume and vegetable crops were introduced in the interspaces between trees. Supporting measures like appropriate soil and water conservation structures, biomass recycling and decentralized water resources were introduced. The programme was implemented in 163 villages covering 13500 families. (Sohani, 2014, Indian Farming, ICAR, 33-35; Ajwani et al, in: Subsistence to Sustainable: The Power of Aggregation, 2010, Access, 1-24).

A study was conducted to assess the impact of the wadi programme on livelihoods and distress migration of the families. 2135 families were selected through stratified random sampling. The study involved survey of individual families at the beginning of the project (baseline) and at project completion stage. The comparison against baseline situation indicates significant impact of the wadi programme.

Distress migration (number of days per annum) has reduced by 51%. The number of non-migrating families increased by 2.6 times of the baseline number. Migration of women and children has completely stopped in 70% of the families.

Distress migration has reduced due to significant increase in farm income. The integrated farming system promoted through the wadi approach resulted in more than100% increase in farm income. The increased number of income sources offer better resilience to the farmers. The diverse forestry species in "wadi" provide benefits in the form of windbreak, improved microclimate, green manure, improved fodder, timber and income from sale of surplus timber. The fruit and forest trees are a valuable carbon sink. (Watson, 2017, www.thegurdian.com).

Owing to the significant impact of the wadi programme, it has been emulated in 25 states of India, benefiting more than 0.45 million families. This paper details on the components, processes, impact and learning's for wider replication of the "wadi approach".

Keywords: wadi, agroforestry, tribal, migration, livelihoods.

References:

1. Sohani, 2014, Indian Farming, ICAR, 33-35
2. Ajwani et al, in: Subsistence to Sustainable: The Power of Aggregation, 2010, Access, 1-24
3. Watson, 2017, www.thegurdian.com/working-in-development
4. Sawant et al, 2016, National conference on Forestry in India, HFRI, 26

L06_O.02

Gender relations at the forest-farm interface in West Africa: prospects for transformative processes in agroforestry

Smith Dumont E.[1] (e.smith@cgiar.org), Paez Valencia A. M.[2], Nadembèga S.[3], Adeyiga G.[4], Chiputwa B.[5], Pagella T.[6]

[1] *Systems, World Agroforestry Centre, Nairobi, Kenya*; [2] *Impact Acceleration and Learning, World Agroforestry Centre, Nairobi, Kenya*; [3] *INERA, Ouagadougou, Burkina Faso*; [4] *FORIG, Bolgatanda, Ghana*; [5] *World Agroforestry Centre, Nairobi, Kenya*; [6] *SENRGY, Bangor University, Bangor, United Kingdom*

The gender dimension of tree-resources dependency has been well documented in the West African agroforestry parklands where women are the main beneficiaries of non-timber forest products, which are critically important for food security and cash income. Diminishing tree resources, land degradation and climate change have increased women's vulnerability, while restrictive socio-cultural norms offer limited opportunities for women to participate in landscape restoration or agroforestry initiatives, and to benefit from these. There is a need to develop transformative processes that can redress gender inequalities in access to and control of resources, and to actively engage communities in these processes of change. To understand ways that this can be done, we first developed an innovative approach that brought together elements of the Gender Action Learning Systems (Mayoux, 2014) and the Forestry Poverty Toolkit (Shepherd, 2008) with system thinking. We applied this set of participatory tools in three communities in northern Ghana and four communities in southern Burkina Faso; interviews were conducted with male family heads and one adult female in each of 84 households. Analysis shows the contribution of income from trees, particularly shea *(Vitellaria paradoxa),* to total household cash income was very significant in both countries, especially in poor households. This income was almost exclusively sourced by women, who often have neither control over how it is spent nor a voice in decision-making for land restoration (e.g. tree planting and/or management, as well as soil and water conservation improvements). Furthermore, activities typically done by women, both in respect to farming and tree-product harvesting and to their reproductive role, are significantly less valued than are men's. We presented these findings to the communities through structured community dialogues around gender relations. These included culturally sensitive workshops that brought together an engaged men and women from different ages and generations. Participants were encouraged and motivated to reflect on how local gender norms generate constraints and limit their opportunities to increase resilience in landscapes and livelihoods. We show that this integrated and innovative approach has substantial potential to tackle gender norms, one of the major bottlenecks to scaling up restoration interventions.

Keywords: agroforestry parklands, Landscape restoration, Intra-household dynamics, Tree resources, Resilience.

References:

1. Mayoux, L., 2012, Enterprise Development and Microfinance 23, no. 4 319-337.
2. Shepherd, G. and Blockhus, J., 2008. PROFOR Poverty-Forests Linkages Toolkit, 2011

L06_O.03

«Silakouda» or how rural women's entrepreneurship preserves and values a local agroforestry resource in Upper Guinea

Keita S.[1] (saran.keita@united-purpose.org), Person S.[2], Martin C.[1], Ntab S.[1]

[1] *United Purpose, Conakry, Guinea*; [2] *Forest Goods Growing, 34070, Montpellier*

Guinea is among the least developed countries, with nearly 55% of its population living below the poverty line, concentrated mainly in rural areas where more than two-thirds of the population lives.
The country, however, has natural wealth and particularly forest resources covering 53.60% of the national territory. The African locust bean tree or "néré" (*Parkia biglobosa*) stands are particularly important in Upper Guinea and constitute a resource still underutilized. Key specie of the agroforestry parklands of this sub-Saharan zone, its seeds are processed into a traditional flavor enhancer used as a condiment very consumed in the country and the sub-region: the *soumbara*. The exploitation of its seeds is an important source of income for many Guinean rural women.
The "néré" value chain has great potential for development, but many constraints hamper its development: threats to stands (shifting cultivation, consumption of fuel wood, development of cash crops, uncontrolled exploitation of non-timber forest products), weak technical equipment and quality not meeting demand, limited access to markets, insufficient organisation of producers…
The solutions traditionally delivered by development actors are limited to the distribution of equipment and the provision of subsidies and have limited impacts and little or no sustainability.
From 2013, the UK NGO «United Purpose», has aimed at both responding to the impoverishment of rural populations and guiding to sustainable management of natural resources. The decidedly innovative approach focuses on the development of rural women entrepreneurship and improved market access for by combining «Market Analysis and Development» (MA&D) and «Making Markets Work for the Poor» (M4P).
This approach, that the communities has named locally «Silakouda» meaning «the new preferred way out of poverty», has enabled 1,412 women to establish 52 sustainable business groups and multiply by 4 their annual average income in the 32 villages of the project area. It has also enabled to put under protection 276 ha of community forests managed by local communities in connection with environmental and forestry services.
The development and support of this rural women's entrepreneurship has proved to be a real driver for improving this traditional market and is promising for the inclusion in the initiated approach of other species composing this agroforestry system, thus participating in its safeguard and valuation.

Keywords: agroforestry parklands, Parkia biglobosa, entrepreneurship, rural women, M4P approach.

L06_O.04

Migration, gender and agroforestry in Indonesia

Mulyoutami E. (eloknco@gmail.com), Lusiana B., van Noordwijk M.

ICRAF SEARO, Bogor, Indonesia

Migration connects land use in areas of origin with that in areas of (temporary) new residence, impacting both through individual (gendered) choices made. Synthesizing across a number of case studies in Indonesia, we focus on five aspects of three two-way linkages through migration: West Java to Lampung/South Sumatera; South to Southeast Sulawesi; and Lampung to Jambi.

The condition within the community of origin, where people have different reasons to seeking new job and opportunities elsewhere, at least temporarily. From in-depth interviews and focus-group discussions we learned that decisions vary with gender and age, between individuals, households joining after signs of success and sometimes groups of households. Most of the decision making is linked to (perceived) poverty, natural resource, land competition, and emergency situation such as the force of natural disaster or increased human conflicts.

The changes in the receiving community and its environment, generally in rural areas with lower human population density. Absorption of new labour can start as paid labour and patron-client relationships or share cropping, but also involve land renting and buying, within customary land ownership rules (rarely involving formal land certification). In some of the cases experience with more intensified land use in the source area (e.g. W Java) proved to be enriching agriculture and agroforestry in the new environment (e.g. S Sumatra).

The effect of the migration on land use and livelihoods in the areas of origin. Feminization of agriculture, as described elsewhere for dominantly male migration patterns, appears to be less common than a pattern where elderly people taking care of grandchildren that stayed behind struggling to maintain their agricultural practices. The extensification of land use and a greater reliance on trees rather than annual crops are often constrained by lack of relevant knowledge, skills and technology.

The dynamics of migrants returning with different levels of success. People coming back with success may help to rebuild the village and its agricultural system and could invest in social capital (mosques, healthcare, schools). Some who have failed may find other land use or urban labour options elsewhere.

The interaction of migrants in all four aspects with government and other stakeholders in relation to development policies.

In conclusion, our analysis suggests that positive aspects in both areas of origin and receiving areas may prevail, with exchange of knowledge between areas of different land use intensities spreading agroforestry practices. The latter may well be more effective than the routes through formal knowledge and extension, and in some cases is combined with tree germplasm exchange. Feminization of agriculture through preferentially male-based migration is not common in Indonesia, but age-based consequences are common, in both urban (or overseas) migration, and dispersal to areas of lower human population density.

Keywords: Migration, Decision Making, Land competition, Feminization, Agroforestry.

L06_O.05

Conflicting interests around shea-tree : gender inequalities and degradation of shea parklands in Benin

Droy I.[1] (isabelle.droy@ird.fr), Bidou J. E.[2]

[1] *UMI Résiliences, IRD, Bondy, France*; [2] *LAM (Les Afriques dans le Monde), IEP Bordeaux, Pessac, France*

Shea parklands (Vitellaria paradoxa C.F. Gaertn.), which spread across sudanian Africa, reflect a human construction under certain conditions of land management and population density. They provide socioecosystems services : support and regulation services or provision services like traditional pharmacopeia, handicraft or food supply, which contribute to the reduction of socioeconomic vulnerability in the current context of climate change. In Benin as in other shea parklands, the resource management (land, trees, fruits etc.) keeps the gendered character described since the colonial period and the shea-tree is a particularly significant archetype. Men own land rights and control of trees which they can protect or cut. Women rights concern the collection or harvest of fruits, for family consumption or sale (raw or transformed) ; with this monetary income, women can cover the financial charges which fall to them inside households, where the budgets are largely separated. However, the state of shea parks is contrasted and often engaged in a process of degradation like in Djougou (Benin), where we have conducted our study between 2010 and 2015. Our objective was to identify and analyse the causes of this paradoxical situation of deterioration of the park, while the world demand for shea-nuts is rapidly increasing (Bidou et al., 2018). Our analysis was done at while different scales : regional (with remote sensing), village and households. At household level, we have conducted socio-economic surveys among 230 households and 381 women and qualitative interviews of a sample of women and men focused on the place and role of shea tree. By replacing the activities of the women within the families to which they belong (by ethnic group, religion, socioeconomic level), we see that they are largely dependent on the degree of freedom which they have in their family(Droy et al., 2014).

Results show that shea parkland degradation is due to a lack of regeneration in a context of population rapid growth, land pressure and reduction of fallows where the young shea-tree can grow (Boffa, 2000). But also to men choice, who favour the cashew trees over the shea trees at the expense of women.

This factor will be particularly developed in this paper.

Main results of our analysis can be summarized in the following points : 1) Income of the shea-tree, even low, remains important for the poorest women and contributes to reduce the food vulnerability because the sale of shea nuts takes place during hunger season. 2) Women ressources are decreasing as their rights on land and trees are questioned, although their family charges are rising (with monetary expenditure for children). As a consequence, child chronic malnutrition has been steadily increasing in the rural regions of northern Benin 3) Difference of interest between women and men is deepening, in particular with the expansion of plantations of cashew trees, controlled by men while using women workforce.

Keywords: Gender inequalities, Shea parkland, Access to ressources, Vulnerability, Benin.

References:

1. Bidou J-E et al. (2018) Espaces, Population, Sociétés.
2. Boffa J-M (2000) Unisylva, 51, 11-17
3. Droy I. et al. (2014) Genre et savoirs. Pratiques et innovations, IRD, 81-115

L06_O.06

Gender perspectives of climate change adaptation in smallholder cocoa systems in the techiman municipality of Ghana

Asante W. (winstonasante@gmail.com), Kyereh B., Gyampoh B., Echeruo J., Neequaye T.

Silviculture and Forest Management, Kwame Nkrumah University of Sc & Tech, Kumasi, Ashanti, Ghana

In the wake of major climate change impacts on cocoa, farmers in the Techiman municipality have rolled out various adaptation and coping interventions. However, there is very minimal information on the gender dimensions of these adaptation interventions. There is therefore inadequate information which could inform improved resilience of cocoa systems and livelihoods to the threats of climate change impacts, given that climate change impacts and its responses are mostly differentiated along gender lines. The research focused on the transitional zone of Ghana, where cocoa cultivation is dominant, and the climate is also characterised by high rainfall deficits and high temperatures. Using a stratified random sampling approach, key informant interviews and focus group discussions, data was generated on farmer's perception on the manifestation of climate change and current adaptation strategies employed by farmers, as well as gender-driven challenges male and female cocoa farmers encounter during the implementation of these adaptation strategies. Findings of the study indicated that, small-holder farmers in the Techiman municipality were highly exposed to negative climatic impacts and they adopted agroforestry strategies, on and off farm diversification, and soil fertility management to respond to climate change stress on the cocoa system. However, the study revealed no disparities between male and female farmers in the choice of specific on-farm adaptation strategies that are needed to respond to climate change impacts on cocoa, but rather, gender differences manifest during the execution of these on-farm strategies. Furthermore, it was observed that while male farmers increased their reliance on activities like driving, palm wine tapping, and alcohol brewing, female farmers diversified their sources of income into mostly trading, with animal rearing being common to both gender groups. The findings of the study also showed that there was disparity between male and females with regard to access to finance to respond to climate change impacts on their cocoa systems, with male farmers being more likely to access finance to implement various measures to respond to climate change impacts than their female counterparts. The study also revealed that, issues relating to household chores, and labour intensiveness of most of the adaptation strategies such as *"line and pegging"*and agroforestry tree species access and incorporation in cocoa farms posed major barriers to female farmers' decision making and capability to improve the resilience of cocoa farms to climate change impacts. The study brings out the complexity of access, differentiated household responsibilities and decision making on a holistic response to climate change impacts, and the need to pay attention to specific gender issues at the household level which exposes the vulnerability of cocoa farmers, in spite of farmers' knowledge of adaption strategies.

Keywords: Gender, Cocoa agroforestry, Vulnerability, climate change, adaptation.

References:

1. Benefoh, D. T., Villamor, G. B., Noordwijk, M. V., Borgemeister, C., Asante, W. A & Asubonteng, O. 2
2. Asante, Winston., Acheampong, Emmanuel., Edward Kyere and Boateng Kyereh. 2017. Farmers' Perspective
3. Asare, R., Asare, R. A., Asante, W. A., Markussen, B., Ræbild, A. 2016. Influences of shading and fe
4. Acheampong, E., Dawoe, E. L. K., Bosu, P. and Asante, W. A. 2014. Moving Forward with REDD+ in Ghana

L06_O.07

Gendered knowledge on food trees for addressing food security and nutrition in Uganda & Kenya

Gachuiri A.[1] (a.gachuiri@cgiar.org), Paez-Valencia A. M.[1], Marlene E.[2], Carsan S.[1], McMullin S.[1]

[1] *World Agroforestry Centre, Nairobi, Kenya*; [2] *Bioversity International, Rome, Italy*

Food trees provide fruits, nuts, leaves and seeds that contribute substantially to food and nutrition security of African rural households. Farmers have a wealth of local knowledge on food tree species for cultivation and use for various household needs. This knowledge is influenced by gender and age-related factors often neglected in research and development endeavors. This study sought to understand gendered and age-related knowledge on food trees use in Uganda and Kenya. The purpose was to identify context-specific food tree portfolios that can sustainably address food and nutrition gaps while responding to the needs and strategic interests of different gender and age groups. Data collection was conducted through gender- and age-segregated focus group discussions in two sites in Uganda, Nakaseke and Nakasongola, and two sites in Kenya, Kitui and Mwingi west. Participatory research using seasonality calendars and score - ranking was conducted with sixteen focus groups and comprised of a total of 160 participants to understand knowledge and preferences for food trees. A total of 61 food tree species were listed with differences among countries. In Uganda, the total species number was 47 (including 58% exotic species), and in Kenya 55 (65% exotics). In Uganda, knowledge on food tree species differed between genders, with older women listing the greatest number of priority species (22), followed by younger women (19) and older and young men (15). In Kenya, older women and men identified 38 and 36 species respectively, whereas younger women identified 26 species and younger men 23 species. In all four sites, both men and women preferred exotic food tree species such as *Mangifera indica*, *Passiflora edulis* and *Persea americana*. Both men and women especially valued food trees that contribute to improved health, nutrition and income, those whose products have a good taste, and with medicinal properties. For old and young women, the main reasons for selecting food trees species was their availability and role as children's food. Findings show diverse food tree species that fill food and nutrition gaps and the value of gender-sensitive participatory research for understanding local knowledge, needs and constraints, to inform project implementation decisions.

Keywords: food trees, participatory research, local knowledge, gender, youth.

L06_O.08

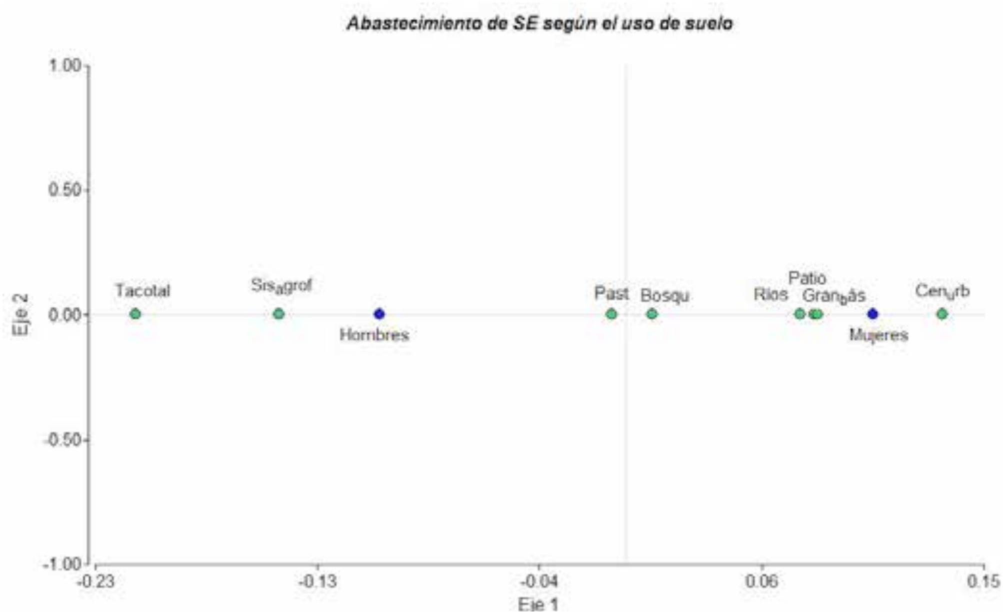
The importance of agricultural land uses in the provision of ecosystem services. A gender perspective in Nicaragua

Cifuentes J.[1] (jaime.cifuentes@catie.ac.cr), Feintrenie L.[2], Gutiérrez-Montes I.[3], Sibelet N.[4]

[1] *Postgraduate school, CATIE, Turrialba, Cartago, Costa Rica*; [2] *RU Forest and societies, CIRAD, Montpellier, France*; [3] *Postgraduate school, CATIE, Turrialba, Costa Rica*; [4] *UMR Innovation, CIRAD, Montpellier, France*

There is a link between agricultural systems (crops of basic grains, livestock, agroforestry systems for coffee and cocoa) and poor populations in rural areas. These land uses not only provide food, but also other ecosystem services (SE). In turn, each of these farming systems impacts the communities differently and the benefits they provide are perceived differently, for both men and women.

In Nicaragua, agricultural production in rural and poor areas is poorly technified and is closely linked to the benefits offered by nature. The main objective of the study was to determine the importance of land uses in the provision of different ecosystem services with a gender focus. We studied nine farming communities in three municipalities in the center and north of Nicaragua: El Tuma-La Dalia, Waslala and Siuna. We conducted 58 semi-structured interviews and 13 open interviews with key informants in order to determine access to the SEs. We also conducted two focus groups per community, one for men and one for women, using participatory mappings and the pebble distribution method, in total 41 men and 53 women attended. Our study finds that the use of forest land is one of the largest providers for SE communities; however, it is perceived as one of the least contributes to the family's economy. We also find that the land uses that provide the most benefits for women are the urban center and the crops of basic grains, while for men it is the agroforestry system.



Provision of ecosystem services according to land use for men and women

Keywords: Land uses, community capitals, participatory mapping.

L06_O.09

Migration and agricultural practices in the Haut-Sassandra Classified Forest (Midwest of Côte d'Ivoire)

Zanh G. G. (zanhgoloug@gmail.com), Kpangui K. B., Barima Y. S. S.

Biodiversité et Conservation Durable, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire

The region of Haut-Sassandra in Côte d'Ivoire, home to the Haut-Sassandra Classified Forest (HSCF), experienced a significant migratory flow during the Ivorian political and military crises of 2002 and 2011, encouraged by the high availability of arable land (Barima *et al*., 2016). Population movements in this region have changed the rural landscape both on the periphery of HSCF and inside it. This has led to changes in farming practices at the farm level aimed at converting old cocoa plots to the periphery and the creation of new cocoa plots within the HSCF. The general objective of this proposal is to analyze the typology of farming systems in the FCHS space in a context of migratory flows caused by social unrest. To achieve this, socio-economic surveys were carried out in 11 villages on the outskirts of HSCF to analyze the profile of farmers operating both inside and outside the FCHS and to determine the characteristics of the farms set up. Floristic inventories combining surface (25 m × 25 m) and traveling survey methods were carried out in the agrosystems located at the periphery and within the HSCF to analyze the diversity of species associated with these agrosystems. Surveys revealed that 64 % of the farmers living on the outskirts are allochtones whose age varies between 18 and 85, with 67 % aged over 40. On the other hand, the farmers settled within the HSCF are dominated by Burkinabe (95.1 %) rather young with an age ranging from 18 to 35 years. Still on the periphery of the HSCF, most farmers are converting their cocoa and coffee plantations to new, more afforested crops such as cashew and rubber trees. Similarly, three main production systems based on cocoa, coffee and cashew nuts were identified. The association of these three types of cultures varies according to the communities (Aboriginal, Allochtone and Allogenic). On the other hand, farmers living in the interior (95% of Bukinabe allogens) have developed only one type of crop, namely cocoa farming.

The floristic inventories realized in the main agrosystems have allowed to identify 118 species divided into 88 genera and 38 families. These species are represented by forest species (83 %) and fruit species (17 %). The fruit species are dominated by *Mangifera indica*, *Citrus sinensis*, *Persea americana*, *Psidium guava*, *Cola nitida*, *Ricinodendron heudelotii* and forest species are dominated by *Elaeïs guineensis*, *Ficus exasperata*, *Lannea acida*, *Holarrhena floribunda*, *Ficus mucuso*, *Newbouldia laevis*, *Funtumia africana*, *Ceïba pentandra* in the farms located on the outskirts. These species associated with agrosystems have many whose food uses, medicinal, timber and shade but also allow soil fertility.

Keywords: Agricultural practices, Agrosystems, Migrations, Perennial crops, Côte d'Ivoire.

References:

1. Barima Y. S. S., ..., Andrieu J. & Bogaert J. (2016). Global Ecology and Conservation, 8 : 85-98.

L06_O.10

Migration in the Nepalese hills: Prospect for agroforestry and its gender dimensions

Manandhar S.[1] (manandhar.sam@gmail.com), Sharma Paudel N.[1], Adhikari Y.[1], Adhikari A.[1], Tamang S.[2]

[1] *Forestry, ForestAction Nepal, Lalitpur Metropolitan City, Nepal*; [2] *University of New South Wales, Lalitpur Metropolitan City, Nepal*

This paper presents the gendered dimension of agroforestry practices which is one of the outcomes of mass outmigration of youths to international labour markets. While planting and managing trees in farmland is a traditional practice, modern forms of agroforestry have just begun to flourish in Nepalese hills albeit with significant gendered outcomes. The paper is based on five-year long action research implemented in two hill districts Kavre and Lamjung of Nepal. Household survey, focus group discussion, key informant interviews and other participatory methods were used in gathering data. The areas of enquiry were primarily on the scale and nature of migration, its links with land use change, trends in recent agroforestry practices, and effects on those who were left back home.
Migration of young men have resulted in decreased availability of labour and increased cost of labour have led to dwindled returns from traditional agriculture. This has induced gradual adoption of extensive farming including fodder trees, forest trees, goat farming, and other agroforestry practices. While labour scarcity is a primary driver, we found good economic rationale for taking these alternative farming practices. As a whole, the changing demographic picture has opened up new opportunities for promotion of agroforestry practice. At the same time, agricultural feminisation has been a major characteristic of the rural society, due to changing demography in the hills. Two important policy implications have been identified in the paper. First, the policy environment should be redefined and reframed towards facilitating increased forest-farm interface for minimizing the distinction between agriculture and forestry activities. Second, considering increased role of women in agroforestry, the public support system such as service provisioning including technologies should be geared towards making them more women friendly.

Keywords: Agroforestry, Migration, Gendered.

L06.P.01

Climate change and shea tree: women's perceptions and impact on flowering and fruiting in Burkina Faso

Dao M. C. E. (dao.ebou@gmail.com), Rouamba P., Pare E.

DEF, INERA, Ouagadougou, Burkina Faso

Fruit yield of shea tree is irregular and insufficient in Burkina due to negative impact of climate change on its productivity. Women and children are main collectors and processors of shea fruits for multiple usages but less is known about how they perceive climate change and its impact on their activities.
The study was to determine women's perceptions of climate change and the impact on the flowering, fruiting and quality of the pulp and butter. We sampled 80 women collectors and shea butter processors within 4 associations in north-Sudanese and south-Sudanese areas. The group focus and individual questionnaire were used in 2017 for the study.
The results showed that women perceive climate change through the declining rainfall, violent and dusty wind and the high temperature. 80% said that flowering and fruiting process are influenced by the wind and the declining rainfall. The insufficient rain causes less flowering intensity and fruiting with high non-mature fruits rate. Fruits do not taste good and nuts become whitish and give less butter compared to the reddish colored nuts with high butter rate (Photo 1). The frequent winds dry out the blooming flowers and cut off unmatured fruits. The dusty deposit on flowers prevent pollinators to access to the anthers and the stigmates, thus limiting sexual reproduction success.
Their perceptions provide key guidance for future adaptation plans to climate change.

Photo 1: Characterization of shea nuts with high and low butter content according to women

Keywords: Shea tree, women, climate change, flowering, fruting.

References:

1. Ouoba et al 2014. VertigO Vol 14 Num 2, DOI:10.4000/vertigo.15131
2. Gnanglè et al 2009. ww.sifee.org/Actes/actes_niamey./1_GNANGLE_comm.pdf;1-18
3. Bambara et al 2013. BRAB Num74: 1840-7099
4. Naess 2013. Wiley Interdisciplinary Reviews: CC, 4: 99-106

L06.P.02

Restoring natural capital and reducing social tensions through tree-based practices in humanitarian settings in Uganda

Duguma L.[1] (l.a.duguma@cgiar.org), Okia C.[2], Ariani C.[3], Watson C.[4], Nzyoka J.[5], Fungo B.[6], Kihumuro P.[2]

[1] *Landscape Governance, World Agroforestry Centre, Nairobi, Nairobi, Kenya*; [2] *Uganda Country Office, World Agroforestry Centre, Kampala, Uganda*; [3] *National Forestry Authority Uganda, Kampala, Uganda*; [4] *World Agroforestry Centre, Nairobi, Kenya*; [5] *Landscape Governance, World Agroforestry Centre, Nairobi, Kenya*; [6] *National Agricultural Research Org., Kampala, Uganda*

Uganda is currently hosting over one million refugees within its borders, most of them in the north of the country. With the increased human population due to the influx, pressure on the surrounding ecosystems has intensified. Hosts and refugees both depend heavily on the surrounding vegetation for construction wood, firewood and farm areas. As a result, exploitation of the surrounding woody vegetation is leading to user right conflicts between the two communities. Refugees intensively cut down trees in their surroundings and further degrading the ecosystem. The objective of this study was to identify the potential for tree-based restoration options (e.g. agroforestry, farmer-managed natural regeneration) and identify the enablers to fast-track restoration of the ecosystem.
Over 84% of both the host and refugee communities believe their ecosystem is degrading, causing societal tensions. From the field assessment using stump density as proxy, we found that 60% of the trees in the landscape had been cut in the last 2-4 years, mostly post the influx. Three potential pathways of restocking the woody biomass in the landscape were highlighted: tree planting (woodlots, fruit orchards, boundary planting and agroforestry - scattered trees and shrubs on farms and refugee plots), conserving existing trees, and promoting natural regeneration of sprouting trees. Among refugees, 66% of planting was suggested to be on plot boundaries and within homesteads. In contrast, host communities suggested that a similar share be in the form of woodlots. Refugees requested on average 32-50 trees to grow per household while the hosts expressed an interest in growing 863-1249 trees per household (they possess larger landholdings). Natural regeneration was suggested for communal degraded areas rather than areas currently used by refugees. To operationalize the ambition of restocking trees in the landscape, participatory farm sketches were designed with refugees and host community members. Further, a community learning center, consisting of a training unit and a tree nursery, was established to provide training and preferred planting materials to enable both refugees and hosts to engage in tree growing. In addition, an extensive extension system consisting of technicians and local community-based facilitators was setup to support tree growing. A partnership scheme was also agreed between the relevant government authorities and humanitarian organizations handling refugee matters to ensure the planted seedlings grew to provide ecosystem goods and services.
Bringing back trees to the landscape is believed to restore natural capital hence reducing conflicts between communities. This intervention has been lauded by the relevant authorities and tools and approaches developed and piloted have now been upscaled to other refugee settlements in Uganda and elsewhere.

Keywords: agroforestry, landscape restoration, refugees, host communities.

L06.P.03

Agroforestry practices in cocoa farming and migration: Between ignorance and conservation strategy of farms

Kouakou A. T. M. (tamiakouakou01@gmail.com), Zanh G. G., Barima Y. S. S., Timité N.

Environment, Jean Lorougnon Guédé University, Daloa, Côte d'Ivoire

The development of Côte d'Ivoire is based on agriculture. This political choice led to the promotion of agricultural activities and mainly cash crops. The natural spaces and particularly the forests of this country are thus exploited for timber and especially cleared for industrial export crops, mainly cocoa. Côte d'Ivoire is the world's largest producer of cocoa with 35% of world production. Cocoa also accounts for 22% of the Gross Domestic Product and more than 50% of Côte d'Ivoire's export earnings. This high production of cocoa is also linked to immigration to Côte d'Ivoire from the hinterland countries. In addition, Côte d'Ivoire had a decade of politico-military crises from 2002 to 2011, which led to a significant displacement of populations. Thus, this period has seen the influx of populations from neighboring countries, mainly Burkina Faso, into protected areas (national parks, classified forests and reserves) located in Côte d'Ivoire's forest zone in search of suitable land. to cocoa growing (Kouakou et al., 2015; Assalé et al., 2016). These different population movements have increased the pressure on the forest resources and modified the different agroforestry practices of the populations. Henceforth, deliberately leaving a tree on one's farm is governed by economic rather than ethical considerations. For Aboriginal producers, the tree is a land marker, a cultural richness and a source of non-timber forest products (Kouakou et al., 2017). For Aboriginal producers, the tree is a land marker, a cultural richness and a source of non-timber forest products (Kouakou et al., 2017). For agricultural migrants operating in protected areas, the tree on the contrary marks the presence of state managers and must be systematically eliminated so that these managers downgrade these areas. The ignorance of local tropical trees by migrants from Sudano-Sahelian areas is also one of the reasons for the total destruction of trees in migrant plantations (Zanh et al., 2016). These populations do not know the utility or the use of non-woody trees and forest products. trees with high yields but which support little shading is a brake on the promotion of agroforestry by migrants. One of the consequences of these practices is the recrudescence of *Swollen shoot* disease in Ivorian forest areas where the presence of outbreaks seems to be related to different agroforestry practices.

Keywords: ocoa, agricultural migration, non-timber forest product, Côte d'Ivoire.

References:

1. Assalé et al., 2016, International Journal of Innovation and Scientific Research, 22(1), 123-133
2. Kouakou et al., 2017, Tropicultura 35, 121-136
3. Kouakoua et al., 2015, American Journal of Life Sciences 3(5), 375-382
4. Zanh et al., Int. J. Pure App. Biosci., 4 (5), 212-225

L06.P.04

Whose rights count? Public participation dilemma of transmigrant population in Indonesia's environmental decision-making

Lai J. Y. (jy.lai@ed.ac.uk)

School of Geosciences, University of Edinburgh, Edinburgh, United Kingdom

Indonesia's transmigration programme (*Transmigrasi*) is the world's largest government-led voluntary resettlement program. The program was initiated under Dutch colonial rule during the early 20th century and taken over by the Indonesian government after independence. Until 2015, the government has relocated over 20 million populations from areas of degraded or densely populated land on Java and Bali to rural areas on the other islands. Land clearing associated with resettlement programmes was identified as one of the major drivers of Indonesia's deforestation in the 1990s. On the other hand, transmigrant populations experienced challenges in adapting different agricultural environment and fitting into the community. Facing the new waves of land conversion to monoculture plantation, transmigrant and indigenous population have been increasingly facing interest conflicts on land use and land tenure decisions. This paper aims to understand the perceptions and constraints of the transmigrant people in engaging in institutional environmental decision-making settings. The study uses qualitative methods, including semi-structured interviews and group discussions, to collect data in four transmigration and indigenous villages in East Kalimantan Province, Indonesia.

L06.P.05

Gender issues in household fuel wood and energy consumption: A case of Bundelkhand Central India

Prasad Dwivedi R. (raghudwivedi66@gmail.com), Singh R., Singh M., Rizvi R., Kb S.

Central Agroforestry Research Institute, ICAR, Jhansi, Uttar Pradesh, India

The importance of gender issues in agroforestry has been broadly recognized and demonstrated. Still there remain a number of issues that require special attention. Particularly collection of fuel wood from agroforestry lands for household consumption. Gender plays an important role in cow and buffalo dung cake making for household fuel consumption. Proportion of cow and buffalo dung cake replaced by fuel wood collected from agroforestry lands is also very important aspect in intra-household decision making and power dynamics as they relate to agroforestry. Socio-economic component of society from agroforestry view point is considered in present interdisciplinary approach of research work. The present investigation was carried out in Bundelkhand region (230 8'- 260 31' N, 780 11'-810 30' E) spread over 7.16 million ha in Central India between seven districts of U.P. (Jhansi, Jalaun, Lalitpur, Hamirpur, Mahoba, Banda and Chitrakoot) and six districts of M.P. (Sagar, Tikamgarh, Chhatarpur, Panna, Damoh and Datia). The landscape is undulating with characteristic hillocks and experiences semi-arid climate. Average annual rainfall of different districts ranges 750-1100 mm. One of the basic objectives of National Agroforestry Policy-India (2014) is to encourage and expand the tree plantation in complementarily and integrated manner with crops. Against this background, the present investigation was carried out during 2016-18 at Garh Kundar-Dabar watershed area of Tikamgarhgarh district of Bundelkhand region in M.P. The data were collected by using structured interview schedule and Focused Group Discussion (FGD). It is revealed that in watershed villages 70-95% of required fuel wood is collected from adjacent forest areas and 5-30% from own agroforestry field. The available tree species are Butea (*Butea monosperma*), Neem (*Azactiracta indica*), Subabul (*Leucaena leucocephala*) and Dhaunkara (*Delonix regia*). The consumption of fuel wood is 4.5-5.5 Kg/day during rainy, 6.5-7.5 Kg/day during winter and 4-5 Kg/day during summer season. It is found that the collection of fuel wood is being performed mostly by women (50-85%). Cow & Buffalo dung cake is another important fuel being used for cooking. The amount is 4 to 7 kg/day as per requirement. The migration of women farmers' practicing agroforestry is reduced in the watershed area due to agroforestry interventions. Therefore there is relevance of gender issues in agroforestry adoption in general and in fuel and energy consumption in particular. In such situation, agroforestry management through watershed interventions with due emphasis on gender concern appear an effective tool to make the gender dynamics in agroforestry systems.

Keywords: Gender issue, Fuel wood, Cow dung cake, socio-economic.

References:

1. Ministry of Agriculture Govt. of India 2014 National Agroforestry Policy India 15

ABSTRACTS

Agroforestry and world challenges

Agroforestry: riding to the world's rescue

- L7 -

Jobs, business, finance: can agroforestry make it great?

Pouring concrete or planting trees?
Can agroforestry fit the green growth agenda?

Green growth means fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. Agroforestry is a sustainable land use practice and system that can be implemented worldwide in any type of land cover. Agroforestry is able to fulfill any of the three pillars of sustainability: economic, environment and social by fostering green growth and creating jobs. Green growth is produced thanks to the diversification of production of the agricultural and forest systems that should choose the best agroforestry components (woody and agricultural production from the lower storey) to increase profitability of the farm but also because agroforestry is the best tool to ecointensificate as it is able to optimize the use of the resources including light and nutrients. This session aims at developing best combinations of woody perennials and agricultural production from the lower storey to promote economic growth and development and therefore the creation of the new jobs world wide.

L07_O.01

Does sustainable forestry, agroforestry and new business opportunities lead to better livelihood? The DECOFOS in Mexico

Cavatassi R. (r.cavatassi@ifad.org), Alfani F., Paolantonio A., Mallia P.

Research and Impact Assessment, IFAD, Rome, Italy

Starting from the '80s, Mexico has experienced one of the largest deforestation rates in Latin America. As a response to the country forest deforestation and degradation, in March 2011, implementation began of the project Desarrollo Comunitario Forestal en los Estados del Sur (DECOFOS), an initiative financed jointly between IFAD, the Global Environment Facility (GEF) and the Government of Mexico. The project had the dual goal of improving the livelihood of people living in poverty and extreme poverty in degraded or marginalized areas and of contributing to climate change adaptation and mitigation through the restoration and revitalization of degraded lands and deforested areas as well as by supporting, both technically and financially, the implementation of sustainable productive activities. To assess the impact of the DECOFOS project a rigorous Impact Assessment has been conducted ex-post through a quasi-experimental mixed method approach which combined quantitative primary data with qualitative analysis and climatic and geo-referenced satellite data plys secondary census data. The combination of different data sources and apporach has produced quite robust and rigorous results suggesing that the DECOFOS project has been successful in increasing agro-forestry and vegetation index as well as the income deriving from forest resources. The project presents different nuances tailored to the diversity of the three Mexican States where it has been implemented: Oaxaca, Chiapas and Campeche. A richness of heterogeneity is found across the three states, whereby higher impacts are found from better and larger use of forest and forest resources in the most forested areas namely Chiapas and Campeche, a stronger focus on agribusiness activities and agro-forestry is found in the State of Oaxaca. With regard to indirect beneficiaries, results suggests that the project facilitated specialization in the local economy: whereas project participants focussed on the use of forest and non-timber forest products through the use of permits and on starting or strengthening micro-business enterprises, indirect beneficiaries seem to strengthen agricultural activities. Economic mobility is positive across participants. Income, dietary and crop diversification is also a result of the project across the three states. Analysis has also been run controlling for climatic variables and variation to ensure that higher and more diverse forest resources where not linked to more favourable climatic patterns. Impacts on vegetation index have also been assessed finding positive results.

Keywords: Agroforestry, Climat Change, Mexico, Impact Assessment, Mitigation.

References:

1. Wunder, S. Angelsen, A., and Belcher, B. (2014) Forests, Livelihoods, and Conservation, World Deve
2. Tompkins, E. L., and W. Neil Adger. 2004. "Does Adaptive Management of Natural Resources Enhance
3. Cavatassi, R. 2004. Valuation Methods for Environmental Benefits in Forestry and Watershed Investmen
4. Winters, P., Salazar, L. Maffioli, A. 2010. «Designing Impact Evaluations for Agricultural Projects,

L07_O.02

Building markets for forgotten wild Sahelian tree foods. A case study of Sahara Sahel Foods

Garvi J.[1] (josef@saharasahelfoods.com), Garvi A. V.[2], Garvi-Bode R. D.[1]

[1] *Sahara Sahel Foods, Zinder, Niger*; [2] *Rewild.Earth, Zinder, Niger*

The Sahel belt of Africa has been grappling with chronic food insecurity ever since the droughts of the 1970's. In Niger, the national cereal production averages 400 kg/ha, which is inadequate for many farming households, so new livelihood models must be sought. Sahara Sahel Foods (SSF) is a social food-processing entreprise based in Zinder, Niger, that develops new food supplies from the near-forgotten wild trees and shrubs of the Sahel, so-called Wild Perennial Crops. These native plants were commonly eaten in precolonial times, but became neglected and stigmatised as agriculture expanded. They are well adapted to the dry climate, easy to grow in polyculture, often have a higher productivity than annual crops, and provide diverse and nutritious foods. By combining tradition and innovation, SSF has developed 50 different food products from 15 of these species, succeeded in destigmatising the popular conception of these foods, and turned them into symbols of national pride. A network of 1500 primarily female suppliers has been organised, from which the tree produce is sourced. However, for this new livelihood to become sustainable, the entreprise must become profitable and the volume of products processed and sold must grow substantially. The strategy for achieving this goal lies in scaling up three sectors: pseudo-cereals, food oils and drinks. This needs to be coupled with added marketing efforts on how to cook and eat these foods, and a larger distribution network.

Fresh marula juice (Sclerocary birrea)

Keywords: Wild Perennial Crops, Value Chains, Sahel, Lost Crops, Food Processing.

References:

1. Direction Générale de l'Institut National de la Statistique du Niger, 2012. Annuaire statistique du Niger 2008-2012.
2. Spittler G., 1993. Les Touaregs face aux sécheresses et aux famines (Les Kel Ewey de l'Aïr (Niger), Karthala, Paris.
3. Garvi A.V. (2001) Passive Transfer. In: Pasternak D., Schlissel A. (eds) Combating Desertification with Plants. Springer, Boston, MA
4. Maman Mato H. 2014. Evaluation de la capacité de la productivité du « hanza » dans la région de Zinder. Institut Universitaire de Technologie/UZ, Zinder, République du Niger.

L07_O.03

No hassle with the hazelnut? The economy-wide impacts of a large-scale contract farming scheme in Bhutan

Feuerbacher A. (a.feuerbacher@uni-hohenheim.de)

University of Hohenheim, Stuttgart, BW, Germany

The Mountain Hazelnut Venture (MHV) is a contract-farming scheme in Bhutan under which 10,000 hectares or about 12% of cultivated land are planted with hazelnut trees. An estimated 15,000 farmers, about 20% of all agricultural households, are expected to benefit from hazelnuts as an additional income source. However, there are concerns that the contract-farming scheme could negatively impact output of other crops, particularly cereals. The government of Bhutan is alarmed about its increasing dependency on cereal imports, as the country is landlocked and imported cereals, which comprise 35% of domestic cereal demand, are only sourced from neighbouring India.

We apply an economy-wide model to simulate the effects of the contract-farming scheme particularly focusing on agricultural output, food self-sufficiency and household welfare. We utilize a 2012 social accounting matrix (SAM) for Bhutan, which is extended to depict seasonal labour markets and the hazelnut activity using data from MHV. Based on the SAM, we employ a comparative-static computable general equilibrium model to simulate the contract-farming scheme by exogenously shifting land from the crop sector to the hazelnut activity.

As the hazelnut is a high-value crop, we expect our results to show a general increase in agricultural output. Yet, we also anticipate that maize output is reduced as the harvest seasons of maize and hazelnuts coincide, which should increase seasonal wages and thus the cost of maize production. We expect farm households' welfare to increase, as except for the harvest months hazelnut growing requires relatively little labour, thus providing higher returns to land. With potentially decreasing maize production and increasing household income, cereal imports are likely to increase. However, the potential impacts on cereal self-sufficiency are contrasted with overall food self-sufficiency accounting for the higher nutritional value of hazelnuts. These aspects are specifically discussed when drawing policy implications from the model results. Mindful of the data structure, we intend to demonstrate how depicting seasonal labour markets matters for an adequate assessment of the scheme's impact. While cereal self-sufficiency declines, alternative policy options to reduce Bhutan's dependency on cereal imports are briefly highlighted.

Keywords: Economy-wide modeling, Contract farming, Foreign Direct Investment, Bhutan.

L07_O.04

Pathways to agroforestry wealth in Nepal

Nuberg I.[1] (ian.nuberg@adelaide.edu.au), Cedamon E.[1], Shrestha K. K[2]

[1] *University of Adelaide, Adelaide, South Australia, Australia*; [2] *University of New South Wales, Sydney, New South Wales, Australia*

Food insecurity is rife in the middle-hills of Nepal because of under-utilised land resulting from outmigration of male labour and underperfroming agroforestry systems. Agroforestry here is inextricably linked with surrounding community forests. We present a conceptual framework describing the links between farm and community forest and role of improved agroforestry in enhancing food security. This underpinned the work of the EnLiFT research project (2013-2018). Results from EnLiFT are presented concerning drivers of under-utilised land, and how simple agroforestry interventions can lift households above the poverty line. However, widespread prosperity requires commercial agroforestry systems on the under-utilised land. Five propositions are made to establish the pathway for agroforestry wealth: 1] Agroforestry should be institutionally integrated with agriculture and community and private forestry; 2] The greatest potential for improving agroforestry is in fodder-livestock and timber-woodlot systems on under-utilised land; 3] The regulations for sale of private-grown timber needs to be rationalised; 4] Multi-sectoral commitment is required to support youth to engage in agriculture, encourage investment of remittances into agriculture, and provide legal systems to encourage investment in commercial agroforestry partnerships;and 5] Current constitutional changes provide an excellent opportunity to develop policies and institutions to encourage wealth-generating agroforestry.

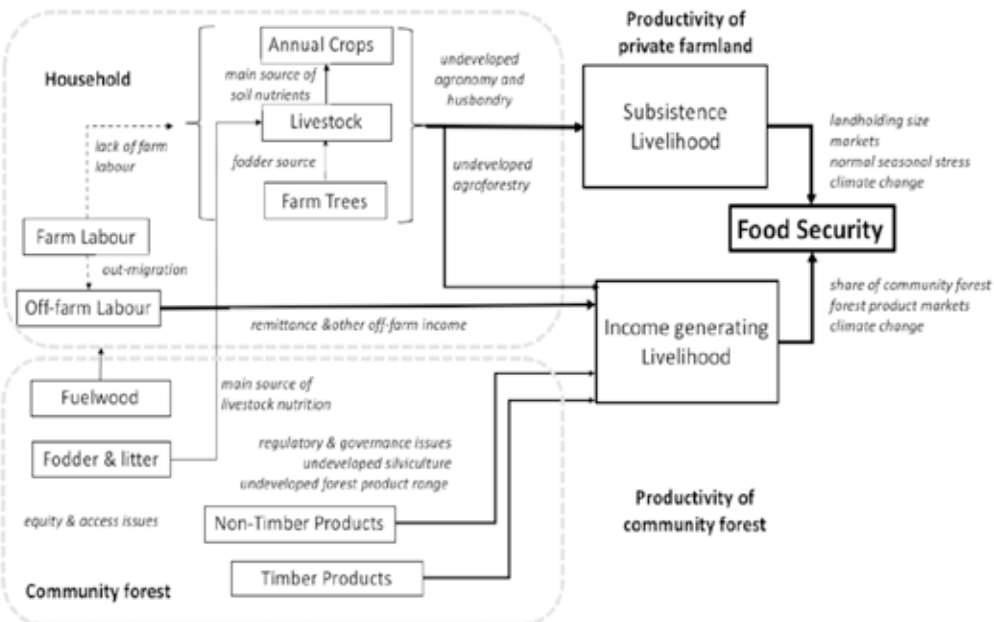


Figure 1 The farm-forest interface and food security in mid-hills of Nepal

Keywords: Nepal, community forestry, livelihoods, under-utilised land, food security.

References:

1. Nuberg IK, Shrestha KK & Bartlett AG (2018) Australian Forestry (in press)
2. Cedamon, E., Nuberg, I., Pandit, B., & Shrestha, K. (2018) Agroforestry Systems, 92(5), 1437-1453
3. Karki, R., Shrestha, K., Nuberg, I. et al (2018) Small-scale Forestry, 17(1), 89-104.
4. Ojha, H., Shrestha, K., ...Nuberg, I., et al (2017). Journal of Rural Studies 53, 156-172

L07_O.05

Improving the livelihoods of 30,000 Kenyan farmers through agroforestry with milk-water-carbon value creation

Mutua W.[1] (wangu.mutua@viagroforestry.org), Nelima M.[2]

[1] *Regional Office, Vi Agroforestry, Nairobi, Kenya*; [2] *Alpha Women Group, Kiminini Cooperative, Kitale, Kenya*

In the **Mt Elgon region in Kenya**, deforestation, inefficient agricultural practices, uncontrolled grazing and soil erosion have a direct impact on biodiversity, soil fertility and farmers capacity to adapt to climate change. Crop yields and milk production are low and smallholders don't have a guaranteed sustainable connection to markets for their produce. The dairy sector's development is hindered by unsecured milk supply and collecting challenges.

The **Livelihoods Mt Elgon project** is improving the livelihoods of **30,000 smallholder farmers** by empowering farmers to increase adoption of **Sustainable Agricultural Land Management (SALM)** practices with a strong focus on **agroforestry,** and establishing connections to **dairy markets** through **15 cooperatives**. The project will sequester **1 million tCO2e** through increase in tree planting, soil organic matter and dairy cow productivity.

The **overall mission** is to secure thriving livelihoods for smallholder farmer communities through widespread adoption of Sustainable Agricultural Land Management (SALM), that delivers value across carbon credits, milk supply chain and water resources.

Farmers are trained on SALM practices such as agroforestry to **adapt to the impacts of climate change, increase farm productivity and food security**. The monitoring of SALM also tracks carbon sequestration. By year 10, the project will have reached a wide spread adoption of SALM on 35,000 ha of agricultural land with 4 million trees planted. Free grazing within small area of land, which severely damages the ecosystem, is avoided as cows have access to feed and water throughout the year. To increase milk productivity, farmers produce fodder crops on farm to feed the cows all year round.

The project strengthens the **capacity of 15 cooperatives to offer services** to their members such as farming advisory services, milk collecting and veterinary services. Also governance of the cooperatives is strengthened to enable women to participate more actively in the dairy value chain, with the aim of **women in 50% of the leadership positions.**

The project is developed through an **innovative investment model**. It is pre-financed by the **Livelihoods Fund**, an investment fund created by private companies, who bears the investment risk. **Brookside Dairy**, a private company, co-invests in the project, pays according to milk production and commits to buy all milk produced within the project over a period of 10 years. The carbon sequestered in the project is the return to the investors which they can use for offsetting in their own companies. **Vi Agroforestry**, an NGO, implements the project together with local communities organised in **15 cooperatives**.

The project delivers **environmental, social and economic benefits** and has already delivered tangible results. By May 2019, at the World Congress on Agroforestry, fresh results from 3 years of implementation will be presented by Vi-skogen and by Margaret Nelima, a smallholder farmer and leader in Kiminini Cooperative.

Keywords: PPP, dairy, carbon, cooperatives, restoration.

L07_O.06

The State of community forest enterprises (CFEs) as successful social enterprises: Empirical evidence from Cameroon

Piabuo S. M. (p.mandiefe@cgiar.org)

Markets, Policies and Institutions, World Agroforestry Centre, Yaounde, Centre, Cameroon

The legal configuration of community forests(CFs) in Cameroon demands that communties exploit resources like business units but invest the profits like charity organisations to solve community problems. This setup portrays the characteristics of social enterprises, which are enterprises that apply commercial strategies to improve the financial, social and environmental welbeing of communities. However, the extend to which community forest enterprises have effectively developed and generated profits from forest resources as business units is not clear, their ability to invest profits in development projects is not clear. This paper seeks to evaluate to what extend community forest enterprises (CFEs) are social enterprises in cameroon over the past 20 years. It would equally underscore if the business or charity side of social enterprises have been lacking and under what conditions can CFEs be designed into successful social enterprises. Document review and focus group discussions with CFs managers, youths, women and minority groups of 36 CFs were used for data collection. The results shows that more than 90% of CFEs in Cameroon are timber based, with significant enterprise management dimension weaknesses; low capacity, poor business planning and development and low profits. Due to poor poor governance, business management of these enterprises, there is hardly enough to invest in community development projects, however standout cases shows that CFEs can be successful social enterprises. Significant improvement were registered in environmental sustainability of CFEs but economic and social welbeing of communities due to CFEs is mitigated. Therefore CFEs can be developed into successful social enterprises, however CFE governance, capacity and business model have to be well developed.

Keywords: Social enterprises, Community forest enterprises, Income generation, benefit sharing, Enterprise management.

L07_O.07

Not all roads lead to Rome: Inclusive business models and responsible finance in pursuit of sustainable cocoa in Ghana

Stoian D.[1] (d.stoian@cgiar.org), Menza G.[2]

[1] *Bioversity International, Montpellier, France*; [2] *Bioversity International, Maccarese (Fiumicino), Italy*

In response to grand challenges in global cocoa production (e.g. poverty, low productivity, deforestation), major chocolate companies have committed to a sustainable cocoa sector by 2020. Their efforts are supported by governments, NGOs and responsible investors. Focusing on Ghana, our study aims to identify synergies and trade-offs between different approaches to sustainability, the potential for inclusive business models, and possible blind spots toward sustainability. Our assessment is based on a comprehensive literature review and key informant interviews (n=32), involving government agencies, NGOs, private companies, responsible investors, and certification bodies. Results show that sustainability goals and approaches vary widely among stakeholder groups. A common goal is increased productivity, mainly through improved planting materials. Efforts to maximize profits (companies) and royalties (the State) also reflect that business-as-usual models still largely prevail. Approaches to more inclusive business, with higher benefits and lower risks for smallholders (e.g. agroforestry, capacity building), are being promoted by NGOs and certification schemes. In addition, providers of responsible finance enable investments with more favourable conditions. Looking forward, innovative arrangements are needed for aligning and de-risking sustainability interventions and investments, and for ensuring credible engagement of large companies and effective support from the government.

Diversity of initiatives in pursuit of a sustainable cocoa sector in Ghana

Keywords: Sustainable cocoa, inclusive business, responsible finance, smallholders, multi-stakeholder approaches.

References:

1. Several publications available as of 2019

L07_O.08

A stimulus to 'green growth' in post-mining peri-urban Africa with elite Pongamia pinnata

Warr B.[1] (bwarr@sun.ac.za), Worms P.[2]

[1] *Soil Science Department, Stellenbosch University, Stellenbosch, Western Cape Province, South Africa*;
[2] *CGIAR, Waterloo, Belgium*

Mining for copper in Zambia has left a legacy of degraded and contaminated landscapes, where the incentives and finances for restoration are limited. This situation is exacerbated by the decline of mining activities. Under such circumstances peri-urban communities suffer high levels of unemployment and a degraded environment. The considered establishment of elite *Pongamia pinnata* bioenergy orchards and 'inter-crops' on disused mine facilities offers significant potential to simultaneously incentivize investment and initiate a process of local economic diversification, job creation and environmental remediation. We describe the rationale and challenges of establishing such operations, the observed benefits of a pilot in Chingola, Zambia and the potential benefits for job creation and sustainable economic growth when replicated and scaled across the region.

Our all female tree planting team, benefitting from flexible job creation and improved environmental conditions.

Keywords: economic diversification, Zambia, land restoration, Pongamia pinnata, mine site reclamation.

References:

1. G. Dwivedi and M. P. Sharma, "Prospects of biodiesel from Pongamia in India," Renew Sustain Energy R
2. A. M. Tulod, A. S. Castillo, W. M. Carandang, and N. M. Pampolina, "Growth performance and phytoreme
3. L. M. R. Al Muqarrabun, N. Ahmat, S. A. S. Ruzaina, N. H. Ismail, and I. Sahidin, "Medicinal uses, p
4. S. N. Bobade and V. B. Khyade, "Detail study on the properties of pongamia pinnata (karanja) for the

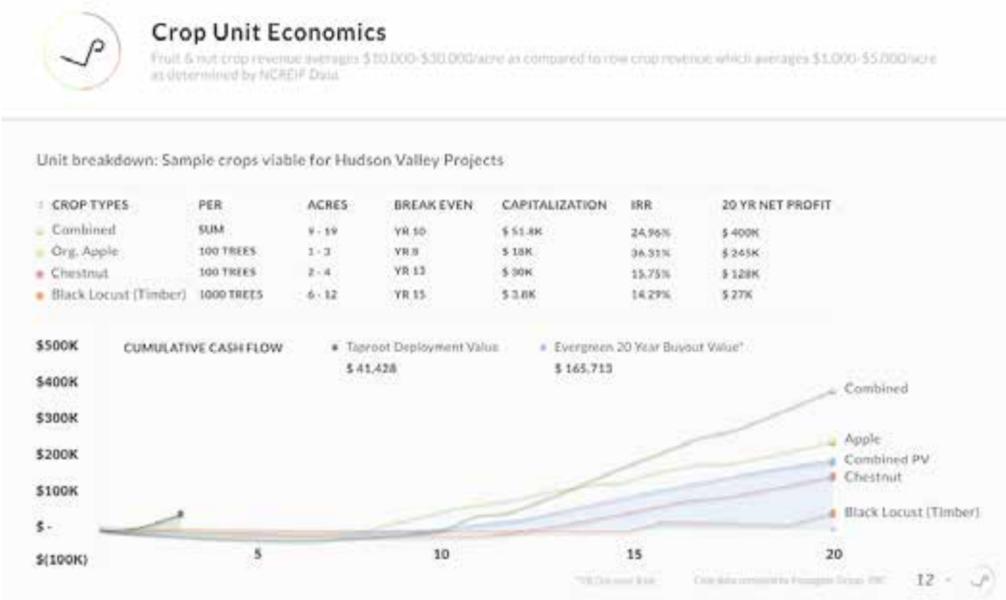
L07_O.09

Marketplace approaches for context-based agroforestry investments and project development

Greene H.[1] (ethan@propagateventures.com), Steinberg E.[2], Kaufman J.[3]

[1] *Farm Development, Propagate Ventures, Hudson, NY, United States*; [2] *Business Development, Propagate Ventures, Brooklyn, NY, United States*; [3] *Design & Technology, Propagate Ventures, Hudson, NY, United States*

By learning from the solar industry we can de-risk investments while creating ownership opportunities for farm managers. It is important to contextualize farm decisions with economic assumptions, such as yields and profit, making crops within growth markets a clear path to profitability.
In the US, purchasing land requires outside capital, as profits from agriculture are insufficient to pay a mortgage, and it is challenging to debt-finance a system that will not break even for up to 7 years. Investment opportunity sits in separating the tree assets from the land. This increases return potential with direct investments into agroforestry, *as real assets, s*imilar to investing in a solar array.
Trends in solar such as tax incentive programs and power purchase agreements play an important role. In the US, opportunity zones and new market tax credits create incentives for investors. Meanwhile, long-term purchasing contracts allow brands to secure supply, mitigating risk by providing secured buyer relationships. Brands and investors can meet climate goals and address consumer demands, while increasing supply certainty and profitability.
By working across the value chain from farmer to investor to corporation, the pursuit of long-term landscape regeneration and financial sustainability can be addressed through market-driven agroforestry solutions.



Keywords: agroforestry assets, project development, investment readiness, crop economics, purchase agreements.

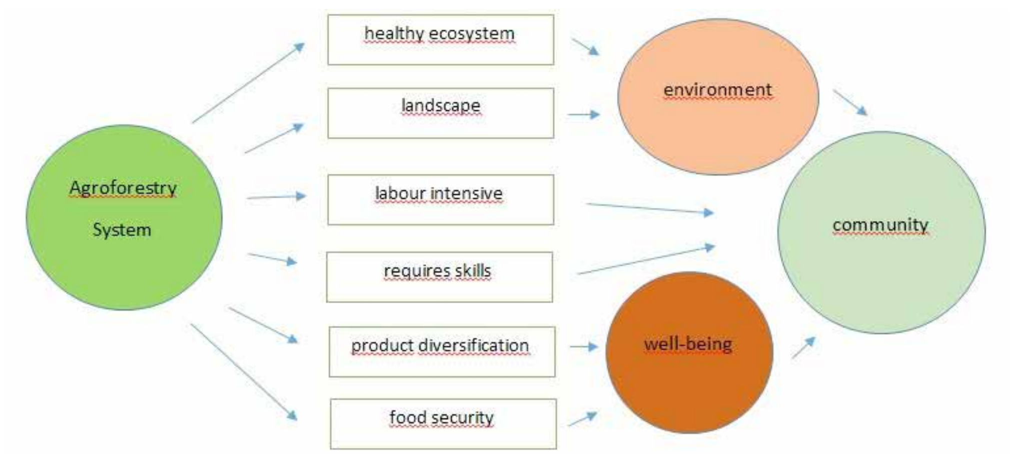
L07.P.01

The effects of agroforestry on local community and landscape – changing approach and strategies in a rural family's life

Csikvári J. (judit.csikvari@gmail.com), Barsony D.

Zsörk, Pápateszér, Veszprém, Hungary

Zsörk is a very diversified land which was partly abandoned when we started our project. We intend to keep it in its complexity, produce fruit while conserving natural values. The villagers' significant part commute to nearby towns and cities, work as factory hands or in services. Few families practice agriculture –mechanized farming on arable lands -,which does not create jobs to keep workers on the field and in the village.
We believe agroforestry can have a local effect on the health of the landscape, on people's well-being and on the community. Agroforestry affects local communities in different areas of life, through several features.
Our system is labour-intensive and therefore costly - a challenge we tackle by product diversification and high added value products - which is labour-intensive again. Two persons (father and son) are working for us permanently. The son was working as a production line worker. Now they draw certain pride out of their status as the workers of Zsörk, and the rest of the village seem to respect that, too. Which makes it easier to involve occasional workers more efficiently.
After decades of abandonment or cultivation with heavy agricultural machinery, now, you can see groups of workers at Zsörk, coping with sophisticated tasks. Locals start to see Zsörk as a multifaceted resource, and some rediscover fruit producing.
Agroforestry can foster community development through different factors that mostly belong to ecologic and economic stability.



L07.P.02

Can traditional agroforestry in Albania lead to environmental protection and increase renewable energy production?

Kacani A.[1] (alborakacani@hotmail.com), Kola H.[2]

[1] *National Federation of Communal Forests, Tirana, Albania*; [2] *CNVP Foundation, Tirana, Albania*

Albanian Ministry of Environment has set the ambitious objective to plant 20 million and 200 thousand trees within 2020 with the aim to increase the forest area and raise public awareness of environmental protection. Moreover, a 10 years forest moratorium was approved by the Government as a measure to stop the destruction of forests mainly for industrial and commercial purposes. While the demand for fuelwood is three times more then what Albanian forest can offer. According to the World Bank in 2017, biomass is the most important heating energy source in Albania.

In a situation when forest and environmental protection is a priority and the demand for fuelwood is very high, the introduction of short rotation agroforestry system by planting fast-growing species on rivers banks and canals could be one of the suitable systems to address these issues, improve land management and reduce flooding in plain areas. In Albanian rural areas, agroforestry represents one of the oldest land-use systems where trees and shrubs are used on the same land-management units as agricultural crops and grazing for animals. These traditions remain alive in rural areas where trees are cut at ground level or above to produce shoots which are harvested for various family uses including fuelwood, animal fodder, and building materials. Actually, coppice and shrubs cover 1 053 239 hectares or 37 % of the total area of the country (Agrotech 2004). Little attention has been given to coppice and shrubs during the last 20 years, an approach inherited from the central forest governance system before ‘90. They are a great unused potential for biomass production and their exploitation can both improve natural conditions and create more employment opportunities for farmers. Thus, apart from the areas near houses which farmers use for family needs, they can use other lands (bare or unused) to plant fast-growing species, initiatives which can boost family business and increase their income. Local case studies recognize that agroforestry is a major source of income to farmers. It shows that agroforestry activities have a significant contribution of 40% to the total annual income of rural households or around 1900 dollars a year (Kacani and Peri 2017). However, there is a lack of studies on the benefits of agroforestry systems and scientists and experts often hesitate to undertake a more in-depth analysis. This is a challenge for the Albanian context, as sectors such as agriculture and forestry have been isolated from each other for a long time. The review focused in understanding the advantages of short rotation coppicing and explore how the integration of these silvicultural techniques with traditional agroforestry might be used for environmental protection and increase production. It could be the first step in assessing whether promoting or not these means of vegetative reproduction and traditional agroforestry practices is the way towards a more sustainable and productive use of land.

References:

1. Agrotech (2004) Albanian National Forest Inventory. Main Report. Tirana.
2. Kacani A and Peri L (2017) IJEES. 7 (4): 703 – 708
3. The Word Bank (October 2017) Biomass-Based Heating in the Western Balkans. Final Report.
4. Sjölund M.J, Jump S Alistair (2013) Forestry. 86, 503–513. doi:10.1093/forestry/cpt030
5. Zeneli G, Kola H (2017) Forest Res 6: 212. doi:10.4172/2168-9776.1000212

L07.P.03

Food security and income from traditional African oil trees

Lykke A. M.[1] (aml@bios.au.dk), Bassolé I. H. N.[2], Ouédraogo A.[2], Padonou E. A.[3], Kouyaté A. M.[4]

[1] *Bioscience, Aarhus University, Silkeborg, Denmark*; [2] *Plant Biology and Ecology, University Ouaga I, Ouagadougou, Burkina Faso*; [3] *School of Tropical Forestry, National University of Agriculture, Ketou, Benin*; [4] *Forest Resources, Institute of Rural Economy, Sikasso, Mali*

Food oil of good quality is important for health, food security and income. Women in rural Africa traditionally extract oil from seeds of numerous native trees, but the potentials are far from fully realized. During two projects, QUALITREE and TREEFOOD, we investigated ethnobotanical knowledge in Mali and Burkina Faso and analyzed physiochemical properties of over 30 native tree oils, of which many revealed interesting qualities and good potentials for ameliorated use, production, sale and export. However, local knowledge about oil production is often confined to specific ethnic groups and areas. Examples of highly interesting oil species are *Adansonia digitata*, *Afzelia africana*, *Balanites aegyptiaca*, *Carapa procera*, *Lannea kerstingii, Lophira lanceolata* and *Pentadesma butyracea*. Despite an extraordinary potential for improving health, food security and economic development in poor communities via diversified and improved oil production, market potentials are poorly developed, value chains are poorly known and in many cases tree planting or nature protection in collaboration with local communities are needed to ensure sufficient and continuous oil seed supplies. Such activities have a potential to improve biodiversity and give opportunities for carbon certification and sale, which makes it a win-win situation. There is a global interest in traditional oils and carbon credits but also a need for value-added sustainable products, fair trade schemes and improved marketing.

Traditional production Carapa procera oil in Burkina Faso

Keywords: Native trees, Oil production, Africa, Local knowledge, Underutilized species.

References:

1. Ouilly JT et al. 2017. Journal of Analytical Methods in Chemistry 2840718.
2. Tietiambou et al. 2016. Bois et Forêts des Tropiques 327: 39-50.
3. Dembélé et al. 2016. Africa Fokus 29: 49-65.
4. Kouyaté et al. 2016. International Journal of Biological and Chemical Sciences 9: 2754-2763.
5. Ouédraogo et al. 2013. . Ethnobotany Research and Applications 11: 71-83.

L07.P.04

Shifting cultivation: is there a place for traditional land use system in the present time?

Pereira M. F. C. S.[1] (manuela.pereira@uffs.edu.br), Ribeiro G. S.[2], Rosário N.[2], Righi C. A.[2]

[1] *Campus Laranjeiras do Sul, Federal University of Fronteira Sul, Laranjeiras do Sul, PR, Brazil*; [2] *Dept. of Forest Science, University of São Paulo, Piracicaba, SP, Brazil*

Swidden agriculture (SAIs) are land use systems adopted by *caiçaras* - traditional people that inhabits Brazilian coast. These systems consist on an itinerancy of cultivated plots alternated by a fallow period. SAIs are criticized for the use of fire and suppression of native vegetation, also they are pointed out as incapable of sustaining people. Nonetheless, these systems endure throughout the pan-tropical region until the present days. Another important aspect is that traditional agricultural systems represent local culture as an expression of people's interaction with nature. To evaluate SAIs capacity to maintain the forest and the population we investigated the dynamic of this system adopted by *caiçara* community in Cananéia, Southeast Brazil. We verified practices and interactions with the environment along time using the Diagnostic and Design tool and participant observation. We found that agriculture is a secondary activity that complements fishing and retirement incomes. Crops are for families' subsistence and feeding small animals. There is a sexual division of labor: preparation of areas (slashing and burning) is a masculine task while cultivation and harvesting are of feminine responsibility. Fallow period varies from 8 to 15 years depending on vegetation size but it's common to find older areas. The cultivation period depends on cassava or sugarcane cycles (2 to 3 years). New areas are chosen depending on crops and soil characteristics. There are no signs of soil erosion and forest seems to regenerate properly despite its temporary suppression, which will be confirmed by complementary field studies. Also, new land arrangements due to protected areas demarcation led *caiçara* people to restrict the areas under forest that could be in use. Finally, we noticed that the younger generations are getting involved into the emerging commercial fishing and leaving agriculture and/or the community. The studied SAIs have an importance in *caiçaras* families' subsistence and its practices seem to be adequate to preserve the local ecosystem. Even so, they seem to be threatened since only the older generations continue to adopt them. The understanding of SAI' dynamics and constrains in order to propose technological adjustments would help to improve its profitability and practice. Even more, it's necessary to conceive legal regulation appropriated to local forest management practices considering a land sharing approach. Thereby it will be possible to apply policies that preserve natural areas maintaining traditional communities, specially future generations, in their landscapes.

Keywords: slash and burn agriculture, protected areas, "roça caiçara".

References:

1. Beniest and Franzel. 1999. Characterization, diagnosis and design: field exercise booklet. ICRAF 59p
2. Van Vliet et al. 2013. Hum Ecol 41: 1 - 5. https://doi.org/10.1007/s10745-013-9562-3

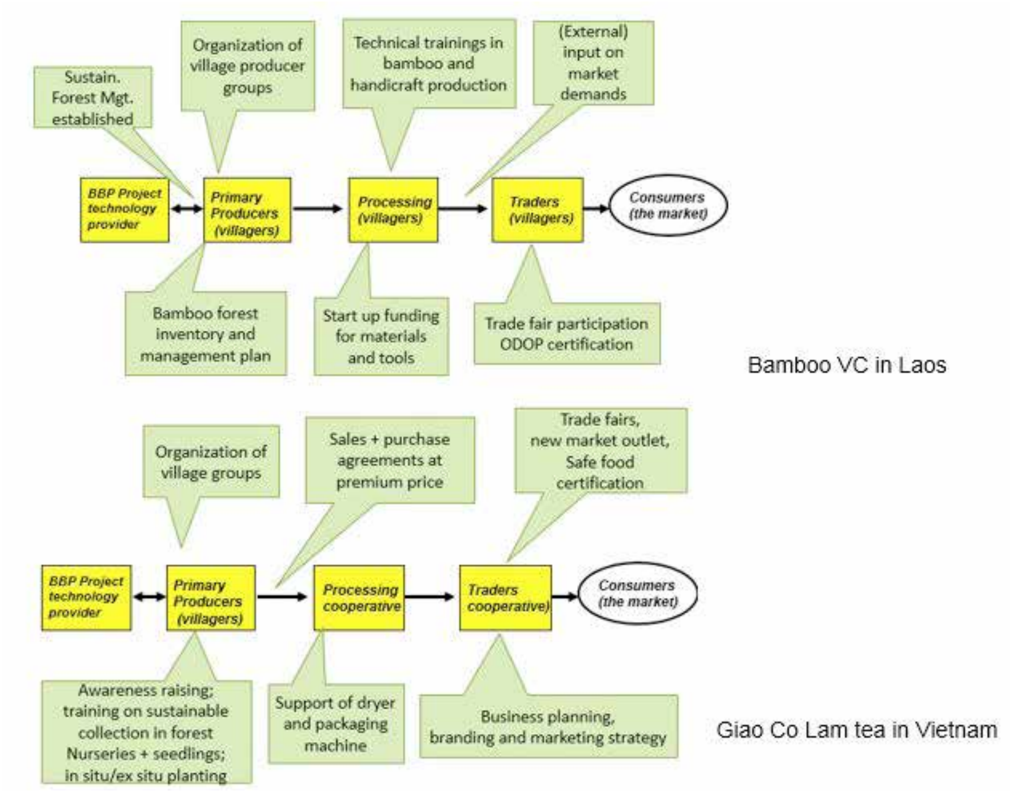
L07.P.05

Balancing economic development and biodiversity protection – Biodiversity-based value chains & certification

Peria E.[1] (evperia@aseanbiodiversity.org), Schlegel B.[2], Simorangkir D.[3]

[1] *ASEAN Centre for Biodiversity, Los Banos, Laguna, Philippines*; [2] *GFA Consulting Group GmbH, Hamburg, Germany*; [3] *GIZ GmbH, Los Banos, Philippines*

ASEAN´s wealth of biological resources does not only represent the diversity of life, it also poses immense opportunities for economic development. The ASEAN Member States want to use this economic potential by further developing sustainable trade relations for bio-products nationally, regionally and possibly globally. However, the exact market potential of Biodiversity-based Products (BBP) is often still unknown. The "Biodiversity-based Products (BBP) as an Economic Source for the improvement of Livelihoods and Biodiversity Protection" Project, funded by the German government via the Deutsche Gesellschaft für International Zusammenarbeit (GIZ) GmbH, is implemented in cooperation with the ASEAN Centre for Biodiversity (ACB) by GFA Consulting Group, to pilot biodiversity-based value chains in Cambodia, Laos and Vietnam, promoting conservation through sustainable use. Villagers around protected areas, local park management, cooperatives and private sector business partners cooperate for the development of marketable products where they did not yet exist or for upgrading of existing products. Biodiversity value chains starts with sustainable sourcing of raw material, including management plans for the input resources which also comprises in-situ and ex-situ planting to enhance available raw material. Value is added through enhanced processing steps and especially certification (e.g. ODOP certification for bamboo) which improves market access for the villagers and their products.



Keywords: certification, value chains, agrobiodiversity, economy, development.

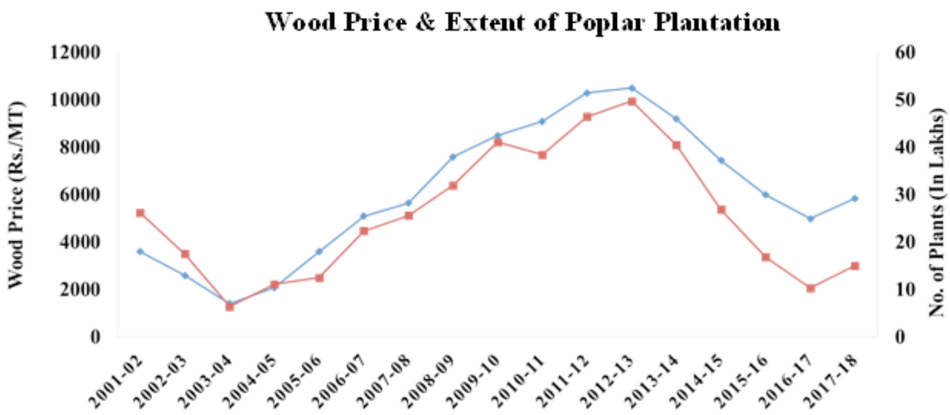
L07.P.06

Poplar Agroforestry Practice: A Responsible Business of Wimco seedlings in North Indian States

Sharma P. (punam.sharma@itc.in), Jha R., Gandhi J.

Plantations, Wimco Seedlings, ITC Ltd, Rudrapur, Uttrakhand, India

Poplar (Populus deltoides) was introduced in 1976 on boundaries in farmer's field in Punjab, north India. Later it was raised in agroforestry model to fulfil the wood demand of match and plywood industries. During 1984 to 1991, Wimco Seedlings initiated an extensive polar culture programme. It revolutionized the commercial tree cropping on farm lands1. A large number of farmers took up poplar cropping. Currently poplar is the main forestry crop in the states of Punjab, Haryana, Uttar Pradesh and Uttrakhand. Besides catering to the wood requirement of plywood & paper industries, poplar based agroforestry model has significantly improved the socio-economic status of farmers engaged in it. It increased their farm income many folds. At a rotation age of 6 years, one poplar tree can yield up to 3.5 q of wood. With 500 trees per hectare, a farmer can earn on an average Rs. 2.00 lakh/ha/year. This implies an income of Rs. 550/per day from the poplar based agroforestry system. So far the area covered under poplar plantations is around 150 thousand ha. This has generated 60 million mandays of employment. Wimco Seedlings has exclusively generated 2.0 million mandays from its own nursery operations. In addition, poplar plantations ameliorate soil conditions and improve micro-climate. These also have huge environmental impact. With an estimate of 20 million trees planted per year under the poplar based agroforestry, approximately 2.5 million tonnes of carbon is sequestrated annually2.



Years, Wood Price (Rs/MT), No. of Plants (In Lakhs)

Keywords: Populus deltoides, Poplar Clones, Plantations, socio-economic status, carbon-sequestration.

References:

1. Dhiman, RC. 2012. Status of Poplar Culture in India. Forestry Bulletin, 12(1): 15-32.
2. Dhiman, RC. 2009. Carbon Footprint of planted Poplar in India. ENVIS Forestry Bulletin, 9(2): 70-81.

L07.P.07

Opportunities for Enhancing Rural Economies through Agroforestry

Stein S.[1] (sstein@fs.fed.us), Bentrup G.[2], MacFarland K.[3]

[1] *Forest Service, Research and Development, United States Department of Agriculture, Washington, District of Columbia, United States*; [2] *Forest Service, Research and Development, United States Department of Agriculture, Lincoln, Nebraska, United States*; [3] *Forest Service, Research and Development, United States Department of Agriculture, Burlington, Vermont, United States*

The United States Department of Agriculture convened a workshop to lay the foundation for assessing economic opportunities for farmers, ranchers and forest owners, to practice and benefit from agroforestry. Over the course of three days, producers, scientists, and others from the public, private, and non-profit sectors examined opportunities for enhancing the profitability of agroforestry through increased access to land and capital; markets for products from agroforestry systems; and participation in ecosystem services markets. Case studies presented featured land leasing for agroforestry; agroforestry impact investing; innovative approaches to creating markets for underutilized products such as pawpaw (Asimina triloba) and American hazelnut (Corylus americana); increased market access through cooperatives and food hubs; and the integration of forest buffers into ecosystem services markets. In addition, participants explored sources of government support for implementing agroforestry systems, value-added processing, and developing market access. This presentation will review a selection of examples explored and present actions identified for expanding such opportunities.

Keywords: Economics, Markets, Ecosystem Services, Products.

L07.P.08

Willingness to establish private forest plantation among households in Oyo state Nigeria

Tijani S. (tsarafat@yahoo.com)

Agricultural Extension and Rural Devt, University of Ibadan, Ibadan, Oyo, South west, Nigeria

The uncertainty of weather condition has really transformed to climate change and fluctuations in economic situation of an individual and entire nation at large. One of the factors responsible for climate change has been identified to be deforestation. This has seriously exposed the surface of the earth to direct sunlight and unprecedented rainfall with consequent ripple effect that threat existence of human being and agricultural crops. Drastic reduction of wood supply for making furniture and construction makes Nigeria as a nation to be importing forest timber products which transcend to reduction on nation's gross domestic product. Ogunwusi (2011) reported that the decreasing supply of wood to the wood products sector couple with the inadequate management of government plantations have made the need for private sector participation in forest plantation establishment imperative. However, through trees planting/afforestation unemployment as a cankerworm to the national development would be combated and also it will serve as means of households' livelihood diversification as noted by Matthies and Karimov (2014) that tree planting has been among the measures to diversify livelihoods, create alternative income, and increase biomass supply. This study therefore investigates the willingness of the households to establish private forest plantation (PFP) in Oyo- State, Nigeria. Two purposively and two randomly selected Local Government Areas with forty household heads randomly selected from each LGA were used for the study. Data obtained through interview schedule were analysed using descriptive and inferential statistics α0.05. Majority of the respondents were male (89.2%), within 41-50 years (43.9%) and 92.8% were married. About 85.6% have knowledge of private ownership and 91.4% had knowledge of forest plantation establishment. It implies that the respondents had a general knowledge of the practice of agro-forestry. Respondents 'attitude to PFP (78.4%) was favourable which might be due to the benefits inherent in the establishment. A large percentage (96.4%) agreed that involvement in PFP serves as income generating activity while 58.3% identified government policy on forestry and land tenure system as major constraints to establishment of PFP. Age ($\chi 2$= 236.256), educational qualification ($\chi 2$=35.283), primary occupation ($\chi 2$ = 62.944)) knowledge of private ownership (r = 0.424), knowledge of establishment (r = 0.451), attitude (r = 0.230), perceived benefits (r = 0180), perceived constraints (r=-0.181) were significantly related to willingness to establish PFP. Respondents' possessed favourable attitude towards PFP establishment despite the perceived constraints. Government in collaboration with Forestry Research Institute of Nigeria (FRIN) should initiate programmes on PFP and policy on land use decree should be reviewed to promote participation in forest plantation establishment.

Keywords: Household, Income generating activities, Forest plantation, Knowledge.

References:

1. Ogunwusi A.A.(2011) Nigeria Journal of forestry 40:1: 8-16
2. Matthies B.D and Karimov A. A. (2014) Land Use Policy 41:474–483

L07.P.09

Adults who which to change job: a chance for agroforestry

Trolle A. (arnaud.trolle@lesavoirfaire.fr)

Savoir-Faire & Découverte, Millau, France

74% of the french employees think of changing life and jobs. 55% of the people who change jobs say they are more satisfied on a personal and professional level. These people want to give more meaning to their professional activities, to invest in social, local economy (1)... We can add migrants who wish to return to their country.
Jobs linked to agro-forestry (2) answer to theses wishes . They bring quality of employment, social utility, diversified tasks.
We have here motivated people who can put in practice agroforestry's "know how". They have the ability to create jobs.
But they need to learn and to be trained for this: the study « SHORT FOOD CIRCUITS...» shines a light on the strong need of skills to answer the growth of demand for products stemming from the local economy.
Savoir-Faire & Découverte trains more than 1000 people every year to ecological and manual know how. 55% pay personally, 45% were supported by existing devices. A survey carried out in 2016 (500 replies) shows that more than 80% of formers trainees put into practice the skills acquired (personal or professional purpose). More than 30% create their activity between 1 and 2 years after the end of the training. Trainees then settle as peasant-baker, market gardeners, arboriculturist, natural canning manufacturers… We will provide testimony of former trainees and lines of action

1 - See the report «MAKE TOGETHER, to live better together», Patrick Levy-Waitz.

2 - includes trades related to product processing

Transform and sell agro-forestry products locally

Keywords: local economy, short food circuit, retraining, practical training, jobs.

References:

1. SHORT FOOD CIRCUITS, economic issues and perspectives for the territori.. - www.pourla-solidarite.eu
2. Pool Viavoice - June 2014

ABSTRACTS

Agroforestry adoption

Adopting the future of land use

- L8 -
Scaling up of agroforestry innovations

Scale it up, now! Getting proven innovations into the landscape

Contributions expected in this session refer to effective scaling ups of agroforestry research outputs and experiences. The session also considers research embedded in development across varying contexts and scales including technologies, socio-economies, service deliveries, policies and institutional environments. This may accelerate impacts of agroforestry innovations and systems to provide better, equitable and sustainable agroforestry benefits to the greatest number of people over the widest area. This does not only improve agronomic, economic, environmental performances of the current practices; and optimize trade-offs among them, but it also contributes to changes in institutions, policies, rules laws, cultural values, and beliefs which may support scaling ups of agroforestry innovations with concrete and sustainable impacts. The session also considers participatory, holistic and multidisciplinary approaches, action researches, innovation platforms, and models by ensuring participatory, and inclusive engagements of extended peers of communities (including scientists, producers and other stakeholders) who play key roles in accelerated scaling ups of and sustainable impacts from agroforestry intensification.

L08_O.01

Achieving transformational impact from agroforestry research

Bartlett T. (bartlett.forestry@gmail.com)

ACIAR, Deakin, ACT, Australia

In developing countries, many farmers incorporate trees into their farming systems. For decades, donors have funded agroforestry research aimed at improving livelihoods and food security, while enhancing productivity and sustainability. Much good research has been done over the years, but rarely has it transformed rural communities. What then are the factors that catalyse transformational impacts from research projects? Do they vary in different regions?
This presentation will draw on research conducted by the author to understand factors that influence success in collaborative agroforestry research. A new methodology for evaluating the relative success of agricultural and forestry research projects will be presented, and the lessons identified from case studies of transformational agroforestry research funded by the Australian Centre for International Agricultural Research (ACIAR) in Africa, Asia and the Pacific.
More than 30 factors can either enhance or diminish agroforestry project success, most of which can be influenced during project design and implementation. However, a successful research project may not necessarily lead to widespread adoption of the agroforestry technologies and therefore the desired impacts. Some ACIAR forestry projects, for example on Acacias in Vietnam, have already catalysed transformative impacts. Other current work is demonstrating great potential to transform both adoption rates and farming livelihoods. Understanding the lessons from these projects could assist others to get better outcomes and greater impact from future investments in agroforestry projects.

L08_O.02

Potential for managing natural regeneration by family farmers in the Amazon: making the most of biodiversity

Ferreira J.[1] (joice.ferreira@embrapa.br), Elias F.[2], Nascimento D.[1], Silva J. S.[3], Almeida Á.[4], Nascimento R.[4], Carneiro R.[5], Navegantes L.[5], Coudel E.[6]

[1] *Amazônia Oriental, Embrapa, BELEM, PA, Brazil*; [2] *Ecology, Federal University of Pará, BELEM, PA, Brazil*; [3] *Federal Rural University of Pará, BELEM, PA, Brazil*; [4] *Environmental Sciences, Federal University of Pará, BELEM, PA, Brazil*; [5] *Family Farmer Institute, Federal University of Pará, BELEM, PA, Brazil*; [6] *Green, Cirad, Montpellier, France*

Natural regeneration represents more than half of all tropical forests. Within the Brazilian Amazon, the area of regenerating forest increased by 70% between 2004 and 2014, currently occupying more than 17 million hectares. These ecosystems have an important social roles, such as increasing food security and alleviating poverty among thousands of family farmers in the Amazon, while also being important repositories of biodiversity and carbon. Brazil has made bold commitments to the restoration of 12 million ha of forest by 2030 through the Bonn Challenge, Initiative 20 × 20, and its Forest Code law. The management of natural regeneration can be a viable alternative for accomplishing these commitments with less socioeconomic costs and higher environmental benefits. Here, we present a collation of different studies from the authors addressing natural regeneration on family farmers' land in the Eastern Amazon, aiming to address three overarching questions: i) How diverse are tree communities on these lands following natural regeneration? ii) What proportion of trees in regenerating forests have potential use recorded in the literature? iii) What are the real uses and motivations for farmers to maintain and manage these areas. We performed field surveys in 10m x 250m transects placed in regenerating forest fragments, followed by a literature review on potential uses for the dominant trees (> 80% of basal area). We separated the different uses in categories encompassing timber and non-timber forest products-NTPF (e.g. medicine, ornamental, food, handcraft, firewood). We applied semi-structured interviews and use the likert-scale to understand the uses and motivations for managing natural regeneration. The high tree diversity in the studied regenerating forests (up to 120 species ha-1) is reflected by a high variety of potential uses reported in the literature. Using an old regenerating forest plot (~50 years) as a case study in Northeast Pará, we found the vast majority of species reported in the literature as having potential for timber (76%), followed by firewood/charcoal (34%), medicine (29%) and food (20%). Natural regeneration has been used by family farmers in the Northeast of Pará for multiple uses, but mainly for extracting timber (50%) and hunting (18%). In fact, NTPF-extraction and beekeeping management are important motivations for family farmers to conserve naturally regenerating areas. Despite the high potential for Farmer-Managed Natural Regeneration, the reality is that these areas continue to be prioritized for slash-and-burn agriculture. Therefore, public policies are needed to encourage family farmers to protect areas under natural regeneration to capitalize on the potential this form of restoration offers in the Amazon.

Keywords: ecologial restoration, secondary forests, tree diversity, ecosystem services, Brazilian Amazon.

L08_O.03

Agroforestry systems and research in Eritrea: Review of concepts, practices and research findings

Araia W.[1] (woldearaiahac@gmail.com), Sultan Z.[2]

[1] *Arid Land Agronomy, Hamelmalo Agricultural College, Keren, Eritrea*; [2] *Forestry Research, National Agricultural Research Institute, Halhale, Eritrea*

This paper reviews agroforestry systems, highlighting the potential and significance of agroforestry in Eritrea with the objective of improving its adoption. A combination of trees, agricultural crops and livestock production is an ancient practice that farmers have used in Eritrea. Agroforestry has been practiced by communities in order to fulfill the immediate basic human needs of food, fuel, fodder, shelter, protection etc. There are three basic types of Agroforestry systems such as Agrisilviculture (crops and trees), silvopastoral ((Pasture/animal + trees); and Agrosilvopastoral (crops + pasture/animals + trees). There are other specified agroforestry systems such as apiculture (bees + trees), aquaculture (fish + trees/shrubs) and multipurpose tree lots. In Eritrea, the most common agroforestry practices are multipurpose trees on crop land, wind breaks and shelter belts, tees for soil conservation measures, living fences, wood lots in villages and community, apiculture (apisilviculture), agro forestry in river banks and water ways, rangelands (protein banks), mangrove forest based aquaculture, urban agroforestry and home gardens etc. are descried in this paper. Agroforestry has been recognized as a land use system which is capable of yielding both wood and food while conserving and rehabilitating the natural eco systems. Review of research results on agroforestry in Eritrea showed that the highest grain yield on barley was obtained from fallow land planted with Crotolaria grahamiana (1165 kg/ha). In studies done on hedgerow intercropping, a 4.5 m alley relatively gave the highest grain yield (793 kg/ha) on barley compared to that of 6 m alley. Demonstration on three sites have shown that trees have stabilized the soil and water conservation structures and farmers were able to cut and carry grasses to feed their livestock. It is very important to create awareness to the community on the benefits of agroforestry and promote the different agroforestry practices in order to preserve the indigenous woody species. Furthermore, tree legumes are very important source of protein which provide animal feeds during the dry periods. However, it is important that extensive research programs be carried out on agroforestry and transfer the technology generated from research. In addition a lot of effort is needed so that farmers could be convinced in the adoption of agro forestry practices in a very aggressive manner.

Keywords: Agroforestry systems, practices, research, Eritrea.

References:

1. Bein, E. 1997. MSc thesis, University of Aberdeen, Scotland.
2. Habte, B. and Araya, E. 2004. Regional Land Management Unit and World Agroforestry Center. Working p
3. National Agricultural Research Institute. 2002. Unpublished report, Eritrea.

L08_O.04

Developing livelihood trajectory models for screening and scaling agroforestry options

Crossland M.[1] (afp43d@bangor.ac.uk), Sinclair F.[2], Pagella T.[1], Taylor J.[3], Duguma L.[2], Winowiecki L.[2]

[1] *Bangor University, Bangor, United Kingdom*; [2] *World Agroforestry, Nairobi, Kenya*; [3] *Simulistics Ltd., Edinburgh, United Kingdom*

The need to move away from blanket recommendations and to tailor agroforestry innovations to local circumstances is well established. Yet there is a lack of tools for screening options based on current knowledge so that farmers can be offered suites of 'best fit' technologies to choose from. Here, we describe the development of livelihood trajectory models to assess (ex-ante) the extent to which planting on-farm trees for fuelwood can influence the livelihoods of those living in the drylands Northern Ethiopia and the degree to which they can directly and indirectly contribute to reducing poverty and increased fuel and food security.

Due to scarcity of firewood, households in rural Ethiopia resort to using cattle dung as a supplementary fuel source, displacing its use as manure on farmers' fields. Planting on-farm trees for firewood could help meet household energy demand, reduce pressure on local forest resources and substitute the use of dung as fuel thus allowing for its return to croplands and increased production. Using the simulation modelling environment Simile (www.simulistics.com), participatory methods, expert knowledge and data collected from large-n trials, the impact of different levels of on-farm tree planting were evaluated in relation to enabling households with different resource profiles to reach fuelwood self-sufficiency and cross food security and income thresholds.

The first version of the model, which simulated the establishment of *Acacia decurrens* woodlots, showed that the number of trees required to meet household fuelwood demand is substantially higher than current levels of on-farm tree planting and would require potentially unrealistic changes in land use for the majority of households, especially those with small farms. These findings motivated us to develop a more detailed model that enabled us to explore alternative configurations of on-farm trees, management regimes and species. Results from this second iteration of the modelling process suggest that while agroforestry practices such as trees scattered in cropland and manged through pollarding are unlikely to cover 100% of household fuel demand or lift the majority of households out of poverty, they can attenuate trade-offs between on-farm fuel and food production and may have indirect implications on food security through the substitution of dung as fuel.

Our results highlight the need to scale up current tree planting efforts while finding ways to integrate trees with current farming systems, and that initiatives promoting trees for fuel need to be realistic about the extent to which on-farm trees can contribute to meeting household fuel demand. The modelling process also revealed major knowledge gaps and data deficiencies in relation to understanding key livelihood-options interactions, such as feedbacks in the wider rural economy, helping to focus ongoing research and model development.

Keywords: Systems modelling, On-farm trees, Trade-offs, Fuel wood, Ethiopia.

L08_O.05

Roles of Agroforestry in sustainable intensification of small farMs and food SEcurity for SocIetIes in West Africa

Seghieri J.[1] (josiane.seghieri@ird.fr), Bastide B.[2], Ingram V.[3], Jourdan C.[4], Sanogo D.[5]

[1] *UMR HydroSciences Montpellier (HSM), IRD, Montpellier, France*; [2] *Département Environnement et Forêts (DEF, INERA, Bobo Dioulasso, Burkina Faso*; [3] *Department of Environmental Sciences, Wageningen University and Research, Wageningen, The Netherlands*; [4] *UMR Eco&Sols, CIRAD, Dakar, Senegal*; [5] *CNRF, ISRA, Dakar, Senegal*

Since agroforestry is an option to design resilient farming systems facing global changes in West Africa (demography, markets, climate), the questions addressed by the project **RAMSES II** are : *How agroforestry can be sustainably intensified and how this intensification can be upscaled* ? Compared to crop alone, the C sequestration is supposed to be increased, climate variations buffered, and farms food and income diversified and increased. This way of intensification may be sustainable if its adoption by small farmers is maximized.
The approach is based on a multi-scale diagnosis of the parkland drivers and the characterization of the environmental, agronomic, social and economic services provided by four common agroforestry parklands based on cereal crops in West Africa (*Piliostigma ssp*. and *V. paradoxa*, in Burkina Faso, *G. senegalensis* and *F. albida* in Senegal). They are inputs to multi-stakeholders innovation platforms at territory scale. To maximaze adoption, intensification scenarios have to be contextual and proposed by farmers themselves, scientists providing them with the simulated impacts on farm income and cereal yields. In addition, governance realistic arrangements able to support intensification are planned to be co-built by authoriries and all parkland users (famers, women, youth, migrants, etc.). The upscaling is expected to be achieved by «snowball effect», and monitored during- and after- the project by the NGOs and national scientific institutions involved.

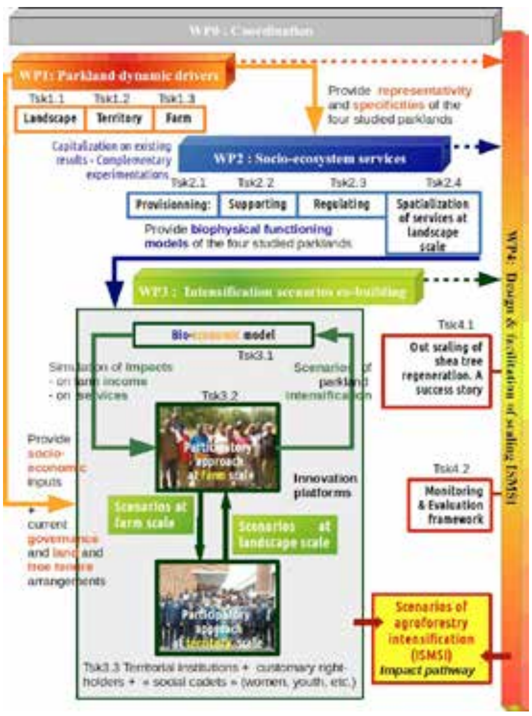


Chart of the RAMSESII project organisation

Keywords: Extended-peer-community, Participative-approach, Bio-economic-modelling, Systemic-approach, Upscaled-intensification.

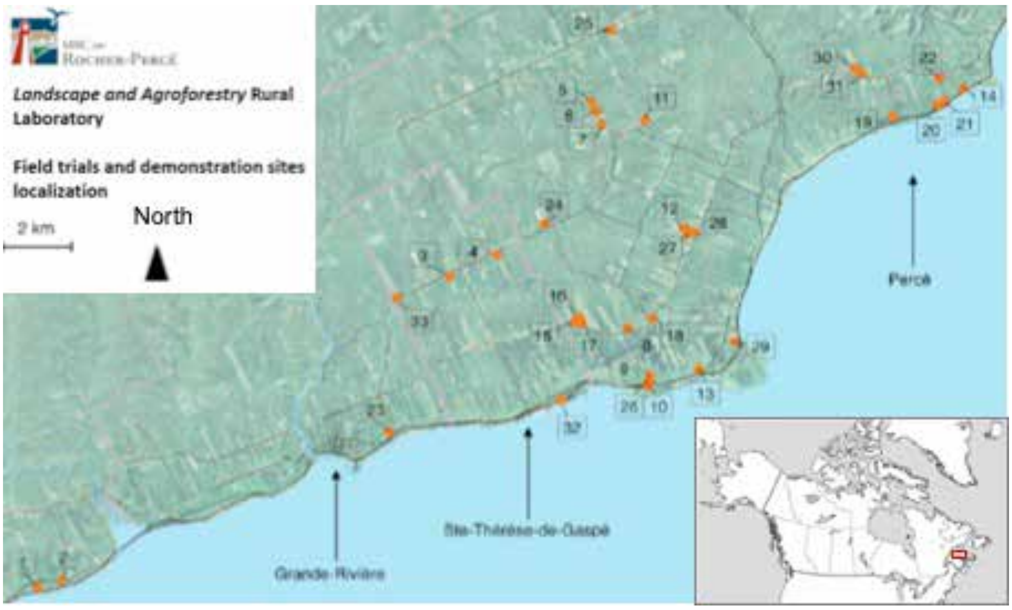
L08_O.06

Lessons from the «Agroforestry and Landscape Laboratory» in Rocher-Percé regional county, Quebec, Canada.

Laroche G.[1] (genevieve.laroche@fsaa.ulaval.ca), Anel B.[2], Olivier A.[1]

[1] *Phytologie, Université Laval, Québec, Québec, Canada*; [2] *MRC Rocher-Percé, Percé, Québec, Canada*

From 2009 to 2014, the "Agroforestry and Landscape Laboratory" gathered various stakeholders in Rocher-Percé regional county (Quebec, Canada) committed to maintain regional landscape's attractivity and agricultural dynamism through a landscape-scale agroforestry project. We used this project as a case-study and performed document analysis and interviews to identify key processes and features that facilitated agroforestry adoption. The long-term and flexible project scheme enabled the implementation of innovative concertation, funding, decision-making and follow-up mechanisms that facilitated agroforestry adoption. The full commitment of the agroforestry team throughout all the project helped the building of key trusting relationships between stakeholders. By formalizing unofficial agreements between land owners and farmers for land uses on a long-term basis, the project enabled agroforestry system implementation and secured the agricultural use of the land for the farmers. While most agroforestry public support follow agricultural funding schemes, the project team implemented an innovative funding structure directly inspired by regional afforestation programs. Finally, the decision-making process combined both regional and farmers interests to maximize private and societal benefits. The case-study illustrates the importance of a grounded, human-based, long-term, flexible and concerted approach for the implementation of agroforestry systems at the landscape scale.



Localization of the 33 agroforestry field trials and demonstration sites implemented during the «Landscape and Agroforestry Rural Laboratory».

Keywords: Landscape, Social innovation, Stakeholders, Policies, Concertation.

L08_O.07

Opportunities for agroforestry in Finland

den Herder M.[1] (michael.denherder@efi.int), Vanhanen H.[2], Mattila I.[3], Mattila T.[4], Puro E. M.[5], Lokki H.[5], Makkonen O.[6], Rois Díaz M.[1]

[1] *European Forest Institute, Joensuu, Finland*; [2] *Natural Resources Institute Finland, Joensuu, Finland*; [3] *Kilpiän tila, Pusula, Finland*; [4] *Finnish Environment Institute, Helsinki, Finland*; [5] *Suomen Agrometsä Oy, Karjalohja, Finland*; [6] *Vaahermäen tila, Savonranta, Finland*

Agroforestry is often not immediately associated with cold climates but it has a long tradition in Finland. The main aim of the AFINET project and its Finnish farmer network is to promote the uptake of agroforestry by facilitating knowledge exchange between farmers, advisors and researchers. In 4 workshops, participants identified the challenges and barriers for the uptake of agroforestry, as well as potential innovations to tackle the challenges. In total, the stakeholders identified 89 innovations across Europe. After evaluation by the Finnish stakeholders, 12 of these innovative ideas would be applicable to Finland. Some examples are: 1) alley cropping and trees planted on contour lines on steep slopes initially to reduce wind speed and erosion but it also helped to reduce the impact of recent summer droughts, 2) active mushroom cultivation as a forest management tool generating additional income for the forest owner, and 3) sheep grazing in young forest stands reducing the need for pre-commercial thinning and additional feeding, while at the same time enhancing animal well-being. The AFINET project will produce science-based information for farmers (factsheets, videos, seminars, tutorials) helping the uptake of the innovations into practice. The AFINET project helped making the agroforestry concept better known in Finland and the practice is gradually gaining popularity. However, much work remains to make this practice better known among farmers and the general public.

Shiitake mushrooms grown on birch logs

Keywords: Alley cropping, active mushroom cultivation, sheep grazing, innovative practices, farmer network.

References:

1. AFINET project, 2018. Agroforestry Innovation Networks. URL: http://eurafagroforestry.eu/afinet

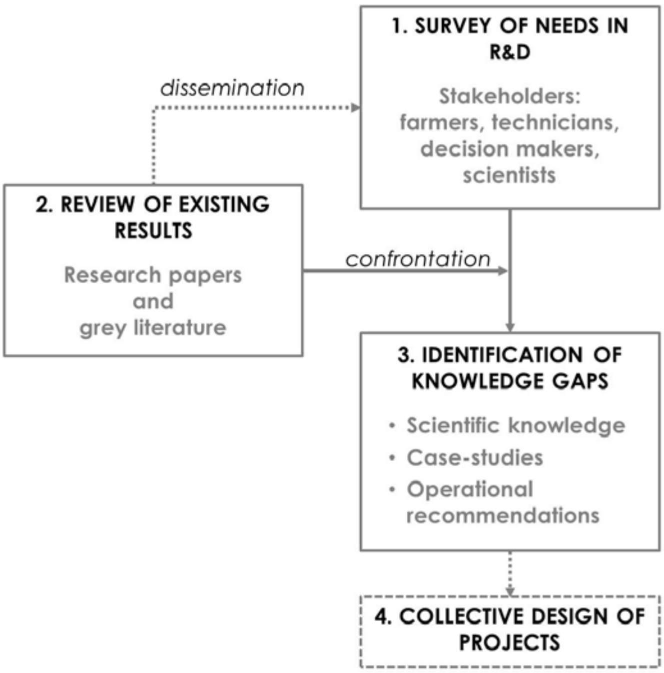
L08_O.08

How can Research & Development efficiently support the French practitioners of agroforestry?

Grimaldi J.[1] (juliette.grimaldi@inra.fr), Saubion C.[2], Warlop F.[3], Hannachi Y.[4], Mézière D.[1]

[1] *INRA UMR System, Montpellier, France*; [2] *CA Hérault (34), French Chambers of agriculture, Montblanc, France*; [3] *GRAB Vaucluse (84), Avignon cedex 9, France*; [4] *APCA, French Chambers of agriculture, Paris, France*

Agroforestry is raising the interest of more and more farmers together as of some academics and technicians willing to support the development of more sustainable food production systems and the maintenance of ecosystem services. Nonetheless, in the context of France, not enough links have been made so far between research projects and the concerns of agroforestry practitioners: many scientific results remain unknown to farmers or technicians while scientists may miss the red-hot questions to be targeted in priority. In this context, an overall analysis was carried out. First, the results from several surveys carried out among the French practitioners of agroforestry and targeting their needs were synthetized. Second, both the already existing and relevant scientific or grey literature was reviewed. By confronting the two, the remaining and further needs in research and development were identified. These needs were formulated as gaps of scientific or practical knowledge per types of agroforestry practices met in France (sylvopasture, sylvoarable agroforestry, riparian buffer-strips, forest-farming, etc.). The first main results from this analysis will be presented at the conference and shall in the future help stakeholders to collectively design efficient research and development projects and to disseminate existing knowledge.



A four-step approach is carried out in order to identify the red-hot topics to be addressed by the French R&D in agroforestry

Keywords: Research and Development, practitioner needs, outstanding questions, literature review, knowledge gaps.

L08_O.09

Scaling up oil palm Agroforestry in the Brazilian Amazon: lessons learned from the SAFDENDE Project in Tomé Açu, Pará

Miccolis A.[1] (a.miccolis@cgiar.org), Ramos H. M. N.[2], Silva J. A.[3], Arantes A. C. V.[3]

[1] *World Agroforestry Centre - ICRAF Brazil, Belém, Pará, Brazil*; [2] *World, Belem, Pará, Brazil*; [3] *World Agroforestry Centre - ICRAF Brazil, Belem, Pará, Brazil*

In the Brazilian Amazon, oil palm has expanded rapidly since 2010, largely driven by policy incentives that led major companies to invest heavily in the sector and establish agreements with smallholder farmers. Many family farmers in Tomé Açu, Pará question the risks associated with planting a single crop that takes up most of their land and labor. Biodiverse agroforestry systems can reconcile oil palm production with more resilient livelihoods while also providing environmental functions, however, upscaling will require tailoring the systems to local contexts and improving the enabling environment. This study aims to identify the key factors underlying the adoption and scaling of biodiverse oil palm agroforests in this region. The methodology was comprised of: a comprehensive literature review; analysis of biophysical and socio-economic characteristics; semi-structured interviews within Tomé Açu; and an analysis of access to assets and farmer objectives through farm-level socio-environmental appraisals, conducted on 15 farms in Tomé Açu through PLANTSAFS (Planning and Evaluation for Decision-Making on Agroforestry Systems). Preliminary findings show a high demand for diversification because of the reduced risks of more diverse systems in coping with market fluctuations, disease, and climate factors, particularly prolonged droughts. The key constraints for upscaling such systems among family farmers are: low access to labor, knowledge and capital required to establish and management complex systems, access to markets and processing equipment for agroforestry products. These factors vary largely according to farmer type. «Marginalized farmers", who are more resource-constrained and have less access to policies, require more capacity-building, extension services and credit for initial establishment costs, whereas «organized" family farmers and medium-sized farmers (such as CAMTA) have higher access to knowledge and key policies such as credit, as well as labor and machinery, with systems becoming increasingly simpler and dependent on external chemical inputs. Given these constraints, upscaling will require, at initial establishment, mingling relatively smaller high biodiversity plots with simpler systems on larger plots that can be enriched gradually. Expansion of biodiverse systems with agroecological management practices will also depend on costs of inputs and market factors. Across all farmer types surveyed, key motivations for adopting diversified systems include: greater resilience to market risks and fluctuations, adaptation to climate change, and optimization of scarce labor and land. This study is part of the project *SAF Dende: Oil Palm Diversification: reconciling conservation with livelihoods*, an alliance between NATURA, EMBRAPA - Brazilian Agricultural Research Company, CAMTA, a farmer cooperative, and ICRAF - the World Agroforestry Centre, with support from USAID, in Tomé Açu, Pará State, Brazilian Amazon.

Keywords: oil palm agroforestry, biodiverse, scaling, Brazil, SAF Dendê.

L08_O.10

Sustainable grazing options for enhancing accelerated scaling ups and impacts of agroforestry innovations in Ethiopia

Fantaye S. K.[1] (selamawitsole@yahoo.com), Hadgu K.[2], Birhane E.[3], Haile M.[3], Muthuri C.[4], Mowo J.[4], Georgis K.[5], Negussei A.[6]

[1] *Addis Ababa Institute of Technology, Addis Ababa University, Addis Ababa, Addis Ababa, Ethiopia*; [2] *World Agroforestry Center (ICRAF), Addis Ababa, Addis Ababa, Ethiopia*; [3] *Mekelle University, Mekelle, Tigray, Ethiopia*; [4] *World Agroforestry Center (ICRAF), Nairobi, Kenya*; [5] *Ethiopian Agricultural Research (EIAR), Addis Ababa, Ethiopia*; [6] *WeForest, Ethiopia, Mekelle, Tigray, Ethiopia*

The culture of livestock free grazing has been practiced for long time in Ethiopia. However, the livestock free grazing has been posing a major threat on agroforestry because the livestock has been freely grazing trees and crop residues on farm which led to deforestation, soil degradation, and nutrient depletion and environmental degradation, at large. Hence, the free grazing contributed to low adoption and scaling up of agroforestry in the country. This, in turn, led to declining overall agricultural production systems. To address these challenges, the Ethiopian government developed and implemented several rural development strategies and programmes which aimed to restrict free grazing practices and to improve tree-crop-livestock production systems. However, the initiatives failed to address the problem of free grazing. To understand the context specific challenges and sustainably address the existing free grazing problem while facilitate accelerated adoption and scaled up of agroforestry, a study was done in Ethiopia through conducting field assessments, interviews and discussions with farmers, religious and informal institution leaders, policy makers and experts; reviewed different documents and complied the opportunities and gaps of the existing policies, institutions and technologies on grazing systems and management; and experimental trials were also done to test and identify best grazing technologies and management options. The result showed that there are major constraints on the existing policies and institutions including lack of grazing land use policies, less clarity on tree tenure security, weak institutional set up, weak coordination among key stakeholders and top-down extension approaches without considering varying resources and contexts at different levels. The study also identified technological challenges including shortages of livestock feed and better breeds, limited availability of feasible and best-fit technologies coupled with a culture of keeping high number of livestock per household and production systems. This is aggravated by lack of knowledge and improved skills coupled with low motivation of local experts contributing to low adoption and scaling up of agroforestry. The study concludes that free livestock grazing problem can be sustainable addressed through understanding and building to existing farmers circumstances, and varying contexts. This helps to design best fit sustainable grazing options and improving informed decision-making for enhancing adoptions and scaling ups of agroforestry practices in the country. This study underlines that sustainable grazing options are very important for improving agricultural production and livelihoods of smallholder farmers, and creating resilient ecosystems and societies in Ethiopia.

Keywords: Free grazing, Policy and Informed Decision-Making, Livestock, Resilient Ecosystems and Societies, Local Capacities and Institution.

L08.P.01

Agroforestry and sustainable cocoa production: experience of CEMOI through its sustainability program Transparence Cacao

Assiri A.[1] (a.assiri@cemoi.com), Munoz J.[2]

[1] *Développement Durable, CEMOI Côte d'Ivoire, ABIDJAN, Côte d'Ivoire*; [2] *Développement Durable, CEMOI, Perpignan, France*

CEMOI, the first French chocolate company, has initiated since 2016 a program for sustainable development of the cocoa sector in Côte d'Ivoire. This program called «Transparence Cacao» is implemented in partnership with Le Conseil du Café-Cacao. The program involves 30 farmers organizations. It aims to transform the rural environment by favoring the emergence of professional farmers and cooperatives which integrate the quality of cocoa and the preservation of the environment in their activities. Thus, various activities are carried out by CEMOI and technical partners in four priority areas which are:
- the improvement of aromatic quality of cocoa;
- the traceability of supplies;
- the professionalization of producers and their organizations;
- the agroforestry - environment.

Under this last axis, an inclusive and structured approach has been adopted by CEMOI. Five agroforestry systems were first defined with a list of 24 forest species by capitalizing on previous achievements, but also taking into account the needs and perceptions of producers. To ensure the availability of seedlings of these species and to facilitate their accessibility to producers, two to four nurseries men have been trained and installed per cooperative. Resource centers have also been set up to supply nurseries men with plant material for their nurseries. In the field, to demonstrate the proposed models and train farmers to adopt them as good agricultural practices for improving the productivity and sustainability of cocoa farms, a dozen pilot plots are set up per cooperative. Training is provided by two to four agents trained per cooperative.

At the community level, a social and environmental responsibility committee has been set up in each cooperative. In addition, an agroforestry innovation platform has been set up to engage all key stakeholders (agents of cooperatives, representatives of communities, traditionnal and administrative authorities, ..) in raising awareness among producer communities. To evaluate the overall performance of the strategy, a land use map of the program area was delopped at the beginning of the program. Then, a periodic monitoring of the forest cover is carried out. A mapping of cocoa orchards is also carried out in order to locate them in relation to the classified forests and other protected areas. These data are also used to know the origin of the cocoa purchased.

By 2022, a capitalization of achievements of the program and a scaling up of the approach are planned.

Keywords: Cocoa, Agroforestry, Sustainability, Technical itineraries.

L08.P.02

Preservation of shea resource through the transfer of shea plant regeneration techniques to the female producers

Bastide B.[1] (bastidebrigitte30@gmail.com), Ouoba H.[2], Zerbo L.[1]

[1] *Department of Environment and Forests, INERA, Bobo Dioulasso, Burkina Faso*; [2] *UFR-ST, Nazi Boni University, Bobo Dioulasso, Burkina Faso*

In Burkina Faso, the exploitation of shea fruits is an opportunity to reduce rural poverty and offers a path for development in the country. But the shea stands are degradedthe potential is exploited without any concern for the safeguarding and renewal of the resource. Since 2013, INERA is implementing projects aimed at sustainably increasing women's access to shea nuts by providing them with technical means to conserve and restore shea parks. From 2015 to 2018, 1,460 women from 21 villages in southwestern Burkina Faso have been trained in 8 techniques of regeneration and shea management. They then trained 1,184 women from their villages. A survey conducted in 7 «control» villages focused on the expected contribution of regeneration techniques to stand density and the prospects for adoption and application of techniques by populations. Sowing and planting are positive in the fields, slightly less in shrub savannas, and negative in tree savannas. Protection against fire and livestock applied to the introduced or spontaneous regeneration is the most efficient technique. Regeneration appears to be the first option for women's sustainable access to the resource. However, difficulties with the application of certain techniques and the risks of conflict were noted. The future application of the techniques for a renewal of stands will depend on the common will and the interest that the populations bring to the restoration of the shea parks.

Keywords: shea park, Burkina Faso, women, tree regeneration, forest techniques.

L08.P.03

Are silvopastoral systems in Poland sustainable? Case study of beef cattle farm

Borek R.[1] (rborek@iung.pulawy.pl), Wawer R.[2]

[1] *Dpt. of Bioeconomy and Systems Analysis, IUNG-PIB, Puławy, 24-100, Poland*; [2] *Dpt. of of Soil Science, IUNG-PIB, Puławy, Poland*

Extensive silvopastoral systems, using wooded or abandoned lands can be an alternative for small and medium-sized farms. It offers animals protection, delivers high-quality beef (the case of beef cattle farming) and woody biomass at the same time. We present here financial and environmental effects of silvopastoral beef cattle farm. The case study is 200 ha organic farm in Beskid Mountains, and situated in very diversified landscape, consisting of open and wooded grasslands and forest of different age. Grasslands are planted partly with hedgerows and fruit trees. Beef cattle is kept in rotational system of field use, involving grazing and mowing. Wood is harvested for heating of farm buildings as well as for sale to local buyers. In order to assess cost effectiveness of land use, FarmSAFE spreadsheet model has been used to compare net margins, net present values, infinite net present values, equivalent annual values and labour requirements for forestry, pasture and silvopastoral systems. The adaptation of locally relevant silvopastoral systems is explored by analysis to examine resource use efficiency. Two spatial regional scenarios are assessed in aspect of their environmental and economic influence in the farms. GIS tools are used to carry out analysis. For environmental assessment spatial indicators of erosion risk, soil hydrology, landscape diversity and micro-climate were applied.

Keywords: Silvopasture, profitability, Land use efficiency, Landscape, Ecosystem services.

L08.P.04

How agroforestry systems affect production, management, environment and socioeconomy according to Italian stakeholders

Camilli F.[1] (f.camilli@ibimet.cnr.it), Pisanelli A.[2], Seddaiu G.[3], Paris P.[2], Franca A.[4], Rosati A.[5], Marchi V.[1]

[1] *Institute of Biometeorology, National Research Council, Florence, Italy*; [2] *IRET, National Research Council, Porano, Terni, Italy*; [3] *Dept. of Agricultural Sciences, University of Sassari, Sassari, Italy*; [4] *IS-PAAM, National Research Council, Sassari, Italy*; [5] *CREA-OFA, Consiglio per la ricerca in agricoltura, Spoleto, Perugia, Italy*

The perspectives of local stakeholders (SHs) are critical in any research and policy making process (Sereke 2016). In order to know the opinions of Italian SHs on how agroforestry systems (AFS) affect production (P), environmental (E), management (M) and socioeconomic (SE) aspects (categories), an online survey was performed in Apr-Jun 2016. A questionnaire targeted to farmers, policy makers, technicians, researchers, tourism operators was sent to ca 20,000 email addresses. A total number of 652 responses provided respondents' biographical data and their opinions on AFS. The latter were collected through a Likert-type test scheme (Likert, 1932) based on a five-value scale: 5=completely in agreement, 1=completely in disagreement. The average weighted score (AWS) for each item and the mean of the items' AWSs per category were calculated (Fig. 1)

SHs showed more positive opinions on E, SE and P aspects of AFS; lower scores were related to M. A similar trend was observed in a study on the positive and negative perceptions of local SHs on specific AFS in Italy (Camilli et al., 2018). The results seem coherent with findings on European SHs perceptions of AFS (Garcia De Jalon et al, 2018) even if, in this case, also SE issues were perceived more negatively. In this respect, further analysis is necessary also considering the influence on such items of the single target groups of the sample.

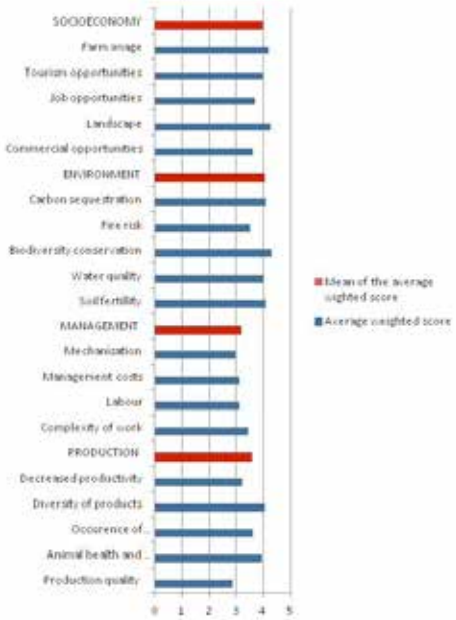


Fig. 1 Responses of stakeholders calculated as average weighted scores of each item (blue bars) and mean of the average weighted scores of items category (red bars)

Keywords: Landscape, Complexity, Bioviversity, Diversity of products, online survey.

References:

1. Camilli et al., 2018, Agroforest Syst, 849–862 ;https://doi.org/10.1007/s10457-017-0127-0
2. Garcia De Jalon et al., 2018, Agroforest Syst, 829–848; DOI 10.1007/s10457-017-0116-3
3. Likert, 1932, Archives of Psychology, 1–55.
4. Sereke et al., 2016, Agroforest Syst, 385–394; DOI 10.1007/s10457-015-9861-3

L08.P.05

Making rural advisory services more climate smart – can community-based approaches help?

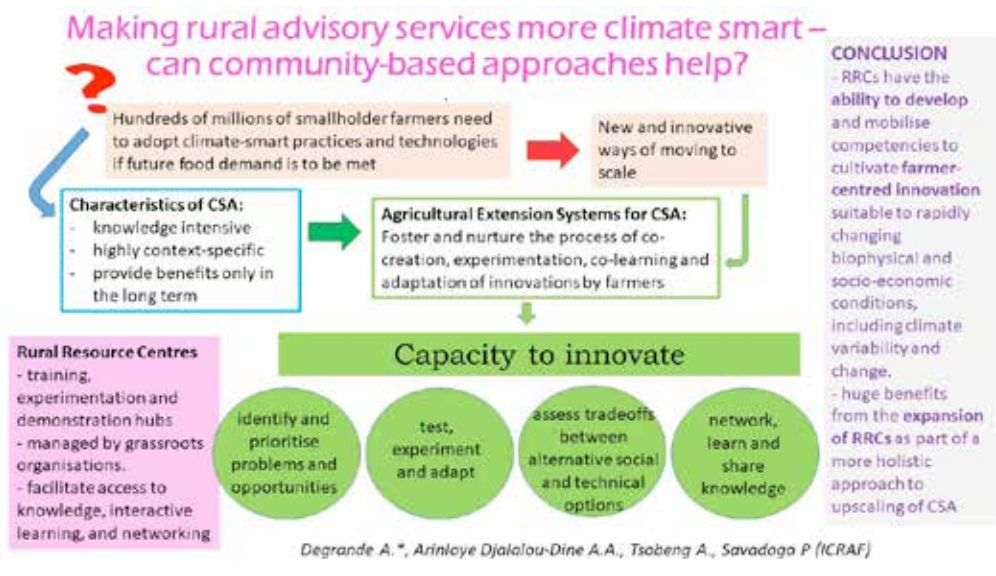
Degrande A.[1] (a.degrande@cgiar.org), Arinloye D.-D.[2], Tsobeng A.[1], Savadogo P.[2]

[1] *West and Central Africa Region, World Agroforestry Centre, Yaounde, Cameroon*; [2] *West and Central Africa Region/Sahel, World Agroforestry Centre, Bamako, Mali*

While the essential role played by rural advisory systems in reducing poverty and hunger is increasingly recognised, agricultural extension in many African countries continues to offer single size interventions that do not take into account the increasingly complex nature of farming systems in the face of global challenges, in particular climate change.

The World Agroforestry Centre (ICRAF) in West and Central Africa, has been experimenting with a novel community-based extension approach, providing a multitude of services and products tailored to farmers' livelihood needs and capacities. Rural Resource Centres (RRC) are training, experimentation and demonstration hubs that are managed by grassroots organisations. Emphasis is put on access to knowledge, interactive learning, and networking among farmers, and between farmers and other actors. RRCs are now used in Cameroon, Burkina Faso, Mali and Chad to disseminate a range of agricultural technologies and practices aimed at building climate change resilience in rural communities.

This paper demonstrates that, through their active participation and direct engagement in the design, evaluation and demonstration of technologies, and partnerships with NGOs, as well as with national and international research institutes and universities, RRCs have the potential to extend complex and innovative technologies, such as climate-smart agriculture.



Extension systems for climate-smart agriculture, including agroforestry, must foster farmers' capacity to innovate

Keywords: agroforestry, agricultural extension, learning, West and Central Africa, resilience.

References:

1. Kenfack et al., 2018, Information Development, doi/10.1177/0266666918754937
2. Takoutsing et al, 2014, IJAEE, doi/abs/10.1080/1389224X.2014.913984
3. Davis et al., 2018 in: What Works in Rural Advisory Services?, GFRAS, 69-72

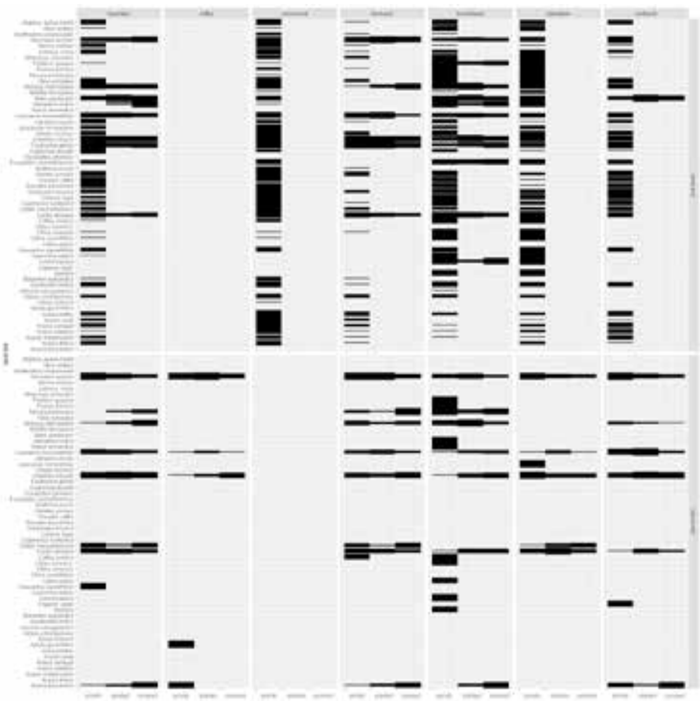
L08.P.06

Farmers seek high tree diversity in semi-arid and sub-humid areas in Ethiopia

Dimenso A. D.[1] (abaynehdd@yahoo.com), Muthuri C.[2], Coe R.[2], Sinclair F.[2]

[1] *EEFRI, Addis Ababa, Ethiopia*; [2] *ICRAF, Nairobi, Kenya*

Background: Increasing tree cover on farms in Ethiopia supports livelihoods and the environment. Most tree-planting schemes rely on a few species.
Aims: We aimed to understand farmers' priorities for tree planting in semi-arid and sub-humid conditions in selected sites in Oromia, Ethiopia and constraints to meeting those demands.
Materials and methods: Farmers' priorities for tree species and planting niches were assessed through focus group discussions. Participatory trials comparing species and on-farm niches were implemented, and seedling survival and growth patterns were evaluated.
Results: Farmers identified a high diversity of tree species for each niche. Most of these are logical but some need exploring further. Fruit species were mainly selected for homesteads. The diversity of desired tree species is much higher than that typically available in nurseries or promoted by projects. Meeting planting demands proved hard as seedling supply does not support diversity. Evaluation of tree survival showed striking differences among species, farms, agroecologies and niches. There was high variation between farmer in survival meaning that local-level risk factors are still not understood.
Conclusion: Understanding farmers' tree species priorities for different niches and designing and implementing participatory trials reveal the diversity needed and should be part of tree supply and planting action. Better understanding of survival risk factors would allow improved management.



Species priorities, trees planted and surviving on-farm niches in two agroecologies of Ethiopia. Line width is proportional to priority, numbers planted and survival rate respectively.

Keywords: agroecology, food security, homestead, on farm niche, priority species.

L08.P.07

Successful experiences to foster and establish agroforestry systems with small farmers in Honduras

Dubon A. (a.dubon10@gmail.com), Sanchez J., Martinez R., Granados R.[1], Diaz J.

Cocoa and Agroforestry, FHIA, La Lima, Cortes, Honduras

Honduras, one of six small countries that join North and South America, with a fast-growing population has 84% non-arable steep hillsides unsuitable for cropping. Tree cover steadily declines as forests and jungle are logged and burnt mainly by shifting agriculture. It has a record climate risk index (1995-2014) together with Myanmar, due to extreme climatic events as hurricanes, flooding and heat waves. Here, it is difficult for unorganized settlers with little education and unsecure land tenure to seek out a subsistence living without further damaging the ecosystem, fueling poverty and migration. In this setting, in 1984 FHIA was created to advance agriculture production via applied research and promoting diversification with high value alternative crops to increase income and quality of life of income-poor rural families and restore and protect the natural resource base. It was natural to pick up on the historical legacy and cultural tradition of cacao-based agroforestry as one of its main programs and create a unique 50-ha demonstration and experimental center; followed in 1996 with a 200-ha a humid tropics agroforestry center in piedmont areas with Canadian government's support. These centers have done research for 30 years in agroforestry and forestry systems, diverse crops and tree species, studied soil conservation practices, nutrient cycling and have an exotic tropical fruit and bamboo collection. This knowledge and technology are the foundation to foster and establish agroforestry systems for the sustainable economic development of small farmers. To promote these agroforestry systems, they should have a fruit or timber component, provide income starting from year one and should be larger than that of traditional activities. Promotion include participatory evaluation of feasibility and commitment, production and partial donation of selected plants, practical training and continuous technical assistance by extensionist. A pioneering integral and sustainable watershed project in 2000 benefited 165 families in the Tocoa and San Pedro river basin with 79 ha of new agroforestry systems, 33 km of hedge or timber trees in rows, 6 community micro hydro-turbines and 550 ecofriendly fire stoves, amongst other activities. Since then close to 20 projects sponsored by international cooperation agencies, private sector and government have ensued with more than 5,000 ha of new agroforestry plantations, 500 certified plantations, some 700 km of hedge or trees in line, around 40 micro-turbines. Reproduction of these models based on cacao and rambutan has occurred spontaneously and the community appropriation of management of the electrical systems and care of tree cover in the suppling water basin is the norm. It has been possible to advance agroforestry production systems with small farmers in Honduras having a strong institutional backing with a clear methodology which requires a medium to long-term commitment.

L08.P.08

Recognition of traditional agroforestry to restore degraded lands in Iran, comparing with the modern systems in India

Esteghamat M.[1] (minaesteqamat@gmail.com), Hegde N.[2]

[1] *PAs and Natural Resource Management, ZIPAK NGO, Tehran, Iran*; [2] *BAIF Development Research Foundation, Pune, India*

Due to changing climate, land degradation, increasing population pressure, and the development of unsustainable land use systems over the last few decades, the natural resources have suffered irreparable damages. Zagros region, located in the arid and semi-arid agro-ecological zone in Iran is one such area, where agricultural production has seldom matched the household needs. The local communities had practiced agroforestry systems since thousands of years, for meeting their basic needs, while restoring the degraded lands, based on their traditional knowledge.

Although extensive research has been carried out on agroforestry throughout the world, little work has been done on improving the systems in Iran so far. Consequently, this research assessed the socio-economic and environmental values of traditional agroforestry systems in the Province of Kohgiluye-and-Boyerahmad located in Zagros region to compare them with the modern agroforestry systems in the world and recommend adaptable systems of agroforestry for Iran. for this comparison, the state of Uttarkhand in India, located at the same latitude of the study area in Iran, with similar geographical and ecological characteristics and also comparative socio-economic condition has been selected.

This study inspected the land-use systems of the pilot areas through Participatory Action Research (PAR), exploring the traditional agroforestry systems practiced by the local farmers and then critical systems and their characteristics were recorded. An inventory was also made on the conservation and socioeconomic significance of the explored systems. For this purpose, a detailed schedule/ questionnaire was prepared and used for interviewing the local community, experts and managers. On the other hand, the modern and traditional agroforestry systems of Uttarkhand in India were reviewed and inspected. Accordingly, strategies for developing sustainable land use systems were recommended for Iran.

The results show that Agro-ecological characteristics can be used as a basis for planning agroforestry systems. Moreover, agroforestry systems in various geographical regions with similar ecological zones, are structurally comparable. It was suggested to improve the productivity through new systems such as “Trees on pastures”, “Multipurpose woody hedgerows”, “Home gardens” and “Multipurpose trees on crop lands”. Finally, constructive solutions for adoption of agroforestry systems and improvement of traditional practices have been proposed for various land-use systems in Iran, including agricultural, range and forest lands which have easy acceptance by local communities. The study also reveals that for improvement of agroforestry systems as a feature of Sustainable Development, there are two basic points: one is application of the power of nature to solve its issues, and the other is use of a complex and sustainable landuse system for nature conservation, which is agroforestry.

Keywords: Traditional agroforestry in Iran, Modern Agroforestry in India, restoration of degraded lands, Agro-ecological zones.

References:

1. Esteghamat M, 2010, Traditional Agroforestry Systems as a Feature of Sustainable Development in Ir

L08.P.10

Farmers' perception and reasons to practice Farmer Managed Natural Regeneration in Semi-arid areas of Tigray, Ethiopia

Kibru T.[1] (tktigana13@gmail.com), Husseini R.[2], Haggar J.[3], Birhane E.[1]

[1] *Land Resource Managment, Mekelle University, Mekelle, Tigray, Ethiopia*; [2] *University for Development studies, Tamale, Ghana*; [3] *Natural Resources Institute, University of Greenwich, Medway, United Kingdom*

Farmer Managed Natural Regeneration (FMNR) is a rapid, low cost and easily replicated approach to restoring and improving agricultural, forested and pasture lands. The study was conducted in low (500-1500 m.a.s.l) and mid (1500-2300 m.a.s.l) agro-ecologies of Tigray region on Farmer's perception on FMNR. Purposive sampling was used to select three peasant associations (PA's) from each agro-ecology. Simple random sampling was used to select respondent household heads practicing FMNR. There were 15 respondents from one PA. The total respondents used for the study in both agro-ecologies were 90. All the data required for the study was collected through in-depth household survey and group discussion. Multiple response, Chi-square and means were used to analyse the data. Half of the respondents 38(42.2%) had 21-30 years of FMNR experience. The 15(17%) of the respondents with FMNR experience were from low land and 23(26%) were from mid land agro-ecology. FMNR has been practiced for more than two decades in the study areas. Respondents motivated to practice FMNR due to training from experts in the lowlands 33(37.1%) while in the midland 26(29.2%) their motivation was neighbours success. In the lowland 44(49%) respondents main reason to practice FMNR was fuel wood and fruit collections while in the midland the main reasons were for fuel wood collection 45(50%), soil conservation 42(47%) and 42(47%) fodder. The result shows that FMNR has the potential in improving income of households and supports the households especially in providing fuel wood, food/fruits, construction materials and farm equipment's.

Keywords: Agro-ecology, Farmer managed natural regeneration, Lowland, Midland.

References:

1. Francis, R., Weston, P., Birch, J. 2015.
2. Haglund, E., Ndjeunga, J., Snook, L., Pasternak, D. 2011. Environmental management 92: 1696-1705

L08.P.11

Options for improving smallholder's contributions to off-reserve landscape restoration in Ghana

Kumeh E. M. (ekumehmensah@gmail.com)

Hans-Ruthenberg Institute, University of Hohenheim, Stuttgart, Germany

Smallholder plantation forestry is on the decline in Ghana because most smallholder efforts have resulted in mixed outcomes in terms of plantation success and economic returns. Meanwhile, plantation forestry presents an opportunity to address livelihood needs and lessening the impacts of climate change on rural households. To reap these benefits, Ghana has plans to establish 25,000 ha of forest plantation per annum. At present, smallholders do not seem ready to engage in this plan. Based on case studies in three forest districts, this study explores: (i) mechanisms by which smallholders integrate forest plantations in their production systems, (ii) their motivations for doing so, (iii) incentives available to them and (iv) barriers to their operations and options for addressing these barriers for effective smallholders' participation in national plantation development efforts. The findings reveal mismatches between smallholders' motivation for engaging in plantation forestry and their current agroforestry practices. A situation exacerbated by limited availability of support systems to smallholders engaged in plantation forestry. The study recommends the urgent need for investments in relevant support systems, including forestry extension to prop up smallholders' efforts.

A farmer exhibiting his Cedrella odorata planted as hedgerows in his cocoa farmer in Ghana

Keywords: Smallholders, Trees on farms, Plantation forestry, Incentives.

References:

1. Hirons, M. et al, 2018, Land Use Policy, 2018, 405–413.
2. Oduro, et al, 2018, Small-Scale Forestry, 2018, 393–410.
3. Warman, R.D., 2014, Biodiversity Conservation, 1063–1078.
4. Szulecka, et al. 2014. International Forestry Review, 128 – 143.
5. Lamb et al. 2005, Science, 31:1628-1632.

L08.P.12

Local knowledge promotes design of adaptive land restoration options that deliver multiple ecosystem services at scale

Kuria A.[1] (A.Kuria@cgiar.org), Pagella T.[2], Winowiecki L.[1], Mitiku H.[3], Sinclair F.[1]

[1] *Systems Science Theme, World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [2] *School of Natural Sciences, Bangor University, Bangor, Gwynedd, United Kingdom*; [3] *Land Resource Management, Mekelle University, Mekelle, Ethiopia*

The increasing global demand to produce more food to support a rapidly growing human population has resulted in adverse ecological effects including land degradation, which threatens the livelihoods of smallholder farmers. In Ethiopian drylands, the effects of land degradation are more severe due to prolonged drought. Although smallholder farming systems are heterogeneous and dynamic, conventional land restoration technologies have focused on promoting few blanket restoration technologies informed by coarse-resolution assessments, rather than customizing technologies to local context. This has resulted in technologies not being locally adapted and effective, thus leading to low adoption of restoration options which leads to continued land degradation. We explored the role local knowledge can play in adapting land restoration options to local context and farmer circumstances. Local knowledge was elicited and analyzed through systematic knowledge-based systems approach (AKT5), on 95 smallholder farmers. Three catchments at different status of restoration were selected through paired catchment design in Samre, Northern Ethiopia. Results showed that farmers had an in-depth understanding of land degradation drivers, processes and effects across four scales namely regional, national, landscape and farm level. Farmers viewed land restoration as rehabilitation of already degraded land, and not prevention of degradation of non-degraded land. This reveals knowledge gaps, which should be addressed to ensure restoration interventions are locally understood and accepted. Farmers reported that some restoration approaches involved conversion of one land-use category to another, which calls for adaptive management approaches. Farmers' knowledge about land degradation and restoration varied with catchment, land-use categories and stakeholder categories. Farmers identified 12 contextual factors that influence the suitability of land restoration options to local context. Biophysical factors were soil erosion type, soil type, soil depth, slope of the field, field location along a slope and field size. Socio-economic factors were: livestock management system, land tenure system, labour, gender, technology and skills. This study also demonstrated that through their own experimentation and observations, farmers utilized their local knowledge to adapt and modify land restoration interventions to suit their needs and context. Hence the acquisition and analysis of local knowledge provides an effective mechanism to track iterative development of adaptation measures and to evaluate both positive and negative consequences resulting from these actions. Combining local and scientific knowledge can help to design, implement and monitor the performance of land restoration technologies to ensure successful scaling of locally adaptive, appropriate and effective restoration options which promote the delivery of multiple ecosystem services for diverse stakeholders at scale.

Keywords: local knowledge, land degradation, restoration options, context, scale.

L08.P.13

From diagnosis to scaling of Agroforestry Systems: lessons learned from case studies in Brazil using the PLANTSAFS tool

Miccolis A.[1] (a.miccolis@cgiar.org), Marques H. R.[2], Peneireiro F. M.[3]

[1] *World Agroforestry Centre - ICRAF Brazil, Belém, Pará, Brazil*; [2] *World Agroforestry Centre - ICRAF Brazil, Brasilia, Distrito Federal, Brazil*; [3] *Mutirão Agroflorestal/ICRAF Brazil, Brasila, Distrito Federal, Brazil*

Designing agroforestry options tailored to the local context requires first assessing the key constraints and potentials in that situation, including biophysical characteristics, livelihoods strategies and access to resources, policies, and markets. Through a dialogue between farmers, technicians and local development agents (Miccolis *et al*., 2017), this study used a tool developed by ICRAF Brazil: PLANTSAFS – Planning and Evaluation for Decision-Making in Agroforestry Systems (AFS). Based on 40 indicators, the tool gauges farmers' access to different types of resources considered important for the long-term adoption and success of agroforests. Divided up into 6 main categories: human, social/political, physical, financial, environmental, and production systems, these indicators are scored on a scale of 1 to 5 and are explained by qualitative data from interviews. The tool was applied by ICRAF and partners in five different contexts in Brazil with the aims of: a) establishing a baseline for monitoring b) proposing improvements and agroecological management practices, c) providing guidance for designing new systems, and d) providing inputs to wider development interventions and proposing systems most suited to that regional context. Based on an aggregate analysis of these five case studies, we draw out lessons for increasing the adoption and success of AFS. The high degree of variability in key indicators between farms in the same context, i.e. where farmers have access to similar training, germplasm, and biophysical conditions, suggests that the human factor is determining to overall performance, and that systems design should be tailored to each family/farm. The main constraints to upscaling common to all five contexts were: low access to knowledge (extension) and labor for establishing and managing the agroforests, particularly more complex, biodiverse systems; low use of biomass-producing species to maintain nutrient cycling and soil conservation , leading to lack of mulch at key moments and decline of systems, lower availability of water at the farm level due to climate factors, and insufficient access to germplasm. Scant rural credit for agroforestry and farm equipment also occurred widely but varied significantly among farmer types. Overall, the more biodiverse systems tended to score higher in key indicators, especially food security, marketing, environmental indicators, and in avoiding drivers of degradation. Upscaling agroforestry in these contexts will thus require investing in capacity-building, strengthening value chains for key products, and supporting germplasm supply. In addition to farmer objectives, key considerations in species selection across contexts should be labor requirements, marketing opportunities and biomass production, ensuring that stories are occupied in different cycles, as well as resilience to climate change, particularly droughts.

Keywords: scaling, agroforestry, PLANTSAFS, Brazil, diagnosis.

References:

1. DFID, 2011. Sustainable Livelihoods Guidance Sheets. 10 pgs.
2. Miccolis, A. et al, 2017, Ecological Restoration through Agroforestry Systems, ICRAF, 266 pgs.
3. Miccolis, A. et al., 2017, Experimental Agriculture, p 1-18. doi:10.1017/S0014479717000138

L08.P.14

The European Agroforestry innovation Network Fostering agroforestry in Europe

Mosquera-Losada M. R. (mrosa.mosquera.losada@usc.es)

Crop production and Project Engineering, Univ. Santiago Compostela, Lugo, Lugo, Spain

AFINET is a European Union funded project which overall objective of AFINET is the promotion and innovation of European Agroforestry (AF) through the development of a multi-actor interactive and innovation-driven network, based on successful sharing of practical experiences and existing research knowledge, applied to different contexts, climates and agricultural sectors. AFINET will modify AF systems design and management in order to increase the agricultural systems production and profitability to promote a sustainable land management throughout Europe. AFINET networking is based on nine Regional Innovation Networks in the nine countries where it is based where over 300 stakeholders meet every six months. AFINET first meeting aimed at asking farmers which are the main challenges to foster agroforestry in Europe. Among all, challenges could be summarized in four main topics: technical, economic, education and policy. Solutions to these challenges were discussed with all stakeholders and a provisional list of innovations was produced that has been validated in the third RAIN meeting. Innovation topics can be seen in Table 1 and the technical challenge can be grouped in several clusters: Livestock management, Lower story management, woody perennials management and horizontal innovation clusters for the technical challenge.

INNOVATION TOPICS			
Alternative use of woody component (7)	Economic analyses (2)	Lower story adaptation (1)	Recreation (3)
Animal feeding (1)	Farmers cooperation (2)	Lower story management (4)	Regular education (1)
Animal welfare (1)	Farming systems (7)	Lower story varieties (1)	Restoration (1)
Biodiversity (1)	Fertilization (1)	Lower story quality (1)	Soil management (2)
Climate change (3)	Fire risk (1)	Marketing (7)	Tree fodder (3)
Consumer education (2)	Forest management (1)	Medicinal plants (2)	Tree management (3)
Continuous learning (13)	Forestry (1)	Mushrooms (2)	Woody perennial varieties (2)
Design (9)	Hedgerows (3)	Protectors (1)	
Digitization (1)	Irrigation (1)	Pruning (5)	

List of AFINET innovation topics

Keywords: innovation, afinet, technical, education, policy.

L08.P.15

Extension approaches to promote effective adoption of agroforestry practices: Lessons learned from Indonesia

Muktasam A.[1] (muktasam03@yahoo.com), Reid R.[2], Race D.[3], Perdana A.[4]

[1] *University of Mataram, Research Center, Mataram, Nusa Tenggara Barat, Indonesia*; [2] *, Australian Agroforestry Foundation, Melbourne, Victoria, Australia*; [3] *The Tropical Forests and People Research, University of Sunsine Coast, Sunsine Coast, Queensland, Australia*; [4] *World Agroforestry Center, Bogor, West Java, Indonesia*

There are commonly two main reasons why agroforestry is a popular topic discussed in the context of rural development. Firstly, agroforestry is often seen to offer a balance between conservation and production in farming systems to provide socio-economic and ecological benefits, rather than either conservation or production systems in isolation. Secondly, agroforestry encourages smallholders to diversify enterprises and create resilient farming systems. Yet there is a gap between "the ideal" adoption of agroforestry and "the fact" that it is seen by many as difficult to optimise and not widely adopted. Government policies relating to building food security in developing countries,such as in Indonesia (where farmers are encouraged to grow rice and corn), still tend to lead to encroachment into forest areas and specialised farming systems geared towards maximising yields of commodity crops. This focus on agricultural production alone has led to severe land degradation including the erosion of farm soils and the siltation of rivers, the drying up of springs, and loss of lives, housing and other infrastructure due to severe flooding. Two research and development projects have been exploring an innovative approach to enhance extension efforts so that agroforestry is more widely understood and adopted by smallholders in Indonesia. This presentation (and associated papers) will discuss the design of the alternative extension approach used by the two projects, discuss the evaluation data collected about the learning impact of the extension approach and the implications for the adoption of agroforestry in Indonesia. The presentation will conclude with the key elements that have been identified about the innovative approach to agroforestry extension among smallholders, which include: close involvement of the local community; capacity building of smallholders' local institutions; framing the advantages within the local market context; and forging strong partnerships between smallholders, industry and government.

Keywords: Rural development, extension, agroforestry, adoption, sustainable farming.

L08.P.16

Strengthening Rural Resource Cenres as Local Practices: Simple and Smart Ways for Enhancing Scaling up of Agroforestry

Niguse Hagazi G. (n.hagazi@cgiar.org)

Ethiopia office, ICRAF, Addis Ababa, Ethiopia

Adoption and scaling up of simple and smart agroforestry practices in degraded areas such as Ethiopia plays key roles in enhancing productivity and resilience of agricultural systems and ecosystems while improving livelihoods of local communities. However, ecosystems and agricultural areas in Ethiopia are threatened by major challenges including land degradation, climate change, free livestock grazing and population pressure. This leads to declining ecosystem health, yield variability, crop failure and food insecurity. This also contributes to low buffering capacities of the local community with increased proneness to climate shocks. A study was, thus, conducted in Ethiopia to identify the key underlying drivers contributing to the problems, and explore best-fit, simple and smart agroforestry technology and scaling approaches. Survey methods substantiated by satellite image analysis were used to understand the Land Use and Land Cover (LULC) dynamics over time and their associated impacts. A multi-scale analysis approach was also used to analyse the data. The result indicated that Rural Resource Centre (RRC) approaches which built on and strengthened local practices were best fit, simple and smart options for enhancing accelerated scaling up of agroforestry practices in Ethiopia. The approaches also contributed to improved restoration of degraded landscapes (by 78%); gully reclamation (by 82%); four fold increase of vegetation cover (e.g., species density increased from 970 to 3310 individual plants ha-1); more honey bee production (from 5 to 75 kg hive-1 year-1); improved year round water availability (e.g., reduced women's travel distance to fetch water from 5 to 1.5 km); increased feed availability (from 3 to 7 months year-1); more rural employments and better income (above the poverty line household-1year-1). Adoption and scaling up of agroforestry contributed to improved overall positive (<0.05) LULC changes, soil fertility (P< 0.01), and higher crop yields (P<0.05). The results of this study provide evidences and insights on best-fit, simple and smart scaling up approaches for supporting design of informed policy- and decision-makings important for enhancing accelerated scaling up of agroforestry practices at national and regional levels.

Keywords: Land Use Land Cover Change, Informed Policy- and Decision-Makings, Productivity, Resilience, RRCs.

L08.P.17

A Proven Evidence of Rural Livelihood Transformation and Poverty Reduction in Ghana: Case of Cocoa Agroforestry System

Nunoo I.[1] (nunooisaac85@yahoo.com), Fromm I.[2]

[1] *Agric Economics, Agribusiness & Ext, Kwame Nkrumah University of Sci. & Tech, Kumasi, Ghana*;
[2] *Agricultural, Forest and Food Sciences, Bern University of Applied Sciences, Bern, Switzerland*

In Ghana, the cocoa sector employs over 800,000 smallholder farm families and contributes around US$2 billion in foreign exchange. It is an essential component of rural livelihoods and it's considered a 'way of life' in rural communities. The countries food security status is under threat due to the declining of per capita farm income and land and soil degradation. Between 2005 and 2010, the rate of deforestation was estimated at 2.19% per annum. On average, cocoa land area increases by 30,000 hectares annually with no evidence of decline. Also no shade cocoa systems have become the new cocoa production system with rich natural forest is rapidly giving way to cocoa farms. There is a knowledge-gap on understanding interactions between native tree species and cocoa yield as well as empirical evidence on this matter. The research therefore aims at determining the yield trends in cocoa under different forest-tree levels. Multi-stage sampling techniques were employed to selected 200 cocoa farmers in the Western Region of Ghana. Descriptive statistics and inferential analysis were used to analyze the data. A yield curve model was also adopted to determine the yield trend for various cocoa agroforestry systems. From the analysis, the R square values obtained under the no shade, low shade, medium shade and heavy shade were 77%, 61%, 53% and 56%, respectively. The highest average yield per hectare was attained for the no shade in year 16 (794 kg ha-1), for the low shade in year 22 (696 kg ha-1), for the medium shade in year 19 (735 kg ha-1) and for the cocoa under heavy shade in year 15 (546 kg ha-1). The no shade system showed the highest yield but there was a sharp fall in the yield compared to the low to medium systems. The conclusion of the study is that, although the no shade cocoa system has higher yields, it is input demanding, environmentally unfriendly and has a short productive life. Therefore, cocoa agroforestry system can be regarded as a win-win practice as it can support sustainable income of farmers with long years of cocoa yield, mitigate climate change and contribute to adaptation to these changes. With sustainable yield over time as a result of the cocoa agroforestry systems, the country benefits immensely and could contribution greatly to the GDP as well as improve livelihood of poor cocoa farming households. This therefore calls for the need to create an institutional system, tools and policies to rehabilitate the cocoa landscape; conserve and expand forests, forest buffer zones and corridors and incentivize cocoa farmers to adopt cocoa agroforestry system since it is an environmentally friendly practice.

Keywords: Cocoa agroforestry, Deforestation, Ghana, Livelihood, Poverty Reduction.

L08.P.18

Utilization of electronic data collection approach in managing scaling-up of agroforestry options in smallholder farms

Nyaga J.[1] (J.Nyaga@cgiar.org), Mukaralinda A.[2], Galabuzi C.[3], Wondwossen G.[4], Ndayambaje D.[5], Seid H.[6], Kimenya G.[7], Mujawamaria P.[2], Kinuthia R.[1], Kuria A.[1], Okia C.[7], Kiros H.[6], Muthuri C.[1]

[1] *World Agroforestry Centre, Nairobi, Kenya*; [2] *World Agroforestry Centre, Kigali, Rwanda*; [3] *NAFORRI, Kampala, Uganda*; [4] *EEFRI, Addis Ababa, Ethiopia*; [5] *RAB, Kigali, Rwanda*; [6] *World Agroforestry Centre, Addis Ababa, Ethiopia*; [7] *World Agroforestry Centre, Kampala, Uganda*

The exercise of data collection is indispensable to the Trees for Food Security II project where research is evidence-based and dependent on information collected from farmers. The project is managed by ICRAF offices at country level (Ethiopia, Uganda and Rwanda) in collaboration with respective development partners. Open Data Kit (ODK) which is a suit of methods that allow data collection using mobile devices, transmission and aggregation of data to an online server was adopted as a way of improving data quality with an aim of providing timely, credible and useful results and recommendations for the farmers. Now in the second year, we had a chance to analyze challenges and opportunities associated with the decision. The challenges observed are; 1) the process of developing questionnaires to be used is time consuming at the initial stages of the project, 2) availability and project awareness amongst the enumerators from partner organization, 3) technological awareness on how to fill the questionnaires and submit data, 4) data sharing concerns in terms of ownership and quality checks, and 5) time lapse between implementation and monitoring of project activities. However various opportunities in use of electronic data collection have been scouted in the project and include; 1) collecting research data in the geographically dispersed environment requires minimal coordination to ensure completeness, accuracy, and timely transmission of the data, 2) electronic systems allow use of transparent decision and improved data entry and data integrity, 3) can be integrated with webform option which can allow desktop data entry for data collected using paper format, 4) timely data analyses become possible which can inform the project early enough on key indicators for improving the process, revising project objectives or adding new ones from the observations, and 5) data archiving is improved and data losses minimized. In conclusion, use of electronic data collection offers a good opportunity for managing project involving multiple organizations with respective staffs as it allows centralization of the science at timely and cost-effective way. However, we observed significant challenges associated with the process and the study therefore offers a great insight into how data collection and monitoring of intercountry projects involving multiple partners can be effectively managed to improve scaling up of agroforestry options.

Keywords: Electronic data collection, Agroforestry, Data quality, Small-holder farms, Eastern Africa.

L08.P.19

Socio-economic impact of farmer managed natural regeneration in the shea parklands of Uganda.

Odoi J. B.[1] (juventineboaz@gmail.com), Gwali S.[1], Odong T. L.[2]

[1] *Tree Improvement and Germplasm Research, National Forestry Resources Research Ins, Kampala, Uganda*; [2] *Crop Production, Makerere University, Kampala, Uganda*

Farmer Managed Natural Regeneration has been linked with low-cost land restoration technique used to combat poverty and hunger amongst smallholder farmers by increasing food and wood resource production and resilience to climate change impacts (Raij 2016). Here we discuss how smallholder farmers in Uganda's shea parklands practice and benefit from farmer-managed natural regeneration of woody species in their fields. Shea nut tree (*Vitellaria paradoxa*) *Karité* (in French) is a commercially useful indigenous fruit tree species found within Sudano-Sahelan Africa. Shea tree provides fruits, chocolates, oils, income, cosmetic and medicinal ointments, hair cream, soaps illuminant and water proofing materials, fuels protein and minerals that subsidize household food and nutrition during the hunger season and various services (Jasaw *et.al.* 2015). Households earn between US$50 and US$150 annually from the sale of such products. It also plays an important contribution in nutrient recycling when the leaves and fine roots decompose. The shea tree parklands result from naturally occurring individual trees that are protected by farmers when clearing their fields, thus creating parkland systems (Boffa *et al*., 1996). Farmers in the Uganda's shea parklands practice FMNR (77%) of economically viable woody species on farm resulting on realized increased profit per unit area over time. Although most of these species are found scattered on the farmland (67%) due to sporadic distribution and farmer random selection methods (Gwali et al., 2011), there is increasing woody species population on farm over the last ten years (74%). This is due to the established additional supportive instruments (bi-laws) that bans cutting and burning the species for charcoal. Seventeen (17) different crop types were registered to be intercropped with shea trees among which beans (30.4%); cassava (24%); maize (10.4%); sorghum (8.5%) and finger millet (4.9%) were the major crops reported to be mostly intercropped. These food crops are preserved for use even during dry seasons for food security. Meanwhile Combretum, Acasia; Terminalia; Albizia species; *Grewia molle* and *Vitex doniana* are some of the commonly naturally regenerating tree species that grow with shea trees within the parkland.

Keywords: Shea, Parkland, Natural regeneration, socialwelbeing, livelihood improvement.

References:

1. Reij 2016. BioTROPICA. Doi.org/10.1111/btp.12390
2. Boffa et al., 1996. In agroforestry systems. Non-wood Forest Products 9. Roma: FAO, 110-122.
3. Gwali et al., 2011. Ethnobot. Res. Appl. 9:243-256.
4. Bouvet et al., 2004. Agroforestry systems no. 60: 61-69.
5. Jasaw et al., 2015. Sustainability ISSN 2071-1050 www.mdpi.com/journal/sustainability

L08.P.20

Portuguese Regional Agroforestry Innovation Network: SWOT analysis after two years of establishment

Paulo J. A. (joanaap@isa.ulisboa.pt), Almeida R., Palma J. H. N., Tomás A. R., Tomé M.

Centro de Estudos Florestais, Instituto Superior de Agronomia, Lisboa, Portugal

The AFINET project acts in nine European countries aiming at taking up available research results on agroforestry into agricultural practice. Portugal is one of those countries. One of the main tools developed by the project is the creation, at each participating country, of one Regional Agroforestry Innovation Network (RAIN). For this purpose a multi-actor approach was considered, which is articulated by the figure of the Innovation Broker (IB).
The development of the Portuguese RAIN started in February 2017. In order to guarantee the representation of the aimed stakeholders categories and a broad regional distribution, the registration process to the RAIN was largely announced by several communication channels. In addition, a direct invitation to key stakeholders was also made. Until February 2019 four RAIN meetings have been carried out.
At this mid-point of the project, a SWOT analysis exercise was carried out in order to analyze current results and promote experiences sharing. The results show:
Strengths
– current interest on Agroforestry
– large impact of the available communication channels, in particular social media
– relationship to the EURAF member’s community
– high number of agroforestry systems and practices referred by stakeholders
– awareness of relationships constraints between different stakeholder types
– Innovation broker motivation and collaboration with other project team members
Weaknesses
– small impact at the national policy level
– practical constrains to increase the implementation of activities covering a broader geographical distribution area
– lack of expertise regarding all of the referred topics, demanding a significant increase of time to tackle them
Opportunities
– using the RAIN as the network for future projects related to the Agroforestry topic
– increase communication of scientific knowledge from science to practice
– establishment of new experimental and demonstration trials in collaboration to farmers
– basis for the creation of a national Agroforestry association.
Threats
– lack of funding for RAIN activities sustainability after 2019
– large scope of subjects approached by the RAIN members, that implies a reduction of the fraction of topics considered in total and increases the demand of funding for future activity
– concentration of efforts in already well established and recognized agroforestry systems in Portugal
– lack of institutional awareness to the agroforestry concept (forest and agriculture usually approached like two separate topics).
The importance of establishing thematic networks in Portugal is evident, and stakeholder’s engagement has been remarkable along these two years. The maintenance and amplification of the RAIN activities to a larger percentage of topics requested my RAIN members are the main challenges still in need of further reflection. This is only possible with the involvement and colaboration with other research institutions in order to guarantee a multidisciplinary approach to the raised questions.

Keywords: AFINET, RAIN, Innovation broker, Portugal, stakeholder.

L08.P.21

25 years on. Landholder group validates alternative extension model for fitting trees into the family farming landscape

Reid R. (rowan.reid@agroforestry.net.au), Curry D., Robinson-Koss M., Stewart A.

Otway Agroforestry Network, Birregurra, Victoria, Australia

Since 1993 the Otway Agroforestry Network has been implementing an innovative extension model that has redefined agroforestry and challenged the paradigm that farmers won't grow trees without proven models, direct subsidies and demonstrations. The result is the spontaneous adoption of a multiplicity of unique designs across hundreds of farms; a diversity that reflects that inherent within our community. At the landscape level we have improvements in water quality, biodiversity, economic resilience, carbon sequestration and aesthetics.
Agroforestry development should be guided by landowner needs and aspirations. Our model focuses on: 1. Exploring how trees can address landholder problems, reduce risk (climate, animal welfare, land degradation, biodiversity, diversification, mental health, nutrient retention etc.) and achieve their aspirations; 2. Providing local education for farmers where science and practice are delivered within the context of their interests (e.g. Master TreeGrower[1]); 3. Training, then paying, farmers to act as Peer Mentors to help others design personally-appropriate agroforestry systems; 4. Researching markets and production options for tree products and services; and, 5. Networking with community, government, interest groups and industry.
Charles Massy[2] wrote: "*This organization is undoubtedly the most innovative, constantly evolving and forward-looking farmer-driven agroforestry network in the nation*". This paper tells our story.

Keywords: extension, farmer2farmer, mentoring.

References:

1. R. Reid, 2017, Agroforestry Systems 91(5) pp 847–865
2. C. Massy, 2018, Call of the Reed Warbler, Chelsea Green

L08.P.22

Wildlife conservation and sustainable tree crop plantations call for innovative planting designs

Rival A. (alain.rival@cirad.fr)

CIRAD, Jakarta, Jakarta Selatan, Indonesia

Reforestation experiments and rehabilitation of riparian areas are key in retaining wildlife and improving local ecosystems in plantations-dominated landscapes [1; 2]. In parallel tree crop plantations are increasingly implementing agro-ecological approaches which rely on environmental services [3] thus asking fo planting designs to change and integrate forest species.
In the Sabah state of Malaysia, several groups including members of the PONGO (Palm Oil NGOs) Alliance have restored and reforested riparian areas for more than 10 years using native forest species including pioneer ones that quickly grow a canopy and fruit trees that provide food to wildlife.
In parallel, agricultural practices in plantations are changing as a response to growing social and environmental concerns. Plantation management increasingly relies on agro-environmental services, which means that basic agricultural functions such as soil preservation, pollination, or pest control can be performed by living organisms (plants, insects, microbes…) [3].
Changes in practices will have to involve new planting designs aimed at mixing selected forest species with plantation crops. A series of measurements will help in characterizing both the performance and the resilience of mixed agroforestry systems compared to traditional planting designs. Changes in wildlife diversity and abundance must be monitored together with the impact of agroforest designs on yields and resistance to both biotic and climatic stress

Wildlife is back to reforested riparian areas along Kinabatangan River in Sabah, Borneo island, Malaysia

Keywords: Agroforestery, Riparian areas, Wildlife, Tree crops, Oil palm.

References:

1. Abram et (2014). PloS one, 9(6), e95388.
2. Horton et al. (2018). Earth's Future, 6(8), 1082-10
3. Bessou et al. (2017). OCL, 24 (2017), p. D305, 10.1051/ocl/2017024

L08.P.23

The Regional Agroforestry Innovation Network in Flanders (Belgium): a diverse and dynamic group

Van Colen W.[1] (willem.vancolen@inagro.be), Pardon P.[2], Reubens B.[2]

[1] *Inagro, Roeselare, Belgium*; [2] *ILVO, Merelbeke, Belgium*

The AFINET project is a thematic network dealing with agroforestry across 9 European countries. In Belgium (Flanders), and the other 8 countries, a multi-actor ‘Regional Agroforestry Innovation Network’ (RAIN) was created. The strengths of the Flemish RAIN lie within 1) its opportunity to expose relevant information from other projects to end-users and 2) the diversity of involved practitioners (starting and more experienced farmers), covering a range of farming models (community supported agriculture, organic, non-organic) and systems (arable and livestock). Although this diverse network leads to just as many different perspectives on agroforestry, the need for more information on fruit and nut trees in agroforestry systems was in general identified as the most important challenge during the Flemish RAIN meetings. Building further on this observation, we gradually invited thematic experts to join the RAIN and/or share their expertise by hosting RAIN members on their farm or by presenting their experiences as an invited speaker. Offering information specifically targeting the demands of the stakeholders yielded an active and motivated network. The Flemish network is establishing synergies with other national agroforestry projects and projects abroad (France, Netherlands), and gathers relevant information supported by examples from practice. This information is made readily available to all practitioners, improving the successful implementation of agroforestry in Flanders.

Flemish RAIN meeting in fruit orchard

Keywords: AFINET, participatory approach, knowledge exchange, stakeholders, synergies.

L08.P.24

Barriers to uptake of agroforestry in the UK

Westaway S. (sally.w@organicresearchcentre.com), Smith J.

Organic Research Centre, Newbury, United Kingdom

Agroforestry farming systems are receiving increasing recognition across Europe for their economic, environmental and welfare benefits as we look for ways to sustainably intensify agricultural production and increase resilience to climatic uncertainty. Agroforestry in the UK offers great potential, a few pioneer farmers have developed successful, innovative and profitable agroforestry projects on their land. There is increasing interest in the positive effects of trees on agricultural land, demonstrated by the success of the sell-out first national Agroforestry Conference in June 2017. A 2016 survey (Stocks, 2016) of more than 1,100 farmers asked how trees could benefit them and what the main challenges to future establishment of trees on farms were. Wildlife protection, shelter for livestock, wood fuel and soil protection were the top benefits of trees identified by farmers, with a lack of financial help and advice the main barriers to tree planting. However, the number of people talking about agroforestry doesn't match the number of people implementing new systems. As part of the EU-funded AgroForestry Innovation NETworks (AFINET) project we wanted to find out why and how to help farmers who are interested but not yet doing agroforestry.

To understand the limiting factors and barriers to uptake we created a short online survey. Out of a total 132 responses, 46% were farmers. Barriers to establishing new agroforestry systems were further explored via three multi-practitioner stakeholder workshops. These workshops, held in different locations aimed to get practitioners with a common interest in trees on farms together, build on the survey results and establish a baseline of common bottlenecks to address. The main areas identified matched those from the survey and were:

- A lack of demonstration farms, case studies and pioneers, for experience-based learning, a need to build local networks and partnerships to facilitate this learning.
- A requirement for detailed cost/benefit analysis of different systems, information on the economic implications of introducing trees to farms and grants and funding sources available.
- Access to advice on specific technical and management issues, for example the nutritional properties of tree fodder, efficient and economic tree protection, machinery to harvest tree products efficiently.
- Lack of clarity around what is permitted under cross compliance regulations, what support is available and how this may change. Issues around land tenure and tree planting, how to make the case for trees to landlords.

The interest in agroforestry by farmers in the UK is high, but as evidenced in our practitioner survey and feedback from workshops there are knowledge gaps to be resolved and a need to provide more opportunities for peer to peer learning. Through AFINET we are bridging these gaps to help farmers overcome perceived obstacles to agroforestry for the benefit of their farming business, environment and productivity.

Keywords: agroforestry, barriers, farmers, tree planting.

References:

1. Stocks, Caroline (2016). Farmer Weekly article 21 October 2016. Woodland Trust survey: The benefits

L08.P.25

Service species biomass cost and quantification for self-sustainable syntropic agroforestry in Fazenda da Toca, Brazil

Ziantoni V.[1] (ziantoni.valter@gmail.com), Costa P.[2]

[1] *Agroforestry R&D, PRETATERRA, Timburi, SP, Brazil*; [2] *Agroforestry R&D, PRETATERRA, São Paulo, SP, Brazil*

Syntropic agroforestry seeks self-sufficiency and independence from external inputs, producing biomass within the system through service-plants. The study evaluated biomass quantity and cost-benefit in a citrus agroforestry. Management and ecological features were registered in Jan-Oct, 2017. Dry biomass was measured and extrapolated. Management practices were assessed using PDCA. Time-motion study and management costs were combined with biomass weight and translated into monetary costs of tons/ha. Calibration based on seasonality-productivity-intensity was used to calculate system average production along 20 years life-cycle. Components, densities, arrangements, costs and canopy covering are shown in figure 1. Annual dry-biomass weight and calibration are shown in figure 2. Results showed annual production of 25.78 ton/ha of dry biomass, twice superior to the natural deposition in semideciduous seasonal forests in Brazil. Banana was the most cost-effective, due to the easy management and decomposition of its biomass. Grass shows similar cost but occupies 2.5 times more area. Eucalyptus is the most expensive, due to time-consuming apical-pruning and expensive machinery. Qualitative features of biomass are object of ongoing studies. Understanding service-plants and their comparable productive indicators, will help regenerative agroforestry to prevail over monoculture-chemical based plantations, while giving necessary tools to spread large-scale agroforestry models worldwide.

Species	Main Service	Unit / ha	Arrangement	Cycle (years)	Canopy area (m²)	Covered area / ha	Ton / ha (per year)	Cost / Ton (USD)
(service species used in the citrus agroforestry)		(number of trees per hectare)	in the line x between lines (m)		(total area covered by the summed canopy individual areas)		(calibrated yearly average for the system life-cycle)	Management cost of the production of 1 Ton of dry biomass in USD (Sep. 2018)
Brachiaria brizantha	Biomass	100	-	20	-	0.84	15.91	$ 17.50
Musa paradisiaca	Biomass	476	3.5 x 6.0	18	7.07	0.34	5.55	$ 12.50
Eucalyptus urograndis	Biomass	139	12.0 x 6.0	19	12.57	0.17	4.32	$ 57.50

Figure 1. Overall data of biomass production average in the agroforestry citrus system (20 years).

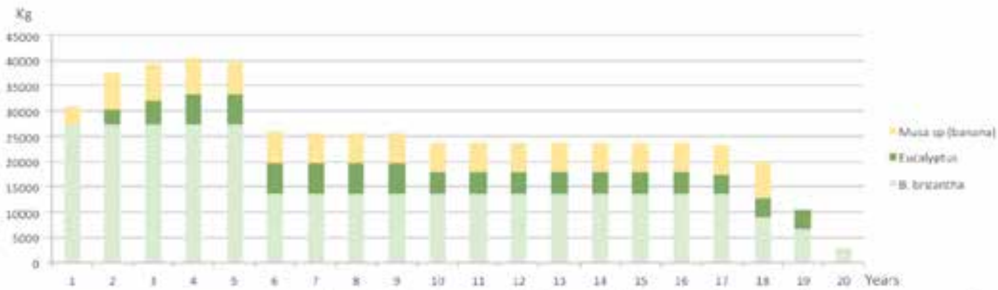


Figure 2. Production per year (in kilograms) of dry-biomass of *Musa paradisiaca*, *Eucalyptus urograndis* and *Brachiaria brizantha during the life-cycle of the system.*

Characterisation and description of the system and general information about biomass production per specie and costs related

Keywords: large-scale agroforestry, regenerative-agroforestry, service-species, syntropic-agroforestry, biomass.

References:

1. Primavesi, in: Manual do Solo Vivo, 2016, Expressão Popular, 35 - 100.
2. Götsch, in: Break-through in Agriculture, 1994, ASPTA, 1 - 15.
3. Steenbock, in: Agrofloresta - Aprendendo a Produzir com a Natureza, 2013, CNPq, 12 - 81.
4. Maezumi, 2018, Nature Plants, 540-547; https://doi.org/10.1038/s41477-018-0205-y

ABSTRACTS

Agroforestry adoption

Adopting the future of land use

- L9 -
Value chains and certification of agroforestry systems and products

Great brands for great lands:
certifying agroforestry products and systems

'Second- and third-party certification systems', 'Participatory Guarantee System' (PGS), 'Internal Control Systems' (ICS): all these voluntary market tools aim to provide a credible guarantee for markets seeking sustainable or legal products. In the case of agroforestry systems, especially with smallholder farmers involved, this guarantee shall be a tool to increase smallholder access to markets. However, often it is seen as a barrier and only appropriate to large scale industrial production. There is a range of certification and verification processes to demonstrate organic or good agriculture practices for food and sustainability for forest-based products. The question is: How to make feasible certification processes for agroforestry based production systems? Researchers or professionals should transfer their agroforestry knowledge and experiences with certification in the forestry or food sector. They should draw on recent certification developments and provide examples of the impacts on livelihoods, incentivising innovation and support of the development of profitable and sustainable agroforestry or 'Trees outside Forests'. Empowerment, active participation of stakeholders, knowledge sharing and relationship building will be the key themes of this session.

L09_O.01

Increasing uptake of agricultural interventions: A case of value chain innovation platforms in Uganda and Zambia

Okia C.[1] (C.okia@cgiar.org), Isubikalu P.[2], Kabwe G.[3], Masikati P.[4], Sekatuba J.[5], Kasonde K.[6], Kimayo J.[7], Oduol J.[7], Hughes K.[7]

[1] *ESAf, ICRAF, Kampala, Uganda*; [2] *Makerere University, Kampala, Uganda*; [3] *Copperbelt University, Kitwe, Zambia*; [4] *ICRAF, Lusaka, Zambia*; [5] *NaFORRI, Kampala, Uganda*; [6] *ZARI, Lusaka, Zambia*; [7] *ICRAF, Nairobi, Kenya*

Smallholder farmers are responsible for most agricultural production in Sub-Saharan Africa but most of them remain poor and marginalized. Efforts have been made to engage these smallholder farmers to increase productivity of their agricultural systems and improve access to markets. Traditional approaches, such as the top-down extension systems have not yielded much. Value chain approaches are emerging to guide economic growth in agriculture. This notwithstanding, opportunities for smallholder farmers especially women to benefit from value chains remains elusive. The World Agroforestry Centre (ICRAF) in collaboration with national and international partners are implementing a project focusing on developing value chain innovation platforms to improve food security in Uganda and Zambia. The project aims to ensure that farmers improve productivity and gain access to better markets through value chain innovation platforms. Through baseline studies and livelihood analysis, the project identified three priority value chains in both countries (coffee, dairy and honey in Uganda, and local chicken, soy beans and Solwezi beans in Zambia) with potential to improve livelihoods of smallholder farmers and with special consideration to women. Three potential models for commercializing smallholder agriculture including linkage with private sector actors, co-financing of critical inputs and boosting productivity have been identified and are being tested for cost effectiveness and fine tuning through planned comparisons. Envisioning of innovation platforms (IPs) and supporting them to develop business plans as well as linkage to financial institutions to access cheaper credit are helping to bridge the farmer's financing gap. Training of IPs in social and technical skills has been undertaken to boost social cohesion and improve collective action. There is increasing appreciation of IPs by government and other stakeholders as a valuable approach for smallholder agricultural transformation and achieving food security.

Keywords: Commercialization, food security, markets, productivity, value chains.

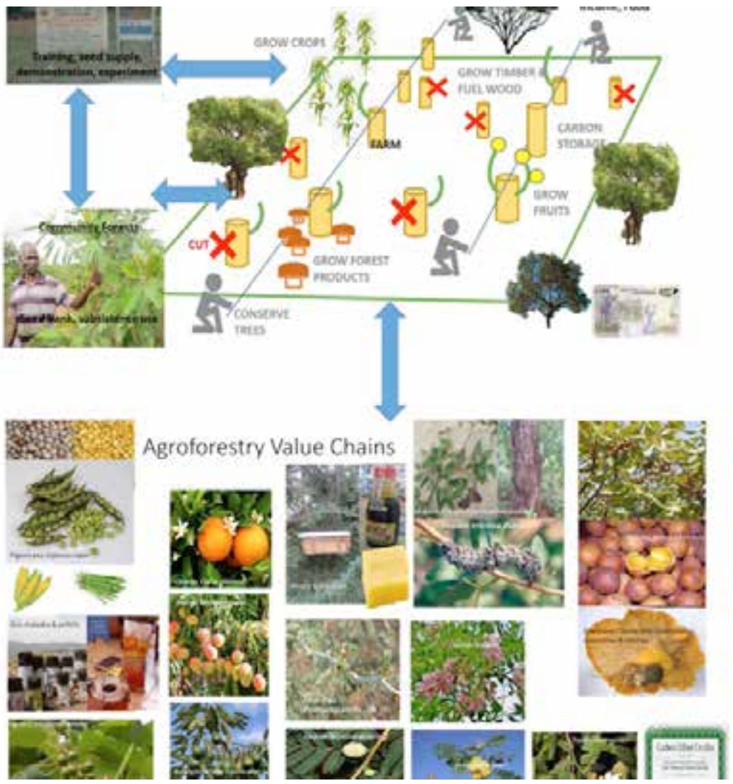
L09_O.02

Agroforestry as a mechanism for reforestation in Zambia: Scenarios within a REDD+ framework

Ingram V.[1] (verina.ingram@wur.nl), van der Goes A.[2], Phiri G.[3], Banda T.[4]

[1] *Forest & Nature Conservation Policy, Wageningen UR, Wageningen, Gelderland, Netherlands*; [2] *SNV Zambia, Lusaka, Zambia*; [3] *SNV, Lusaka, Zambia*; [4] *Zambia Integrated Forest Landscape Prog, Ministry National Development World Bank, Lusaka, Zambia*

Zambia has the 2nd highest per capita deforestation rate, and 5th highest worldwide, highlighting the need to understand deforestation & degradation drivers and reforestation mechanisms. Agroforestry can maintain & enhance the supply of carbon and sustainable wood and non-wood forest products. This paper examines agroforestry practices and policy frameworks and thier intersections to enable agroforestry to meet reforestation, climate change mitigation, conservation and livelihoods goals. For agroforestry-based REDD+ initiatives to work, the business case needs to be clear, tested and viable, and assessing performance and benefits mapped out. After presenting agroforestry scenarios, based on work at the Katete Farmer Training Centre, with farmers, their communities and customarily owned and managed forests (see figure) in Katete, Eastern Province, we investigate how agroforestry can generate income – including through carbon credits. Proposals are made for a revised definition of forests and eligability; baseline and carbon monitoring, additionality requirements; practical methods for measuring, reporting and verifying; delaing with forest fragmentation and connectivity at landscape level; benefit sharing; distinguishing fuelwood and charcoal from farmed and natural forests; and carbon accounting cycles given rotation, coppicing and felling. We conclude with an assessment of how agroforestry could be used under REDD in Zambia, enablers, barriers and trade-offs.



Keywords: zambia, REDD+, Agroforestry systems, value chains.

L09_O.03

Evolving and strengthening cooperative approach for the agroforestry farmers in Bangladesh: lesson learn from Japan

Islam K. K.[1] (kamrulbau@gmail.com), Fujiwara T.[2], Sato N.[2], Hyakumura K.[3]

[1] *Agroforestry, Bangladesh Agricultural University, Mymensingh, Bangladesh*; [2] *Forest Policy Laboratory, Kyushu University, Fukuoka, Fukuoka, Japan*; [3] *Institute of Tropical Agriculture, Kyushu University, Fukuoka, Fukuoka, Japan*

Being an agroforestry based country, the farmers of Bangladesh do not receive proper returns from their products due to some obstacles blocking the way to achieve the ultimate goals. The study tries to identify the major challenges of agroforestry products supply chain in Bangladesh and offer an alternative solution through the involvement of farmer cooperative within the experiences of Japanese cooperative model. The objectives were outfitted by two case studies, and the Bangladesh case clearly showed that the involvement of many intermediaries in agroforestry products supply chain was one of the main obstacles which stunted the outcomes of the agroforestry programs. The intermediaries have maximized their profit by buying the farmer products at low price and selling them back at higher price and resulted high marketing margin. While the second case study in Japan had articulated that the well-organizational, apposite functions and estimable welfare facilities of the farmer cooperative did not have the scope for intermediaries and make the farming system sustainable (Fig.). In spite of decline the coop's member due to the ageing problem, the farmer driven Japanese cooperative approach would be a good solution to tackle the middleman problem and make the agroforestry a sustainable production system in Bangladesh.

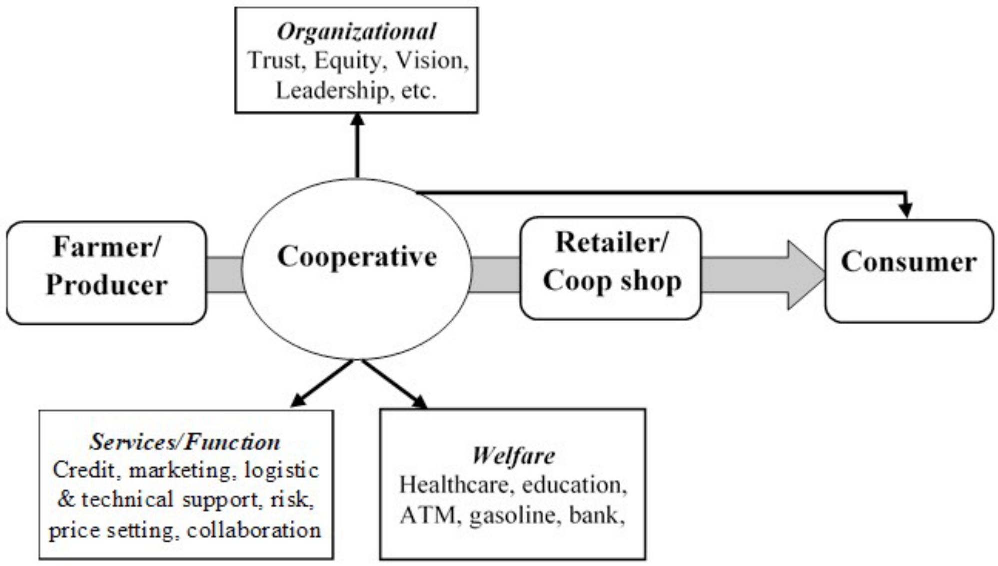


Fig. Sustainable coop model in Japan

Keywords: Cooperative, Marketing channel, Sustainability, Agroforestry, Intermediaries.

L09_O.04

Value- adding agroforestry crops to benefit smallholders in the Pacific

Wallace H.[1] (hwallace@usc.edu.au), Randall B.[1], Johns C.[2]

[1] *Genecology Research Centre, University of the Sunshine Coast, Maroochydore DC, Qld, Australia*;
[2] *Centre for Global Food and Resources, University of Adelaide, Adelaide, SA, Australia*

Approximately 80% of people in Papua New Guinea and the Pacific Islands live in rural areas and earn their livelihoods from farming. Rural farmers often have limited market access for their produce. Processing and value-adding can enhance market access, especially if products can be processed locally and transported to distant markets or central distributors. Agroforestry tree species are widely grown in these countries and provide timber, fruits, nuts, honey and ecosystem services. There is great potential to value-add to products from agroforestry crops in Pacific countries. Industries based on value-added product can also create employment and business opportunities for SMEs. However, a market- driven approach is needed to identify the best opportunities for agroforestry products and a well-functioning value chain is critical to the business competitiveness and sustainability of the industry.
We researched market opportunities and value chain constraints for a suite of agroforestry products (e.g. fruits, nuts and honey) to improve livelihoods in Pacific Countries. Commercial, cultural and environmental drivers were considered as part of the value chain analyses. The research then focussed on value-adding, small scale processing and drying techniques such as small scale solar driers as key enablers of industry development. Solar drying of fruits and nuts shows great promise as a tool to allow farmers to access distant markets for their agroforestry products.

A small scale solar drier used to value- add fruits and nuts

Keywords: drying, processing, fruits, nuts.

L09_O.05

Local value-chain with Coffee/Cocoa agroforestry business driven Clusters to foster social and environmental innovations

Penot E.[1] (eric.penot@cirad.fr), Baufumé S.[2], Etienne H.[3], Mouafi S.[4], Blangy L.[2], Saletes S.[2], Bertrand B.[3]

[1] *UMR Innovation, CIRAD, Montpellier, France*; [2] *Délégation à la Valorisation et à l'Inno, CIRAD, Montpellier, France*; [3] *UMR IPME, CIRAD, Montpellier, France*; [4] *UMR AGAP, CIRAD, Montpellier, France*

Social and environmental issues including climatic changes, plant diseases and vulnerability of producers and smallholders, threaten worldwide coffee production and in particular Arabica coffee. Meanwhile, social and environmental requirements are increasingly at the heart of the consumers' demand. All actors of the value-chain have a clear interest in engaging in agro-ecological and social initiatives preserving ecosystems and offering decent remuneration to farmers through a sustainable production of a high quality coffee. Coffee/Cocoa agroforestry Business driven Clusters (CaFC) are part of such initiatives as a new organizational model to finance social and environmental innovations. Defined as local micro value-chains dedicated to sustainable production under agroforestry of high quality Arabica coffee, CaFC are based on an original organization orchestrated by a network of five types of stakeholders forming an Innovation platform: producers, roasters, brokers, investors and CIRAD for methodology and engineering. In some cases, certification agencies could be integrated to this platform. Based on a 1300 ha prototype project in Nicaragua (MATRICE) initiated in 2016 funded by the Moringa fund. We will describe the operational principles of CaFC, the respective roles of each stakeholder in such projects (Moringa, NicaFrance, CIRAD, producers, ECOM…), as well as the added-value for each of them, the consumers and the environment. In a context of both the falling real prices of coffee and the continuous contestation of certification systems to internalize social and environmental problems, we will discuss why CaFC could be a sustainable governance mechanism among stakeholders as well as an alternative traceability scheme in conventional but also in organic production of Arabica coffee or cocoa. Finally we discuss its possibility of extension to other contexts such as Vietnam or Cameroon through the Breedcafs H2020 European project.

Keywords: coffee/cocoa value chain, cluster, agroforestry, innovation.

L09_O.06

Good forest governance: Improved income for rural communities in Burkina Faso – results from a TREE AID programme

Carpena P.[1] (pietro.carpena@treeaid.org), Ouedraogo D.[2], Sompougdou A.[2], Baines D.[1], Valea L.[2], Hammond J.[3]

[1] *TREE AID, Bristol, United Kingdom*; [2] *TREE AID, Ouagadougou, Burkina Faso*; [3] *Intl Livestock Research Institute (ILRI), Nairobi, Kenya*

For many generations, farmers in the semi-arid and sub-humid areas of West Africa have practiced a traditional system of land use called agroforestry parklands characterized by the deliberate maintenance of trees on cultivated or fallow land. Parklands have the potential to mitigate the effects of climate change by improving soil fertility. Through water tapping and prevention of nutrient leaching, trees help recover nutrients, conserve soil moisture and improve organic matter, while restoring soil structural properties. In addition, the trees in parklands, specifically their non-timber forest products (NTFPs), contribute to dietary diversity, food security and household income (Hill, 2014).

Rural families in Burkina Faso have few opportunities to diversify their livelihoods and thus are vulnerable to climate hazards. Forest products are vital natural assets from which they can earn revenue through agroforestry value chains development. However, poor regulation of access rights and control over the tree resources and protection of parklands puts at risk the natural assets these communities, in particular the most vulnerable, are so dependent on. Recent forest laws[1] and legislation[2] in Burkina Faso are providing a supportive policy and institutional framework for the decentralisation and devolution of forest governance (FG), which in turn should enable rural communities' access, control and derive sustainable benefits from their local forest resources. There is an opportunity for NGOs, such as TREE AID, to support forest actors through FG processes that recognise the rights and duties of local user. Key principles of 'good' FG include participation, accountability, equity, fairness, transparency, local control & management (Paulson, 2012).

Here we present the results of a quantitative study of 1,287 households based on a digital platform, built on open source software, called the Rural Household Multi-Indicator Survey (RHoMIS)[3]. The study shows that communities in the eight districts that adopted good FG principles generate up to 3 times more income, through the development of viable NTFP enterprises, compared to districts that are not yet familiar to FG processes. The comparative analysis also recorded better values concerning the level of control of tree resources by women and young people in the eight districts.

The promotion of good FG is an important condition for the sustainable expansion of NTFP value chains. The approach facilitates value chain development, including their access to adequate financing, which links household-level economic outcomes to the conservation-restoration of forests (Carpena et al, 2016).

[1] *Loi N° 0033-2011/AN du 5 avril 2011 portant Code forestier au Burkina*

[2] *Loi N° 055-2004/ADP du 24 décembre 2004, ensemble ses modificatifs et textes d'application portant Code général des collectivités territoriales au Burkina Faso*

[3] https://www.rhomis.org/uploads/1/1/9/9/119962631/ccafs_info_note_-_rhomis.pdf

Keywords: Forest governance, NTFPs value chains, Burkina Faso, agroforestry parklands, RHOMIS.

References:

1. Carpena, et al., 2016. Food Chain, Volume 6 (2), pp.77-91. https://doi.org/10.3362/2046-1887.2016.00
2. Hill, in: Prioritising support for locally controlled forest enterprises, 2014, Ed.: Duncan Macqueen
3. Paulson, in: Moving Forward with Forest Governance, 2012, Eds.: Broekhoven et.al, p. 222-229

L09_O.07

From Fork to Fork - Towards market integration for agroforestry and agroecology

Balaguer F.[1] (fabien.balaguer@agroforesterie.fr), Buresi A.[2]

[1] *French Agroforestry Association, Auch, France*; [2] *Pour Une Agriculture Du Vivant, Paris, France*

There has long been felt a need to create an entity that could play the role of an agroecology innovation platform, able to integrate vertically the major players of the agroecology production/processing/distribution chains, and to reach out horizontally to a wide range of consumers, including across extended, ethically- oriented, institutions (schools, hospitals, enterprises canteens, etc.)

Pour une Agriculture du Vivant (PADV) is a movement founded by private companies in direct relation with farmers associations and assisted by local organisations and advisory offices specialising in agroecology/agroforestry development. PADV is laying the foundations in France for an integrated and revolutionary agroecological production-distribution approach on a large scale, from corporations in the private sector and high- level political commitment, to engagement from farmers.

As PADV provides services to food companies by helping them creating sustainable distribution chains and identifying producers that fit specified agroecology and agroforestry standards, the additional value is being reinvested in applied research and assistance to farmers for implementing permanent soil cover, low soil disturbance, low phytosanitary interventions and tree reintroduction in landscapes. By bringing the subject to a much wider audience, this project is a major opportunity to involve every consumer in agroforestry development and to go beyond the frontiers of specialist researchers and agronomists.

Pour Agriculture Du Vivant - A collaborative initiative to value farmers' efforts in their transition towards agroforestry

Keywords: agroforestry, agroecology, agri-food chains, consumers, society.

L09_O.08

PEFC endorsement process for the Certification of Trees Outside Forests

Brunori A.[1] (info@pefc.it), Laithy R.[2], Berger M.[3], Lawson G.[4]

[1] *PEFC Italy, Perugia, Italy*; [2] *Independent consultant, Laos, Laos*; [3] *PEFC International, Geneva, Switzerland*; [4] *Centre for Ecology & Hydrology | CEH, Edinburgh, United Kingdom*

The Programme for the Endorsement of Forest Certification (PEFC) is an international, non-profit, non-governmental organization dedicated to promoting Sustainable Forest Management (SFM) through independent third-party certification.
PEFC works throughout the entire forest supply chain to promote good practice in the forest and to ensure that timber and non-timber forest products are produced with respect for the highest ecological, social and ethical standards. Thanks to its eco-label, customers and consumers are able to identify products from sustainably managed forests.
Expanding PEFC's scope from trees within forests, to include trees outside forests (ToF), is an important consideration for advancing sustainable landscapes and rural livelihoods. The term ToF refers to all trees that are grown outside the nationally "designated forestland"[1]; and includes both intensive and extensive, agriculture or settlement production systems. Within the scope are trees growing on private lands in fields and on field-boundaries in orchards and in common and state non-forest lands in parks and gardens, along roads, canals and railway lines in rural or urban areas etc.
Sustainable management criteria and guidelines for ToF are necessary to achieve certification, since this land use is growing in importance, and could represent at least 27% of the global area of tree-based systems (Lawson 2016). The management guidelines should be administered in a similar way to forestry. These would form the basis of future certification of products from sustainably managed agroforestry systems. This approach will bring agroforestry to the attention of consumers, while emphasising its importance for the sustainable production of food, timber, fuel and environmental services.
International requirements for agroforestry certification under the PEFC system have been available since the approval of PEFC's revised benchmark for Sustainable Forest Management at international level (14/11/2018), expanding the benchmark's scope and including an Appendix for ToF interpretation. ToF standards at a national level can be developed and later endorsed by PEFC International.
The next step that is required on the national level would be the decision to either develop a new ToF standard or to adapt an existing FM standard to a ToF scope. Regardless of whether a new standard is developed or whether an existing standard is adapted to agroforestry, in order to achieve PEFC endorsement, the process needs to follow PEFC's standard setting benchmark. The oral presentation will outlines the process to ensure wide and balanced stakeholder engagement and pilot testing in the development process.
[1] Using the national thresholds of minimum area, minimum tree height and minimum crown cover reported by countries under the terms of the UN Framework Convention on Climate Change.

References:

1. Lawson, G. 2016. "ToF Options for Certification of Sustainable Management" Tech Report for PEFC. Fo

L09_O.09

A new payment for ecosystem services in organic cocoa agroforestry system in Ivory Coast

Vaudry R.[1] (r.vaudry@nitidae.org), Ettien R.[1], Nourtier M.[2], Rullier N.[2], Rabany C.[2]

[1] *Nitidae, Abidjan, Ivory Coast*; [2] *Nitidae, Montpellier, France*

Expansion of cocoa fields is the main cause of deforestation in Ivory Coast which is the largest world producer of cocoa. When cultivating a new cocoa field, local farmers maintain a tree cover the first years to grow the young plants and clear cut all the forest trees within few years. To mitigate this important threat for biodiversity and carbon stocks of the few remaining forests of Ivory Coast, our aim was to develop and test a Payment for Environmental Service (PES in order to encourage local producers to preserve a forest cover in their existing cocoa fields. We focus our work on old cocoa plantations with remaining trees and excluded those originated from recent deforestation. An organic cocoa cooperative was created to deal this cocoa production from voluntary farmers and an agroforestry premium price according to a threshold on forest trees' basal area (a proxy of carbon stocks) was introduced through carbon payment from the client. Moreover, the cocoa is certified organic which guarantees another premium price to the producers in addition to the agroforestry one. Our results show that those premium payments represent an increase of 61% of the farmers' revenues from the certified fields. This significant increase due to the combination of organic and agroforestry premium prices compensates the decrease in yields due to the preservation of the forest cover. We observed so far that those premium prices are a sufficient incentive for the producers to maintain the forest cover. Those first results are encouraging and should be strengthened by the refinement of the monitoring system to ensure the respect of the agroforestry threshold. Such incentive is expected to provide a sustainable mean to encourage farmers not only to maintain their actual trees on their cocoa fields but also to stimulate new tree plantations on some of their other fields.

Keywords: cocoa agroforestry, organic certification, deforestation, premium prices.

L09_O.10

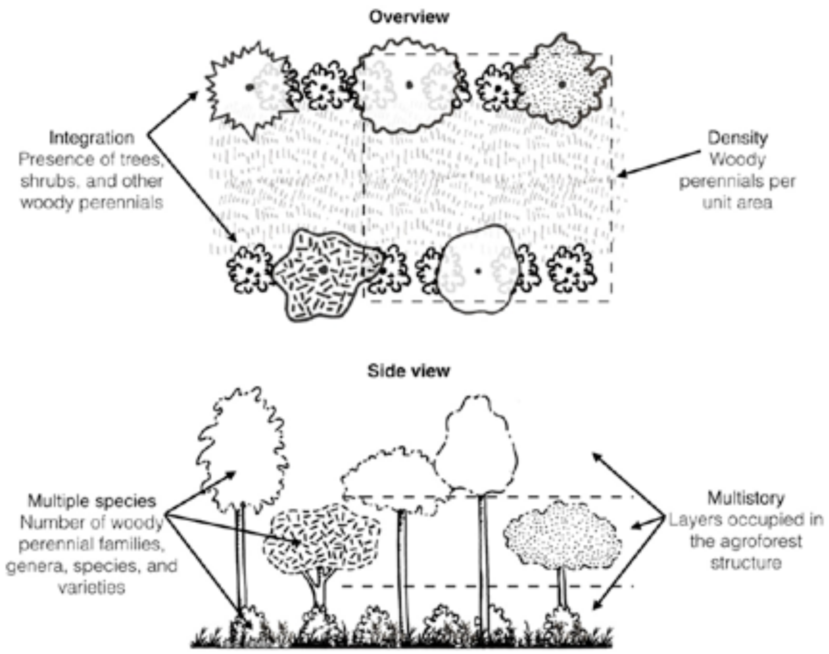
Designing generalizable agroforestry standards for regenerative agriculture

Elevitch C.[1] (cre@agroforestry.org), Mazaroli D. N.[2], Ragone D.[3]

[1] *Agroforestry Net, Holualoa, Hawaii, United States*; [2] *Strategy Research Science, Ventura, California, United States*; [3] *Breadfruit Institute, National Tropical Botanical Garden, Kalaheo, Hawaii, United States*

The first step to making feasible certification processes for agroforestry-based production systems is to design measurable standards. Due to wide variation in agroforestry applications, ideally such standards would allow for endless variations in agroforestry practices while also reflecting likely desirable ecosystem service outcomes. We will share a proposed framework and measurable criteria for an agroforestry standard that could potentially be implemented as a standalone standard or built into existing agriculture, forestry, or resource conservation certification programs.

This research is motivated by a growing interest in regenerative agriculture and efforts to certify regenerative practices. We examined how agroforestry practices can advance regenerative agriculture's five core environmental concerns: soil fertility and health, water quality, biodiversity, ecosystem health, and carbon sequestration. Next, we reviewed a subset of certification programs, standards, guidelines, and associated scientific literature to understand existing efforts to standardize agroforestry. We determined that development of an agroforestry standard alongside current efforts to certify regenerative agriculture offers an opportunity to leverage common goals and strengths of each. Additionally, we determined that there is a lack of standards with measurable criteria available for agroforestry, particularly for temperate environments.



Measurable components of a regenerative agroforestry criteria. Agroforestry systems can be configured in a variety of ways. This generic illustration depicts a system arranged in rows as is commonly done in many agroforestry practices such as alley cropping, windbreaks, and riparian forest buffers.

Keywords: regenerative agriculture, certification standard, ecosystem services, measurable criteria.

References:

1. Elevitch et al. 2018. Sustainability 10 (9): 3337. https://doi.org/10.3390/su10093337.
2. Lovell et al. 2017. Agroforest. Syst. 1–19, doi:10.1007/s10457-017-0087-4.
3. Jose. 2009. Agroforest. Syst. 76, 1–10, doi:10.1007/s10457-009-9229-7.
4. Tscharntke et al. 2015. Conserv. Lett. 2015, 8, 14–23, doi:10.1111/conl.12110.

L09.P.01

Agroforestry in supply chains: strong methodologies and collaboration needed for long-term impact and sustainability

Frier L. (lorena.frier@purprojet.com)

PUR Projet, Paris, France

With ten years of experience, PUR Projet has built up a thorough methodology for sustainable agroforestry projects and supply chains creation, development and strengthening.
Internally-elaborated tools enable staff to identify socio-environmental stakes at various steps of a value chain, list and prioritise potential solutions to those stakes, assess the practical feasibility of such initiatives, and regularly evaluate the compliance of rolled-out projects against key criteria for impact. All those assessments allow us to collaboratively build relevant agroforestry projects (40+) for both companies and the farmers supplying the raw materials, and suggest solutions for continuous improvement.
PUR Projet's model for project development is community-oriented, which means that socialisation and trainings are organised with interested farmer communities to ensure acceptation of the potential agroforestry project locally, but also the application of good planting and maintenance practices over the long term. This is done through the PUR Field Schools methodology, a set of trainings and games that help PUR staff and local technicians animate trainings and workshops with farmers.
When designing the project, planted species are carefully selected according to expressed and identified local needs, in order to increase and diversify revenues (according to a revenue increase model), help enhance crops' quality and resilience to climate change effects, etc. Planting models are elaborated following a landscape approach to generate impactful benefits on the environment and surrounding communities.
Coordination with the sponsoring enterprise is also needed to align field activities with the sponsor's business expectations and constraints. And because sustainability of the projects is key to reach the expected impacts, companies are encouraged to commit over the long run, through solidarity sourcing contracts and the funding of impact studies for example.
Depending on the risks encountered along the value chain, we may also encourage the implementation of innovative technologies, for ex. blockchain traceability or audits of intermediaries thanks to our internal Sustainable Supply Chain Assessment tool (SSCA©, that builds up on international socio-environmental standards).
An effective way to boost sponsoring partners' engagement is to create links between them and the project, notably through field visits and stakeholders' meetings, but also effective and trustworthy reporting. To this aim, PUR Projet has developed several tools that enable to collect, analyse and communicate field data. This includes but is not limited to registries and GPS tracks that monitor planted parcels, planters and planted trees; the economic valuation of PUR Projet's agroforestry projects' potential impacts; or automatically-generated infographics.
Developing and applying relevant methods and tools is therefore key to educate and engage all actors and boost agroforestry in production systems.

Keywords: value chains, methological tools, data management, sustainable production systems, stakeholder engagement.

L09.P.02

Opportunity study of agroforestry projects under shading of forest species (Congo Basin and Ivory Coast)

Jobbé-Duval B.[1] (benoit.jobbeduval@atibt.org), Rivain S.[2], Perthuisot N.[2], Fare Y.[3], Aymes I.[4], Guittard B.[5], Duhesme C.[1]

[1] *ATIBT, Nogent-sur-Marne, France*; [2] *Oréade-Brèche, AUZEVILLE, France*; [3] *Kinomé, Nogent-sur-Marne, France*; [4] *Commerce Equitable France, Nogent-sur-Marne, France*; [5] *AVSF, Nogent-sur-Marne, France*

In 2018, the FFEM financed a study of agroforestry projects with focus on the cocoa-timber agroforestry systems in the Congo Basin and West Africa. We focused our interviews and observations in Cameroun and Cote d'Ivoire: two countries with contrasting trajectories in the cocoa and timber sectors. 30 entities have been met (6 timber companies, 3 chocolate industry, 7 research center and forest authorities, 4 international cooperation agency, 5 NGOs, 2 certification bodies, 3 agroforestry fund) and 16 projects have been analyzed*.
Major observations:
- A large range of association schemes are implemented on a trial stage at small-scale.
- For the moment, the foresters are engaged in plantation projects with chocolate industry, rather to meet compensatory reforestation obligations and not a goal of profitability and long term sourcing modalities.
- The cocoa/timber plantation system with a purpose of wood production and profitability is an innovative approach in these countries. There is a convergence of interest, even early signs of a movement bringing together chocolatiers and foresters around common issues: climate, sustainable access to resources and livelihoods.
- For timber industry, the cocoa + timber model can meet the requirements of FSC/PAFC forest certification, regarding the needs of livelihood projects for neighboring populations.
- The cocoa + timber + annual crops and fruit species model can also be used as a basis for ecological intensification, climate smart agriculture, also leading to organic certifications, income diversification and payment for ecosystem services.
- The development of fair trade cocoa in West Africa can lever on production systems transformation from single cropping to agroforestry: thanks to the guaranteed minimum price, to the development reward and to the multi-year commitment of buyers/importers/chocolatiers, certified cooperatives develop significant support capacities for their member producers.
The success for «cocoa/forest plantation» projects must suppose organizational, technical and economic agreement between the farmer (who plants cocoa and trees and ensures the maintenance of the agro-forestry system), the cocoa buyer and the wood buyer. As in any innovative strategy, obstacles must be overcome. In our case, there are conditions to create: access to quality seedlings, technical support for good maintenance of tree species, adapted financial products and adaptation of the existing legal framework. These elements together can lay the foundation for a strategy for early payment for future timber resources, based on a sustainable partnership between cocoa farmers and foresters.
These findings have been shared with the "Cité du développement durable" (France): 20 institutions involved in sustainable development and international cooperation. Many of them work on cacao agroforestry from different angles (agronomic, adaptation to climate change, agro-ecological transition, fair-trade) and will join their effort.

Keywords: Timber, Cocoa, West-Africa, Fairtrade.

L09.P.03

Research Project: Creating business models for agroforestry

Kijne A.[1] (albertien.kijne@hvhl.nl), Ieyequien E.[1], Stobbelaar D. J.[2], Eweg R.[3], Oosterhof G.[1], Huizinga E.[2], Masselink S.[3]

[1] *Agroforestry, Van Hall Larenstein University, Velp, the Netherlands*; [2] *Sustainable Landscape Management, Van Hall Larenstein University, Velp, the Netherlands*; [3] *Sustainable Business, Van Hall Larenstein University, Velp, the Netherlands*

In recent years agroforestry has received attention in the Netherlands as a mean of transition towards climate adaptive agriculture. Still entrepreneurs come across the challenge on how to develop business models, that also fit juridical, consumers' and societal contexts. The Dutch project 'Business models for agroforestry' focusses on how to develop adaptive business models that are profitable for rural entrepreneurs, while enhancing ecosystem services and strengthening value chains, permitting further development of agroforestry. We approach this challenge by addressing, together with six rural entrepreneurs, the issues on where the products and services can be sold and how the transition can best be made to value (financial or otherwise) by using amongst others a value chain approach and an ecosystem assessment. This approach supports the entrepreneurs to obtain more certainty about the (possible and feasible) agricultural, environmental and other revenues before they undertake the implementation of agroforestry. The six entrepreneurs in this project vary in their type of company, and in their wishes for agricultural transitions. In this way the project gains a broad insight in solutions for entrepreneurial transitions to agroforestry in different contexts.

Research at one of the farmers participating in the project, October 2018

Keywords: Agroforestry, Business models, Entrepreneur, Value chain, Transition.

L09.P.04

Incentivising conservation in agroforestry - Is it sustainability?

Kushalappa C. G.[1] (kushalcg@gmail.com), Rahghuramulu Y[2], Nanaya K. M[1]

[1] *College of Forestry, UAHS (S), Ponnampet, India*; [2] *Coffee board of India, Bangalore, India*

Kodagu district in India is part of the Western Ghats, one of the hotspots of biodiversity in the world. The district is one of the largest wooded region in the country with over 80 per cent of the area under tree cover. It comprises of diverse natural forests managed by state, agroforests managed by farmers and sacred groves managed by local communities. The diversity of ecosystems, associated species and their management by local communities have contributed to make Kodagu among the most diverse landscapes in the tropics. As is the trend in many tropical landscapes, landscape dynamics due to changes in land use and land cover has impacted the density and diversity of biological diversity.
Valuation of ecosystem services and providing incentives to farmers following sustainable practices was attempted as a tool to promote conservation. Studies were undertaken under CAFNET project funded by European Union to value the ecosystem services and look at possible mechanisms of payments to farmers in a coffee based agroforestry system. It indicated that coffee agroforests contribute significantly not only to economic development of the farmers, but also ecologically by contributing to key ecosystem services in terms of water, carbon storage, biodiversity conservation, pollination services and ecotourism. But it found that these diverse agroforestry system are undergoing simplification due to reduction in number and diversity of shade trees in coffee plantations to increase productivity of coffee crop by converting from shade grown to sun grown coffee production system. Hence an attempt was made to explore the possibility of incentivising the cultivation of biodiversity friendly agroforestry practices through eco-certification of farmer collectives. Though incentivising farmers through collectives showed tremendous opportunities, our experiences suggests that there is a need to ensure that these globally driven certification mechanisms need to be modified to suit the local situations where regional stakeholders can come together to workout payment modes and mechanisms. We share the first time effort undertaken in the country to conserve and sustainably manage natural resources involving multi-stakeholder approach aimed at conservation using the principle of ecological economics.

Keywords: Farmer collectives, Landscape labelling, Green tax, Corporate social responsiblity.

L09.P.05

Agrobranche, give a green value to the agroforestry branches

Liagre F.[1] (liagre@agroof.net), Marchal R.[2], Lemoigne N.[3], Bono P.[4], Aouf C.[5], Senegas I.[6], Gerardin P.[7], Dauzat J.[2]

[1] *Agroof, anduze, France*; [2] *CIRAD, Montpellier, France*; [3] *Armines, Ales, France*; [4] *FRD, Troyes, France*; [5] *INRA, Montpellier, France*; [6] *Chambre régionale d'agriculture, Rennes, France*; [7] *LERMAB, Nancy, France*

Agrobranche aims at studying the possibility of strengthening the economic model of the agroforestry by improving the valuation of the intermediate biomass in the new domains of bio-based materials and chemistry.
This objective answers a double purpose:
Agroforestry management requires regular cuttings of branches for the control of the shade and the influence of trees. Branches constitute a resource available throughout the life of trees, very few harvested today.
For the partners of the industrial development, it is the possibility to benefit a resource of quality compatible with the classic agricultural productions, and safer in terms of supply.
Agrobranche will identify the best segments for the agroforestry systems with a comparison between the various uses and to dread the relevance of these agroforestry products among the set of resources mobilizable for these segments. Among the aimed segments, rigid / semi-rigides insulations with wood, particle boards and composites wood-polymer for the « material » way and extractibles molecules for the «green chemistry» way will be particularly envisaged as ways of promising valuations.
The works which are going to be led by our consortium including agricultural professional organizations, research laboratories and companies, aim in :
Defining agroforestry products likely to contain substances extractibles of interest,
Qualifying the industrial potential of valuation of the agroforestry chips for the new markets
Identifying the standard of the agroforestry chips meeting the needs of companies for a given application and an organization of the sector to optimize its development and profitability,
defining on one hand the upstream chips production ways and on the other hand the downstream technological ways dedicated for fibers and molecules extraction,
The main asset of Agrobranche is the concern to connect the needs between research and industrial sectors with an agroforestry product with strong agroecological value, without any competition for the agricultural productions. By this way, we avoid the frequent stumbling block of the green chemistry projects based on rival productions and\or on limited resources or little long-lasting, even few sustainable from an energical point of view.

Keywords: green chemicals, chips, molecule, timber, pannel.

References:

1. Bono P. et al., (2015). Les nouveaux champs de recherche et développement pour la valorisation des
2. FRD/ADEME, Evaluation de la disponibilité et de l'accessibilité des fibres végétales à usages maté
3. Kebbi-Benkeder Z., Colin F., Dumarçay S., Gérardin P.. 2015. Quantification and characterization o
4. Marchal R., Kouakou S.-S., Brancheriau L., Candelier K. Introducing trees into cultivated fields t
5. Thebaut M., Pizzi A., Dumarcay S., Gérardin P., Fredon E., Delmotte L. (2014). Polyurethanes from

L09.P.06

Exploring the Economic Opportunities of the Waste Products in Agroforestry System

Lin C.-H. (Linchu@missouri.edu)

Center for Agroforestry, University of Missouri, Columbia, MO, US

Annually, more than 25,000 million tons of waste plant materials (WPM) are generated in agroforestry system worldwide. Conventionally, the uses of the WPM have been only limited to home gardening, compost and landfills. Our preliminary studies suggested that the WPM could be an excellent source of high value phytochemicals for cosmetics application. The present study explores the possible uses of WPM grounds as the raw materials for cosmetics industry. The objective of this project is to investigate the chemical profiles and identify the bioactive compounds for cosmetics application through global metabolite analysis and high-throughput screening. This study will help identify the bioactive compounds in the WPM and their immediate applications for skin care application (e.g., anti-oxidant, anti-inflammatory, skin-whiting, and anti-aging). The findings from our projects will provide the opportunities to turn abundant, low-value, renewable materials from the WPM into a lucrative industry.

Keywords: Waste Products, Economic Opportunities, Agroforestry.

L09.P.07

Valorization of agroforestry trees compartments into biobased materials and bioproducts: the case of wood branches

Marchal R.[1] (remy.marchal@ensam.eu), Brancheriau L.[2], Candelier K.[2], Terrasse F.[2]

[1] *Research Unit LaBoMaP, ENSAM, Cluny, France*; [2] *Research Unit BioWooEB, CIRAD, Montpellier, France*

Background
In many tropical countries, agroforestry systems provide both services for agriculture and for non-food economic sectors (housing and energy).
Since six decades, European countries, including France, have massively excluded trees from the fields and crops in order to intensify mechanized agriculture. But the current agro ecological transition reverse the trend through the design of new agroforestry systems. Nevertheless, French farmers are still to be convinced about the economic reliability of such systems, building their agricultural models on an annual income, which is not so easy with trees that cost annually making economic returns only every few years. Different ways exist to reduce these misgivings, among them the integration of trees products into conventional wood market or to some niche markets. In parallel, wood or chemistry industries are to be convinced of the interest to harvest such woods.
Aim
Trees growing conditions are very different in agroforestry and in forests and so have a large influence on wood qualities that we currently assess making comparative measurements of mechanical, physical and biochemical properties between agroforestry and forestry woods for some given wood species. Agrpforestry farmers having to prune trees in order to control the light flux to the crops, they harvest every year a quite large volume of branches, valorizing them making mulching or energy. But, according to literature, wood of branches shows higher rates of polyphenols than wood of trunks and can open some new markets for branches.
Materials and methods
In the framework of the project “Agrobranche” financed by the French national agency for environment (Ademe), we screen biochemical contents of branches of different sizes from four species collected in two types of agroforestry systems: interplot systems (oak and chestnut); alleycropped system (poplar and walnut). We make first NIRS qualification on branches and tests of natural resistance to decay. Then we chipped the branches before processing chemical extractions and their qualification using UPLC-ESI-DAD-MS and CG-MS analysis in LERMAB, Nancy. For oak and chestnut, we have make comparison of extractives composition and rates between branches and wood of the trunk of the same trees.
Major results and conclusion
The comparison of extractives composition show a higher biochemical variability in wood of branches than in trunks.
NIRS measurements make very effective prediction of the extractive composition determined by direct measurements; it seems possible to develop a NIRS-based rapid and non-destructive method to assess branches biochemical value directly on trees into the crops.
Woods with more extractives resist more to decay than woods from trunks.
These results are promising for new valorisation of branches coming from pruning of agroforestry trees.

Keywords: wood, bioproducts, branches.

References:

1. Cardinael, R et al. 2012. Agroforestry Systems, 86(2), 279–286. doi:10.1007/s10457-012-9572-y
2. Marchal R. et al. 2016. (IPC) 25th Session, 16 September
3. Niamké B.F et al 2014. Journal of Near Infrared Spectroscopy, 22 (1) : p. 35-43. http://dx.doi.org/1
4. Salem M. Z. et al. 2016. J Wood Sci 62:548–561 / DOI 10.1007/s10086-016-1583-2313
5. Takuya M et al. 2014. Eur. J. Wood Prod. (2014) 72:651–657 / DOI 10.1007/s00107-014-0830-8

L09.P.08

Non-Timber Forest Product Value Chain Development of *Cinnamomum Burmannii*; contribution to Tropical Forest Conservation

Menggala S. (sidirana.menggalasusanto@ugent.be), Van Damme P.

Plants and Crops, Ghent University, Gent, Belgium

Cinnamon is one of the potential forest commodities that have location-specific characteristics, and this commodity is already known in the world as Indonesian cinnamon (Koerintji brand). Kerinci district is the main producer of cinnamon in Indonesia with the unique and best cinnamon aroma in the world. But for its development faced with the main problem, namely certification. Genus *Cinnamomum burmannii* is group in the agroforestry as non-timber forest product (NTFP) which is stated in the regulation of the ministry of forestry, number: p.35 / menhut-ii / 2007, about non-timber forest product.
In October 2017 and October 2018, a qualitative survey of smallholder farmers in Kerinci was designed to surface insights on the relationship of smallholder farmers and government to evaluate their connectivity to strengthen within the chain. This paper illustrated that many levers affect incomes, requiring input from actors such as local and national government. Our research addresses some of the issues faced by cinnamon producers in Kerinci who would like to strengthen the product's value chain through certification. Therefore, the role of the Indonesian government, which in this case the Ministry of Environment and Forestry (MoEF) is significant to be able to guarantee the export demand (quality and quantity) of cinnamon for the international market by addressing the NTFP of *cinnamomum burmannii* through adopting international forest certification standards.

Keywords: certification, value chain, livelihood.

References:

1. Rutherford, 2016, World Development 83: 70–83.
2. R Ruben, 2008, World Development 40 (3), 570-582
3. Bacon, C.,2005, World Development, 33(3), 497–511.
4. Yusida, E., 2014, International Journal of Trade, Economics and Finance, 5(3), 277–284
5. Gavin Fridell, 2007, Historical Materialism, Volume 15, Issue 4, pages 79–104

L09.P.09

Moringa, corn and soy in Tchamba agroforestry (Togo): an innovative value chain from field schools to canteens

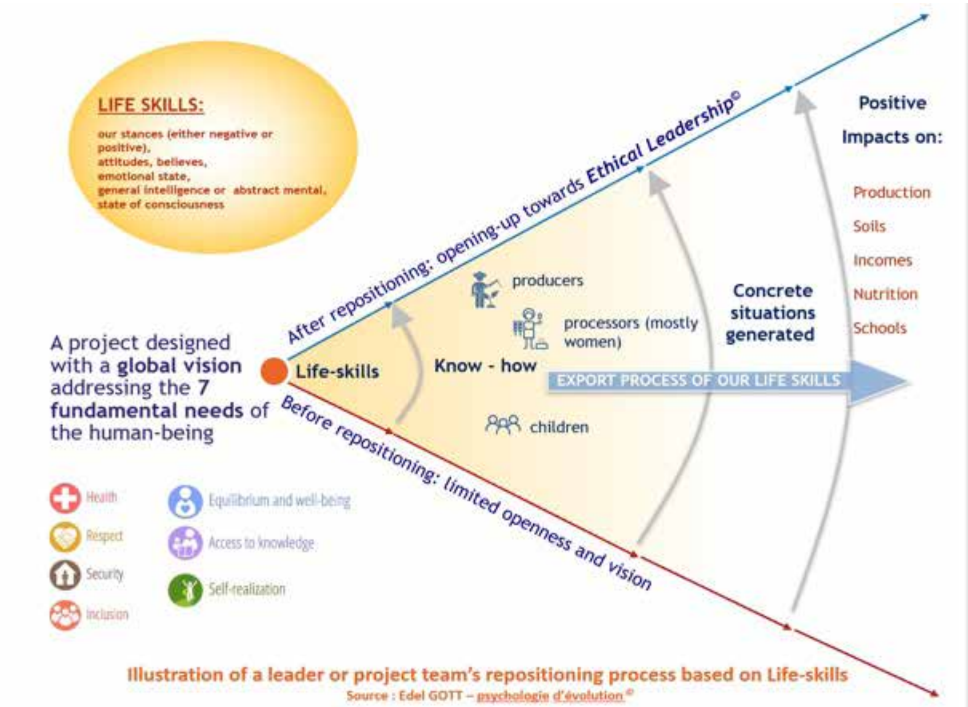
Métro N.[1] (nicolas.metro@kinome.fr), Fare Y.[1], Abotsi E.[2], Adessou S.[3], Fetor A.[3]

[1] *Kinomé, Nogent-sur-Marne, France*; [2] *Laboratoire de Botanique et Ecologie vég, Lomé, Togo*; [3] *INADES-Formation Togo, Lomé, Togo*

Kinomé is a social business that aims to improve communities' economic and human development via forests. Through this project developed in Tchamba (Central Region of Togo) with Triballat Noyal (France) and Inades (Togo), we intend to test an integral solution from fields to schools to address the challenge of agroforestry chains development, assuming that this matter underlines three major issues: agronomy, food and collective gouvernance.

In term of methodology, we first designed an agroforestry model by adding Moringa trees in current local productions (corn, soy). Highly nutritious leaves and seeds would then be cooked by women and distributed in schools. Second, and to motivate stakeholder engagement, we have adapted the GQHD© (Global Quality on a Human Dimension© from the Ethical Leadership) to the context of Togo. This tool enables the analysis of actors' individual and collective interests. To feed this framework, we interviewed 600 students, 10 teachers, 20 producers and 10 women cookers with a holistic and participatory diagnosis based on the 7 fundamental needs (on the figure) assessment.

Finally, we designed indicators to measure how this innovative value chain reorganization could address human development needs. This project was based on life-skills and social entrepreneurship dynamic allowing the repositioning of actors, creating strong partnerships and thus generating positive impacts to develop sustainable and fair solutions for local development.



L09.P.10

Assessing agroforestry value chain and management in northern Thailand

Onprom S. (onpromsurin@gmail.com)

Forest Management, Kasetsart University, Bangkok, Thailand

In rural Thailand, agroforestry is becoming a family strategy for generating income and sustaining food production. This paper analyzes the role, component and actors in the management value chain of agroforestry practiced by smallholding farmers. Researcher employed qualitative research approach, where more than 15 smallholder farmers were interviewed. The study found that value chain of agroforestry in studied area composed of five major components and involved multiple actors. These included 1) production and management of agroforestry 2) group formation and coordination, 3) products collection, 4) transportation and 5) market The study was conducted in Mae Tha community, where is located in Mae-on district of Chiang Mai province. Since the early 1990s, farmers of Mae Tha sub-district have changed from mono-cropping practices to agroforestry system. It is found that the community Network established by farmers has provided opportunity for farmers to transport and distribute products from agroforestry to the market and consumers. The study concluded by suggesting that organizational and institutional arrangement at local level is really crucial to achieve the sustainable agroforestry system. It needed different types of local institutional arrangement that account for location, products, transportation, and market requirements. The multiple of market channels was not possible without the support of farmer's network.

Table 1 Population and distribution of family who practiced agro-forestry system in each village.

Village number and name	Total population (household)	No. of household practiced agro-forestry (%)
No. 1 Bantamon	212	16 (7.55%)
No. 2 Bantakam	149	7 (4.70%)
No. 3 Bankorglaang	114	4 (3.51%)
No. 4 Banhuaysaai	220	14 (6.36%)
No. 5 Banpaanod	106	9 (8.49%)
No. 6 Bandonchai	110	4 (3.64%)
No. 7 Banmaidonchai	121	5 (4.13%)
Total	1,032	59 (5%)

Keywords: agroforestry, value chain, environmental services, smallholder, network.

L09.P.11

WebCorky – Postpone or not the debarking in your stand

Palma J. (joaopalma@isa.ulisboa.pt), Tomás A., Paulo J., Tomé M.

Forest Research Center, Instituto Superior De Agronomia, Lisboa, Portugal

In stands of cork oak (*Quercus suber* L.), the extraction of cork is one of the main productive activities of agroforestry management. The current practice is to debark every nine years, and the question whether it is better to decrease or extend the interval between cork extractions arises very often for various reasons.

WebCorky was developed as an online tool for decision support on the deferral or not of the debarking in a given stand. The web application projects the cork growth of a given set of samples with known caliber (measured before or after boiling), classifying it according to the industrial caliber norms. Cork quality, in the absence of a quality analysis of the samples, can be added through an empirical quality classification (editable by the user), allowing the calculation of the average stand cork value over the years, based on a price table (caliber vs quality) also editable by the user.

The observation of the distribution of the caliber classes over the years, together with the quality classification and price table, provides the yearly projection of the stand value by evaluating its present value on an interest rate also editable by the user.

By simulating for different cork value influencing factors, WebCorky lets the user quantitatively evaluate if the postponing of the debarking is the best option, i.e. if it brings added value to the stand and by how much.

Figure 1: Webcorky online tool available at http://www.isa.ulisboa.pt/proj/webcorky/

Keywords: Decision support system, Debarking, Cork oak, Profitability, Net Present Value.

L09.P.12

Developing Certification Standard for TOF in India

Pandey D. (dpandeyifs@rediffmail.com)

NCCF, Noida, Uttar Pradesh, India

In India, trees growing in private lands in agroforestry, farm forestry, along the farm bunds and in homesteads, in orchards, in parks and gardens, along roads, etc in rural or urban area mostly in non-forests constitute Trees Outside Forests (ToF). Such trees are contributing in a big way in meeting domestic needs of industrial wood of the country. Being in informal sector, ToF remained as invisible resource to land use agencies and their value as industrial wood has not been properly assessed and realized. Though reliable data on production of industrial wood from ToF is not available, using its growing stock data annual potential production has been estimated as 69 million cum as reported by Forest Survey of India (ISFR 2017) constituting about 85% supply of industrial wood. Most of the wood production comes from agroforestry sector.

Despite such a huge production from TOF resource, there are no sustainability adherence systems. As a result, Indian producers using TOF raw material are unable to tap the global market and fetch desired price. Farmers who hold most this resource get adversely affected. There are also problems with the domestic marketing of the TOF product which is often unstable and inconsistent.

Further, being in private sector, there is a lack of uniformity in silvicultural, management and other operational practices. There is also no mechanism to access to the improved and best management practices which are essential for sustainable management.

In the certification standard and scheme developed by NCCF efforts have been made to globally align with other certification programs. Since there is a cost associated with the certification process, care has been to simplify the standard without compromising with global conditions so that it remains within the reach of small and marginal land holders. The standard is fully voluntary and not legal. It is only for the benefit of tree owners interested in value addition.

In developing the standard, representative from all stakeholders including farmers, wood-based industries, pulp and paper mills, governmental and non-governmental organizations, research organizations related to agroforestry and forest professionals were involved. The focus of the standard is on **a.** legality compliance, **b.** management plan and practices, **c.** health and vitality, **d.** maintenance and enhancement of productivity, **e.** socio-economic responsibility and **f.** conservation and environmental safeguards. In all there are 6 themes, 28 criteria and 97 indicators applicable to block plantations of agroforestry. Certification conditions have been relaxed for scattered trees with 6 themes, 16 criteria and 51 indicators. The draft of the TOF standard was on website for public consultation and then under pilot testing in the field. Based on the comments it was subsequently revised. The themes, criteria and indicators developed are subjected to modification based on local, national and global changing conditions.

Keywords: trees outside forests, certification, management, agroforestry, stakeholders.

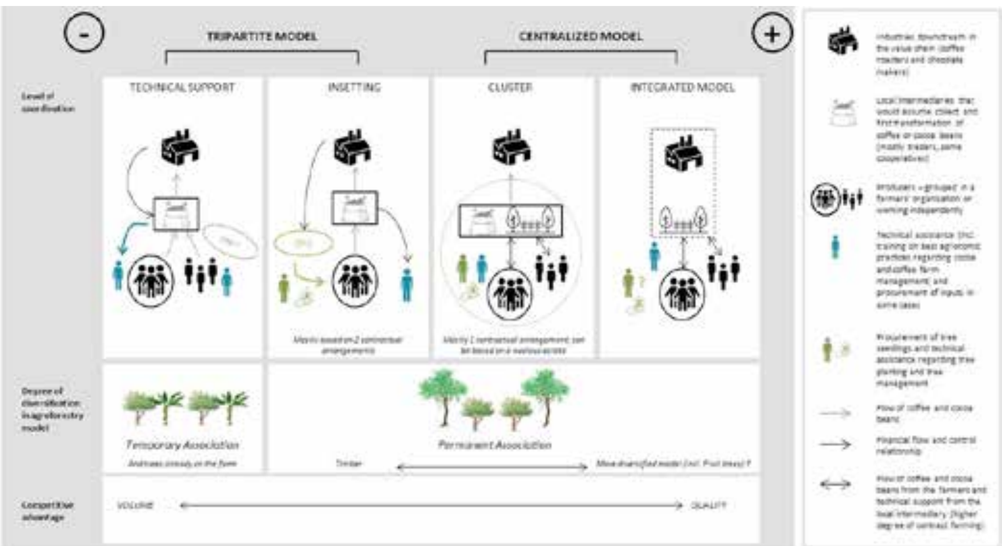
L09.P.13

Agroforestry partnerships in cocoa and coffee sectors : an opportunity for sustainable value chains ?

Plédran O.[1] (oriane.pledran@gmail.com), Phélinas P.[2], Torquebiau E.[3]

[1] *Université Paris Diderot - CESSMA, Paris, FRANCE*; [2] *Université Paris Diderot - CESSMA / IRD, Paris, France*; [3] *AIDA, CIRAD, Montpellier, France*

New programs promoting agroforestry have emerged since the 2000s claiming a contribution to farmers' resilience. The objective of this study is to analyse the evolution of the value chain governance and its implications in terms of farmers' vulnerability reduction. The results are based on a detailed analysis of some thirty programs implemented by the firms holding the majority of market shares in cocoa and coffee sectors, a dozen of semi-structured interviews conducted with these firms, and farm level field surveys in Peru and Nicaragua.
Our results show that cocoa and coffee sectors are facing new challenges on both the demand and supply sides : (1) there is an increasing demand for better quality products ; (2) the security of supply is threatened. This changing context is redefining the governance of cocoa and coffee value chains : industries downstream are developing partnerships with actors upstream to increase their control over their supply leading to an increased vertical coordination.
Firm's position on the market determines the choice of coordination and agroforestry model to implement. The more the firms are positioned in niche markets, the more the link with the producer is essential and the more agroforestry is a central element of the partnership developed. Two key results emerged : (1) traders are becoming a key factor for the success of sustainable partnerships and (2) contract farming is creating an opportunity for more created shared value at farmers' scale.



Typology of agroforestry partnerships in cocoa and coffee sectors (Authors)

Keywords: Coffee & cocoa, Agroforestry, Vertical coordination, Risk aversion, Contract farming.

References:

1. Biénabe, E. et al., Développement durable et filières tropicales, 2016, Ed. Quae, 323p.
2. Chaudey M., Analyse économique de la firme, Armand Colin, 2014, 232p.
3. Eymard-Duvernay, F., 1989, Revue économique 40 (2) : 329-60 , doi:10.2307/3502117
4. Gereffi G. et al., 2005, Review of Int.Polit. Economy 12 (1) : 78-104. doi:10.1080/09692290500049805
5. Porter M. et al., 2011, Harvard Business Review n° January - February

L09.P.14

Agroforestry as an ally for the circular bioeconomy

Rois Díaz M.[1] (mercedes.rois@efi.int), den Herder M.[1], Amaral Paulo J.[2], Tomás A.[2], Villada A.[3], Mosquera-Losada M. R.[3]

[1] *European Forest Institute, Joensuu, Finland*; [2] *Instituto Superior de Agronomía, Lisbon, Portugal*; [3] *University of Santiago de Compostela, Lugo, Spain*

The economic growth in the last decades has been running at the expense of our environment. Given that all products derived from fossil fuel can be obtained from biomass, agroforestry reveals itself as one of the best allies for the circular bioeconomy, which can be part of the solution to address some of the most eminent European and global challenges: climate change, biodiversity loss, increasing forest fires, the plastic ocean…

Agroforestry is known for the diversification of products that can be obtained in an integrative way, providing a great variety of raw materials that may be later on transformed into bio-based products.

Trees provide woodchips that can be used as fertilizer or mulching material, timber for construction, wood-based textile fibres… Cork is used for cork stoppers, insulation and floors or in vehicles. Milk can be converted into powdered milk and later on into textile fibres. Other by-products from the livestock are wool for textiles, insulation materials and bone meal as fertilizer. Many fibre rich crops and trees are now used as carbon fibres for cars, planes, tennis rackets, bicycles, wind turbine blades or insulation material in buildings.

Biofuels are another big part of the bioeconomy: maize, wheat, sugar cane, sorgum generate bioethanol and biodiesel, forestry and agricultural waste can be converted into biogas and biochar. Same raw materials can be the base for bioplastics in cutlery, trays, PLA liner for cardboard coffee cups, or even for toys.

Bioplastics from rice. Source: Adobe Stock.

Keywords: bioplastics, bio-fibres, sustainability, innovations.

References:

1. AFINET project, 2018. Agroforestry Innovation Networks. URL: http://eurafagroforestry.eu/afinet

L09.P.15

Can the certification of cork management agroforestry system in Sicily help to relaunch its future management?

Sala G.[1] (giovanna.sala@yahoo.it), Brunori A.[2], La Mantia T.[3]

[1] *Agrarian Technological Institute, University of Russia (RUDN), Moscow, Russia*; [2] *PEFC Italy, Perugia, Italy*; [3] *SAAF, University of Palermo, Palermo, Italy*

The economic importance of cork oak forests is mainly attributable to the role of provisioning non-timber forest products. The history of human management of these cork oaks stands make them a perfect example of agroforestry system, which surface is totally included in the Mediterranean-climate zones with more than 2.3 million hectares.
In Sicily, the surface covered by cork forests amounts to about 15,000 ha but the most of this area is not affected by cultural practices. The cultural abandonment of many cork oak stands threatens their survival because of the close link between the conservation of cork stands and its use for productive purposes. The abandonment reasons are related to poor enhancement of cork raw material.
However, in recent years some surveys have verified the high quality of cork obtained in Sicily. It is therefore possible to revive the sector through the validation of the product but also the certification of the management processes of the cork, if it is coming from a certified sustainable management.
Certification of sustainable management of the cork stands owned by a Sicilian cork company called Syfar, with the certification of the chain of custody for the manufacture of articles of cork, such as coarse grained cork sheets for thermal and sound insulation, allows the Italian company to sell its product at national level and abroad, for the market of "green building" that is looking for certified material from the ethical and the quality point of views.

Keywords: Quercus suber, abandonment, PEFC, wild fire, sustainable management.

L09.P.16

Strategies for improvement of agro-forestry market practice in North Western India

Shukla S. (shashank.shukla2010@gmail.com), Singh H.P., Rawat A., Chaudhary A.

Silviculture & Forest Management, Forest Research Institute, Dehradun, Uttarakhand, India

Agroforestry has appeared as a most enticing and viable approach for maintaining social, economic and ecological sustainability in India. Especially North western region's of Indian states i.e., Punjab, Haryana, Uttar Pradesh and Uttarakhand. Farmers of these areas often prefer crops with Popules, *Eucalyptus*, *Melia*, *Dalbergia sissoo* and *Azadirachta indica* species in their fields. Agroforestry wants some cost to be borne on the part of the cultivator, which includes purchase of saplings, planting and caring for the trees. But most farmers have little access to market information regarding timber demand and price; little knowledge of market specifications. Marketing of Agroforestry tree produce in North-western India is a three-tier system i.e. Farmer, middlemen/commission agents and saw mill contractors. Commission agents are more often involved in the process from purchasing of plantation, harvest and transport. This has adversely affected the value of wood and simultaneously the interest of tree growers. Keeping this aspect in view, present study was carried out focusing the demand and supply status of wood in Punjab State of India and developing market strategies for the future prospects.

The studies conducted in the State of Punjab in the year 2014 under which market mechanism of farm grown wood, the wood markets/mandis in Punjab were surveyed thoroughly and the data on market channels, method adopted for auction in mandis, sizes of logs in demand, marketing expenditure including Kat (weight loss due to moisture), prevailing market prices of commercially important agroforestry tree species. The required information from State Forest Department collected. The collected information analyzed and suitable measures were suggested strategies to improve the market practices. These aspects discussed in the paper in details.

It is suggested from the present study that to develop viable wood market enterprises, producers must improve their market position excluding the middleman, strengthen their organizational set up and forge strategic business partnerships with the state forest department. Forest market institutions must adapt by providing business services to small-scale farm producers, investing in regional forest enterprise development to fill gaps in the value chain for wood products, and targeting research, education and training. It is essential to remove policy barriers to small-farm participation in markets, by removing excessive regulations, creating fair and open competitive market environment, and involving farmers' organizations in forest policy negotiations. To address these issues, a National Agroforestry Policy 2014 was announced in Feb 2014. The findings of the study also dealing with some of the deliverables mentioned in the Agroforestry Policy 2014. Hence, the present study creates a pathway for taking future policy decisions related to agroforestry, particularly in the State of Punjab and rest of India in general.

Keywords: Agroforestry, Market mechanism, North-western India, Timber.

L09.P.17

Engagement with and perceptions of agroforestry requirements by certified smallholder cocoa farmers in Cote d'Ivoire

Teague M. (mteague@wisc.edu)

Department of Geography, University of Wisconsin-Madison, Madison, WI, USA

Cocoa production has dramatically reduced forest cover in Cote d'Ivoire, once a haven of biodiversity, particularly for primates (Bitty, et al. 2015). Facing intense public scrutiny, chocolate companies are turning to certification programs to sustainably source cocoa and mitigate their role in forest degradation. In addition to rules against clearing remaining forests, the two largest cocoa certification programs in West Africa include agroforestry components, aimed at minimizing environmental degradation and conserving biodiversity in areas already cleared of primary forest. Cocoa-agroforestry systems can sustain significant biodiversity outside of traditional protected areas (Asare 2006). Research suggests that cocoa certification programs are positively correlated with the intention to adopt agroforestry practices (Gyau, et al. 2014), but missing is an in-depth analysis of certified farmers' perspectives on agroforestry and their effects on adoption. This study examines the potential of certification programs to promote agroforestry adoption on smallholder farms. Drawing on in-depth interviews with cocoa farmers (n=42), household surveys (n=98), and discussion with key actors in cocoa production and marketing, I analyze how certified cocoa farmers engage with and implement agroforestry requirements. Preliminary results suggest that certified farmers are less familiar with agroforestry rules as compared to other rules of certification. Furthermore, how, or even if, agroforestry compliance is monitored as a part of certification audits is poorly understood, which could have implications for participation in agroforestry. Finally I discuss how farmer perceptions translate to agroforestry implementation more broadly, and highlight implications for the success of agroforestry components of certification programs.

References:

1. Asare, Richard, 2006, World Cocoa Foundation Partnership Conference, p.15.
2. Bitty, E Anderson, et al., 2015, Tropical Conservation Science, p.95-113.
3. Gyau, Amos, et al., 2014, Agroforestry Systems, p.1035-1045.

ABSTRACTS

Agroforestry adoption

Adopting the future of land use

- L10 -
Agroforestry in practice

Now what? Getting agroforestry to work in practice

Agroforestry practices take advantage of the interactive benefits (both environmental and productive) from integrating trees, shrubs with crops and/ or livestock. It offers ways to take advantage of new and profitable product markets while applying specialized knowledge and skills to the development of stable, resilient and sustainable production systems. Under this session, emphasis is placed on **long-term** agroforestry land use practices and woodlot management satisfying the three criteria: Intensive, Interactive and Integrated. The agroforestry practice session aims to realise a wide variety of case studies of best management practices (BMPs) while generating significant co-benefits, including production diversification, landscape intensification, soil and water stewardship, ecosystem restoration together with achieving economic profitability.

L10.1_O.01

Changes and continuities of Indigenous Agroforestry Knowledge of the Gedeo people, Southern Ethiopia

Legesse Kura A. (abiyotl@du.edu.et)

Geography and environmental studies, Dilla University, Dilla, Southern Ethiopia, Ethiopia

The Gedeo traditional agroforestry system is a multi-strata system composed of an organized mix of mosaics of multipurpose indigenous trees, coffee, and enset components, which is arranged sequentially in time and space. It is known for its uniqueness as it supports large number of population (population density >1000person/km2), on a very steep (slope gradient >60%) and undulating landscape. Despite this, the system remains resilient without modern soil and water conservation measures and able to feed large number of population without external inputs, agrochemicals or improved crop varieties. Arguably, it the most efficiently sustained land use system in the country, thanks to diligent Gedeo elders and their ancestors who meticulously harnessed nature's potential to accommodate the ever-increasing human population through an intergenerational transmission of indigenous agroforestry knowledge (IAK) and practices. However, IAK is not static; change is inevitable. The question is whether the young generation will follow their ancestors' footpath and ensure the continuity of indigenous agroforestry practices. In this regard, this study was carried out to examine changes and continuities of IAK and its implications to its sustainability. Data from 290 sample respondents chosen from four intergenerational groups were collected using semi-structured questionnaires, card sorting, free list, and cognitive mapping. Berkes (2008) knowledge-practice-belief framework was employed to analyse IAK and practices gap and thereby determine IAK change and continuity. Accordingly, IAK of the local people were assessed based on eco-cognitive, practical and normative dimensions. The collected data were organized based on themes and analysed using one way ANOVA, t-test and chi-square. The results of the analysis indicate that there is a clear IAK gap between young people and adults, which implies the loss of some of IAK. Majority of young people failed to identify common indigenous tree species, indigenous agroforestry practices and socio-cultural values and norms which are vital to manage the agroforestry system. They were not able to demonstrate as much knowledge and skills as their elders do. For instance, among the sampled adolescent (12-20 years old), 52% failed to demonstrate their knowledge and skills properly. About 71% of sampled adolescent (12-20) lack knowledge of socio-cultural practices and have never participated in any socio-cultural activities. Very slow transmission of IAK, lack of interest to follow their ancestors' footpath and inclination towards modernization, are among the contributing factors for the gap. The gradual loss of IAK has a negative impact on sustainability of the system. This calls for concerted efforts to maintain the sustainability of IAK through revitalization of IAK transmission and acquisition. Finally, joint effort is required to document IAK, include in school curriculum, and integrate with the modern practices.

Keywords: Agroforestry,, biodiversity, indigenous knowledge, Gedeo.

References:

1. Berkes, F., 2008. Sacred Ecology. Second ed. New York: Rout ledge, Taylor and Francis.

L10.1_O.02

Effects of *Gliricidia sepium* agroforestry systems associated with maize, cotton and sorghum on soil productivity in Mali

Doumbia S.[1] (doumbiasalif@gmail.com), Fliessbach A.[2], Adamtey N.[2], Sousa F.[2], Sissoko F.[1], Dembélé S. G.[3]

[1] *Centre Régional de Recherche Agronomique, Institut d'Economie Rurale (IER) du Mali, Sikasso, Mali*; [2] *Department of Soil Sciences Research, FiBL, Ackerstrasse, Switzerland*; [3] *Enseignement et de Recherche des Sciences, Institut Polytechnique Rural de Formatio, Koulikoro, Mali*

Mineral fertilizers are substantially used in agricultural production systems in order to improve yields in most part of the word. However, the use of fertilizer alone could not increase and maintain soil fertility in most tropical soils including that of Mali. Perennial nitrogen fixing shrubs have the potential to improve soil organic matter, biological activity, and physical properties, while protecting the soil against water and wind erosion. However, these have been underutilized in most agroecosystems due to biophysical, socio-economic and cultural reasons. This study lies within the framework of the organic resource management for soil fertility project (ORM4Soil) and aims at participatory designing and testing of the profitability and environmentally soundness of *Gliricidia sepium* cotton, maize and sorghum – based farming systems with and without alley cropping in order to recommend the best practice for scaling-up in the region. The trial is being conducted in the Sahelian and Sudanian zone of Mali with five treatments of organo-mineral fertilizer - with and without *Gliricidia*. The treatments were arranged in a split plot design and replicated four times. In the Sahelian zone, alley cropping with *Gliricidia sepium* generated 1559 kg.ha-1 dry matter of *Gliricidia* after 377 days of growth which was incorporated into the soil. Similarly, in the Sudanian zone, 3179 kg.ha-1 dry matter was generated after 407 days and incorporated into the soil. The results after two years showed that the agroforestry system with *Gliricidia sepium* had a significant impact on cotton, maize and sorghum growth, biomass and grain yields. Average yields of maize (1330 kg.ha-1) , sorghum (919 kg.ha-1) and cotton (871 kg.ha-1) from the agroforestry system with *Gliricidia sepium* were higher ($p < 0.05$) than those from the same cropping system without *Gliricidia* Maize (742 kg.ha-1), sorghum (903 kg.ha-1) and cotton (568 kg.ha-1) . In zones, organic carbon and total soil nitrogen, increased at an average rate of 120 and 80 kg Nha-1 in the 0-20 cm depth under *Gliricidia sepium* mulch fields as compared to 80 and 40 kg Nha-1 in the field without *Gliricidia sepium*. The study conclude that *Gliricidia sepium* cotton, maize and sorghum- based farming system has the potential to improve crop yields and soil nitrogen, and thus, its scaling-up can improve the livelihood of small scale farmers and soil fertility in Mali.

Keywords: Gliricidia sepium, Organo-mineral Fertilization, Cropping system, Agroforestry, Soil organic matter.

L10.1_O.03

Hybrid poplars for timber with arable crops in Italy: innovating the tradition facing Global Changes

Paris P.[1] (pierluigi.paris@cnr.it), Leonardi L.[2], Cherubini M.[2], Chiocchini F.[2], Lauteri M.[2], Pisanelli A.[2], Dalla Valle C.[3], Mezzalira G.[3], Sangiovanni M.[4], Facciotto G.[5], Nervo G.[5], Colaoa D.[5]

[1] *Inst. of Research Terrestrial Ecosystems, National Research Council, Porano, Italy*; [2] *IRET, CNR, Porano, Italy*; [3] *VenetoAgricoltura, Legnaro, Italy*; [4] *AIAF, Masi, Italy*; [5] *Research Centre for Forestry and Wood, CREA, Casale Monferrato, Italy*

Background
The intercropping of poplar trees for timber production with crops has been largely studied and practiced in Italy until the late '70s (Prevosto et al., 1971). This practice was almost abandoned in the subsequent years, because tree canopy spraying for pest/diseases control was often hindering the management of intercrops. Nowadays, tree-crop intercropping is again studied for its important environmental and productive values for mitigating Global Changes. In Europe, public institutions provide funding for the establishment of new silvoarable (SA) systems. In Italy, new poplar clones are now available, not requiring canopy spraying (MSA clones, Colaoa et al., 2016).
Aims
This paper reports the study at a SA site with a traditional poplar clone (I214). Biophysical experimental data, collected for the first 5 years, are currently implemented with bibliographic data, back to the '70, for an economic analysis of poplar SA system in Italy. New financial simulations are carried out using the new MSA clones. Material and methods. The site was established in 2014 by the Casaria Farm, in the Po valley. The SA area is ca. 9 ha large, on reclaimed alluvial land with permanent drainage ditches (depth of 1 m and spaced at 30-35 m). The tree rows, planted along the outer ditch edge, have an orientation of 5° N. In the SA area, 9 experimental transects of 300 m2 were formed, with measurements on tree growth and intercrops yield, and for studying tree-crop interactions for solar radiation, soil moisture and nitrogen (N) (Paris et al., 2018). For the financial analysis, long terms data, concerning the effect of adult tree shade on intercrops, is obtained by literature.
Results
Alluvial soils, with frequent drainage ditches, can be easily used for the establishment of SA systems using fast growing poplars planted along one side of the drainage ditches, optimizing the use of reclaimed land. Tree growth rate in such conditions is comparable to those in monoculture. The expected tree rotation should be 14 years. Timber quality is not negatively affected by the low planting density required by SA system. Intercrop management, in terms of machinery movement, is not negatively affected by tree rows. Stable isotopes studies show early positive synergic tree-crop interactions, with trees using soil moisture in deeper soil layers than intercrops, and reducing N leaching (Paris et al., 2018). Old literature provides long term experimental data on tree growth and crop yield (Prevosto, 1971). MSA clones have many evident productive and environmental advantages in comparison to clone I214 (Colaoa et al., 2016).
Conclusion
Results show that between trees and associated herbaceous crops, during the years of study, it prevails complementary interactions for light and water, and synergistic ones for N. The above results, along with old literature, are being used for running financial simulations of new SA systems with the new hybrid clones MSA.

Keywords: alley cropping, financial balance, poplar clones, tree-crops interactions, stable isotopes.

References:

1. Colaoa et al., 2016, Sherwood, 31
2. Paris et al., 2018, AGFORWARD Project, Deliverable 4.11, 1
3. Prevosto et al., 1971, Cellulosa e Carta, 1.

L10.1_O.04

Transition to agroforestry in a large-scale project, challenges and results, example of the São Pedro Farm in Brazil

Godard L. (leo.godard31@hotmail.fr)

Floresta Viva SA, Cananéia, SP, Brazil

Floresta Viva SA is a private company which goal is to be the 1st organic producer of heart of palm and other products, cultivated under large-scale agroforestry systems in its own 1'000 hectares farm, the Fazenda São Pedro, in the São Paulo estate with 220 ha of open land, mostly cultivated with the pupunha palm tree (*bactris gasipaes*) associated with banana trees, green fertilizers and various trees for high. The remaining 780 hectares is preserved natural forest.

The Fazenda São Pedro is located in the Vale do Ribeira region, home of most of the remaining Mata Atlântica (the Atlantic Forest, which is the 2nd forest with the most biodiversity in the world, and is also the 2nd most deforested) and one of the poorest regions of the state of São Paulo and Paraná, with the lowest HDI (0,69 mean). Moreover, it is estimated that more than 30% of its population (which is largely rural) live below the poverty line. The local economy relies largely on agriculture (banana and citruses) but is heavily affected by the poor infrastructures relies heavily on the massive use of industrial inputs like pesticides and chemical fertilizers.

The main objective of the Floresta Viva project is to offer a productive and innovative agricultural model, based on agroforestry systems and agroecological practices, capable of regenerate degraded lands and provide a decent livelihood to every farmer, from smallholders to large-scale agricultural projects. This model is inspired by the Syntropic farming, an agricultural model created by Ernst Götsch in Brazil, based on spatial and temporal association of plants and trees following natural forest stratification and vegetal succession, and also inspired by the E.R.A. model (Environmental Revitalization Agriculture) developed by Leontino Balbo, using regenerative agriculture principles for more than 25 years in 25'000 hectares of sugarcane. It is since 2013 that Floresta Viva is developing this model in its own farm, step by step, creating and adapting economically viable techniques and machines, reaching today a 166 hectares plantation that has received the organic certification in October 2018, and is providing job to more than 80 rural workers.

This large-scale transition to a regenerative model, 100% organic, has been successfully operated during the year of 2017-2018, and overall expense has not overpassed 15% compared to a standard conventional project. Even if still incipient, the Floresta Viva project is a good example to understand agronomical and economical challenges and results for agroecological transition in a business landscape. This example is not limited to its size, or production, or geography, since it relies on universal agronomy principles that could be adopted by every agricultural entrepreneur, and the lessons learned could benefit all.

Keywords: Brazil, Agroforestry, Syntropic, Agroecology, ESG.

L10.1_O.05

Benefits of practicing agroforestry – a case study from India

Surendra S. (sks105@rediffmail.com)

Socila Studies, Shemford School, Dehradun, Uttaraknand, India

The agroforestry in India is meant to reducing deforestation and pressure on woodlands by providing farm-grown fuelwood and focuses on improving the major ecosystem services and environmental benefits, namely, the carbon sequestration ; biodiversity conservation ; soil enrichment and the air and water quality improvement, in addition to alleviating poverty. The present study shows that the poplar *(ciliate)* and certain clones of exotic poplar (*deltoids*) have been found to be extremely fast growing trees and well adapted for agroforestry plantations together with wheat and sugarcane crops under irrigated conditions of Uttar Pradesh and parts of Haryana and Punjab in North India. Raising poplar trees on marginal crop and pasture lands incorporates carbon from atmospheric CO2 into biomass and this plantation helps in the establishment of vegetation filters, in which nitrogen and phosphorus in waste water and sewage are used for irrigation and fertilization in short-rotation forestry. It is of particular interest to India where technically advanced purification plants are too expensive. Biodiversity in this agroforestry region is typically higher than in conventional agricultural systems. With two or more interacting plant species in these land areas create a more complex wildlife habitat and found to support a wider variety of birds, insects, and other animals. The agroforestry further fixes Nitrogen of about 50 -100 Kg N/ha/year in the soil, shelters livestock, stabilizes depleted soils from erosion and promotes closed cycling of organic matter and nutrients thus, improving/enriching the soil so that crops are more productive. Poplar is grown to a noticeable extent in plantation programs in the above states because of their market demand and high returns. It has wide industrial use in the manufacturing of paper, matchbox, and plywood among others thus enhancing the rural livelihoods. The author observed that the economic condition of the farmers has improved by practicing agroforestry since the total output per unit area of tree/crop/livestock combinations is greater than any single component alone. It has been estimated that 60,000 hectares equivalent plantations of poplar exists in India. and the author concludes that the poplar trees help in removing atmospheric CO2 and producing oxygen. Further, deep roots of the poplar trees improve ground water quality by absorbing excess nutrients that have been leached below the rooting zone. Therefore, due to their fast growing nature, they serve as renewable resources for future green economies that has added up to a substantial improvement of the economic and resource sustainability of agriculture in India.

Keywords: agroforestry, biodiversity, green economy, poplar, water quality.

L10.1_O.06

Sustaining economic and ecological contribution to local community through participatory agroforestry practice

Prameswari D.[1] (diana_eko@yahoo.com), Sudomo A.[2], E Sebastian G.[3], Perdana A.[3]

[1] *Silviculture, Forest Research and Development Center, Bogor, West Java, Indonesia*; [2] *Silviculture, Agroforestry Research Development Centre, Ciamis, West Java, Indonesia*; [3] *Agroforestry, World Agroforestry Center-ICRAF, Bogor, West Java, Indonesia*

Forest and land rehabilitation involving local community remain the best alternative, and most effective practice for rehabilitation, especially those in relatively densely populated areas. One of the practices used is participatory agroforestry which has been practiced in Java, Sumatra and other islands in Indonesia. Several improved participatory agroforestry practices have been established using several locally adapted and economically valuable commodities in several sites in Java and Nusa Tenggara, Indonesia under the KANOPPI Project. Several commodities such as bamboo (*Gigantochloa atter*), smallholder teak (*Tectona grandis*), medical plant named ules (*Helicteres isora)* and rattan substitute for handicrafts locally known as rumput ketak (*Lygodium circinnatum*) have been planted using this practice and have been contributing to both local community livelihood and ecological aspect surrounding the trial sites from at least 9 trial sites established in Java and Nusa Tenggara islands. Trials and supporting activities under this project have contributed to the livelihood pathway as follows 1). Communities are likely to manage their resource sustainably, 2). Increasing benefits obtained from project activities and 3). New market opportunities and diversifying products that support local economy. Under the current second phase of the project, several activities will be extended and replicated to wider rehabilitation activities not only in Java and Nusa Tenggara but also to other islands in Indonesia in order to produce wider impact.

Keywords: agroforestry, local community, participatory, livelihood.

L10.1_O.07

Walnut and crop yields in walnut orchards intercropped with wheat

Ivezić V. (vivezic@pfos.hr), Stošić M., Zebec V., Popović B., Puškarić J., Ilić J., Jović J.

Faculty of Agrobiotechnical Sciences, Osijek, Croatia

The significance of intercropping is to reduce stress but also to increase productivity. The aim of our research is to investigate the yields in intercropped system of walnut and wheat. The field trial was set up in Eastern Croatia in an 11-year old walnut orchard with alley width of 8m, wheat was sown in 6m wide strips. The field trial consisted of three plots: a) control plot of wheat b) walnut orchard with intercropped wheat and c) walnut orchard without intercropped wheat. The walnut orchard has 10 equally long rows of walnuts. However, walnut yield of first five rows was always around 30% of the total yield, while the last five rows had around 70% of total walnut yield. We have decided to sow crops in the 4 alleys in between first five rows to increase the productivity of this low productive area. After the sowing of wheat in the alleys of first five rows they had walnut yield of 378 kg/ha and wheat yield 4.5 t/ha. Walnut control plot had walnut yield of 746 kg/ha and wheat control plot had wheat yield of 6.7 t/ha. In relative numbers the walnut yield was 51% (0.51) of the walnut yield in the walnut control plot and wheat yield was 67% (0.67) of the wheat yield in the wheat control plot. Altogether it comes out that intercropped plot had land equivalent ratio (LER) of 1.18 which means that by intercropping wheat in this rows of walnut of low productivity we have increased the production of this low productive area in comparison to high productive area by 18%.

Keywords: agroforestry, intercropping, yield, walnut, wheat.

L10.1_O.08

Assessment of the economic and environmental benefits of on-farm agroforestry practice in Northwest Vietnam

Do H.[1] (hung.do.van@slu.se), La N.[2], Pham T.[2], Nguyen T.[2]

[1] *Crop Production Ecology, Swedish Univ. Agricultural Sciences SLU, Uppsala, Sweden*; [2] *World Agroforestry (ICRAF), Hanoi, Vietnam*

Maize (*Zea mays*) cultivation in Northwest Vietnam has dramatically increased on the formerly shifting cultivation lands since the 1990ies, where more than half the area has slopes of over 20 degrees. Traditional cultivation practices in the region, mainly based on intensive tillage combined with burning crop residues, had resulted in severe erosion, soil degradation, reduced crop productivity and significant environmental impacts. However, farmers still apply monoculture maize in sloping lands. The main reason is because they lack financial backup to shift into new practices. The study aimed to assess the economic and ecological benefits of agroforestry practice in the context of the upland areas in Northwest Vietnam. This study presents the actual benefit assessment of a designed agroforestry system with late fruiting-longan (*Dimocarpus longan)* together with maize and forage grass strips (guinea - *Panicum maximum*) during 2012-2017 using cost and benefit analysis, land equivalent ratio (LER) and quantification of soil loss. The two monoculture systems, mono-maize and mono-longan, were used for comparison. The results showed that the longan+maize+forage grass system gave an early income from forage grass and maize. Forage grass yielded 17 ton ha^{-1} $year^{-1}$. Maize yield was not significantly different from mono-maize and the average dry grain yield was 4.5 ton ha^{-1} yr^{-1}. The longan trees started to bear fruit in the 4th year; it yielded 0.06 ton ha^{-1} which increased to 0.38 ton ha^{-1} in the 6th year. Longan in mono-longan system also started bearing fruits in the 4th year. In terms of profitability, the net profit of the mono-maize was initially 23 million VND ha^{-1} yr^{-1}. However, it decreased to 4 million VND ha^{-1} yr^{-1} in the 6th year, mainly due to drop in maize price. Mono-longan system was only reaching a profit of 3 million VND ha^{-1} in the 6th year. Meanwhile, the longan+maize+forage grass system had a positive profit of 18 million VND ha^{-1} in the 2nd year which increased successively to 33 million VND ha^{-1} in the 6th year. The break-even point of the longan+maize+forage grass system was after one year of planting, and the payback period of the loan-credit provided to farmers was one year after planting. The LER from 2013 to 2017 of the longan+maize+forage grass system ranged from 1.05 to 1.84. Regarding the effectiveness in controlling soil loss, longan+maize+forage grass system reduced soil loss by 50, 56 and 77% in comparison with mono-maize system in 2015, 2016 and 2017, respectively. The data proved that the evaluated agroforestry system gave higher productivity, profitability, early returns to investment and significant reduced soil loss as compared to monocultural systems. We will continue monitoring and evaluating different agroforestry systems and tree species to provide the options for agroforestry development in sloping land area in Northwest Vietnam.

Keywords: Agroforestry, Monocultural systems, Productivity, Profitability, Reduce soil loss.

L10.1_O.09

Activity analysis of coffee growers in complex agroforestry systems, understanding the farmers' practices

Durand L.[1] (l.durand@istom.fr), Azéma G.[2], Justes E.[3], Leblanc S.[2], Lamanda N.[4], Allinne C.[5]

[1] *UMR SYSTEM, CIRAD, Turrialba, Costa Rica*; [2] *LIRDEF, Université de Montpellier, Montpellier, France*; [3] *UMR SYSTEM, CIRAD, Montpellier, France*; [4] *ISTOM, Angers, France*; [5] *CATIE, Turrialba, Costa Rica*

In coffee based agroforestry systems, biodiversity management by farmers is a promising lever for innovation to promote system sustainability and increase income. We hypothesized that the co-design of agroforestry cropping systems based on ecological process, and on implementation of innovative practices have to take into account the reality of the technical work as well as the farmer concerns and the knowledge leading to the actual plot management. The aim of this study is to examine how coffee farmers understand the diversity of their agroforestry systems and how do they manage it through their practices.
We have developed an original methodology based on the activity analysis applied to the study of the shade trees regulation practices in the agroforestry coffee plot by coffee growers. The activity analysis is interested in human activity with a view to transforming and designing work situations. According to Theureau (2010), considering enaction paradigm, activity is considered as a dynamic of asymmetrical interaction between an actor and his environment[1]. Thus, human action is not considered to the actual achievement of a predetermined program resulting from the application of decision rules[2]. First, semi-structured interviews were conducted to understand the systems and the cropping practices drivers. Then, practices were studied in real situation, through participant observation and the use of methods of verbalization during practice, of self-confrontation and farmer-guided practice[1]. This study took place in Costa Rica (Turrialba). Agroforestry systems consists of coffee (C*offea arabica*) and various types of shade tree species.
Our results highlight each action carried out by the coffee grower, associated with farmers indicators, considered as the factors that farmer take into account in the agroforestry environment against the background of his concerns, knowledge or habits. These indicators inform about complexity of interactions between the coffee grower and his environment. This interaction occurred at several levels: for a systemic management (to favor the ecological processes like disease regulation), for an ergonomic management (to favor movements, or reduce risk of injury), for a personal management (based on an affective relation with the biotope). In that respect, shade tree regulation is not only intended to increase the incident light energy received by coffee, but also driven by other motivations. The re-design of innovative and sustainable cropping systems has to take into account the interaction between diversity of human situations and the agroforestry system complexity. In this context, how can practices be transformed? How can we support farmers to think about their own practices and initiate changes specific to them? The activity analysis is an efficient framework to nourish the thinking on current management practices and a promising way to support their progressive transformation in complex agroforestry systems.

Keywords: co-design, agroforestry system, coffee growing, activity, farmers indicators.

References:

1. Theureau, 2010, Revue d'anthropologie des connaissances, 290, doi: 10.3917/rac.010.0287.
2. Astier et al., 2003, Recherche & Formation, 121-122, doi: 0.3406/refor.2003.1833.

L10.1_O.10

Changing the discourse from 'tree planting' to 'tree growing' to achieve restoration targets through agroforestry

Duguma L.[1] (l.a.duguma@cgiar.org), Nzyoka J.[1], Minang P.[1], Betemariam E.[2], Jamnadass R.[3], Borona P.[1], Carsan S.[3], Bah A.[4]

[1] *Landscape Governance, World Agroforestry Centre, Nairobi, Kenya*; [2] *Land Health, World Agroforestry Centre, Nairobi, Kenya*; [3] *Trees Productivity and Diversity Theme, World Agroforestry Centre, Nairobi, Kenya*; [4] *Landscape Governance, World Agroforestry Centre, Banjul, Gambia*

Every year, millions of dollars are spent on tree-based restoration activities. Over the last few decades there are few success stories of such interventions and even those do not match the anticipated objectives for which the resources were spent. News articles announcing tree planting campaigns accomplishing millions of seedling plantings are not uncommon. Despite all these, in many countries vegetation cover has not improved proportional to the investment. The objective of this paper is to highlight the main underlying challenges that need to be tackled if restoration through tree-based interventions are to be successful.

The key challenges are as follows. 1) Often tree planting is stated as a goal of an intervention, rather it should be tree growing. 2) Planning cycles of national governments which often implement such tree-based interventions are annual, hence have insufficient resources to support tree growing. 3) In many developing countries priorities shift every year. Environmental issues are of less priority in relation to other short-term pressing societal needs, limiting the funding for such activities. 4) Performance indicators are often number of trees planted or area planted, not number of trees grown, or area of land covered with grown trees. 5) Most projects operate on a short time frame (1-3 years) while many species (e.g. indigenous ones) need more than 3 years to sufficiently grow. 6) Even in most projects, despite having adequate project duration, emphasis on the after-planting management is limited. 7) There is very weak tree tenure to formally transfer the management of planted trees to local communities who reside in the landscapes over a long period of time.

For investments in tree-based interventions to lead to anticipated results (i.e. restored green vegetation areas) the following measures are recommended: 1) Donors, government agencies and any other stakeholder engaged in tree-based interventions should realize that tree planting is a one-time event and tree growing is a process involving management of planted trees. Hence, project or interventions focusing on a one season activity of tree planting should not be promoted as it results in waste of resources. 2) Strategies to strengthen the ownership of the restoration efforts by local actors and communities should be strengthened. This helps communities to take over the management of the planted seedlings even if the projects were short-term. 3) If there is limited local capacity, donors should ensure a clear justification and strategy by the implementors exists to continue managing the planted trees. 4) Unless such strategies are in place, governments and donors should not approve any one-season tree planting activity. 5) Incentives for local communities to take up the management during and after planting should also be crafted. 6) Finally, the basis for restoration discourse should be tree growing, not tree planting.

Keywords: tree Planting, tree growing, planning, indicators, incentives.

L10.2_O.01

Agroforestry food product development: enhancing food security and livelihoods using the baobab tree in Kilifi, Kenya

Meinhold K.[1] (kathrin.meinhold@hochschule-rhein-waal.de), Njiru A. M.[2], Schüring M.[3], Stevens A.[4], Darr D.[1]

[1] *Rhine-Waal University of Applied Science, Kleve, Germany*; [2] *Wild Living Resources, Kilifi, Kenya*; [3] *ttz Bremerhaven, Bremerhaven, Germany*; [4] *PhytoTrade Africa, London, United Kingdom*

The baobab tree (*Adansonia digitata* L.) occurs naturally throughout the drier parts of Sub-Saharan Africa. Since its wood cannot be utilized as timber, and the fruits and other parts of the tree are appreciated by local populations for a number of uses, baobab trees are often preserved on agricultural lands whereas other trees are cut down - creating natural agroforestry systems. The fruit pulp of the baobab tree is rich in vitamin C, minerals and has pre-biotic and antioxidant properties. However, the potential baobab can have in Eastern Africa on improving local diets and livelihoods is not yet fully exploited. Processing of agroforestry food products such as baobab by rural producers or small-scale enterprises can considerably contribute to local food security, employment, alternative household income and improved livelihoods. The development and launching of new products has key influence in achieving such objectives since it contributes to continuous business success and growth of the involved enterprises.
Such considerations are currently being addressed and put into practice within the BAOFOOD project. The project aims to promote the domestication, production, market development, processing and consumption of baobab for the improvement of food security, nutrition and rural livelihoods in Kenya and the Sudan. The project's ultimate goal is to establish a community-based processing unit to sustainably produce and supply highly nutritious baobab products for home consumption and local and regional markets.
Approx. 80 farmers with baobab on their agricultural land are involved in the community-based processing unit. These farmers are currently being trained in the sustainable production, harvesting, and processing of baobab. Furthermore, novel ideas for the integration of baobab fruit pulp into traditional Kenyan recipes for dietary enrichment are currently being developed and tested. This approach gives local baobab producers and processors, often characterized by limited resources and expertise for product and business development, the opportunity to collaborate with stakeholders across the baobab value chain, research institutions, or regulatory bodies. While traditionally the development of new, marketable products has primarily been approached from the perspective of the companies involved in production and sale of such products, it is increasingly recognized that successful product innovation is the outcome of a collective and interactive effort rather than the achievement of a single person or firm. The approach followed in BAOFOOD gives the opportunity to not only contribute to food security and improved livelihood objectives but also to help build local entrepreneurial skills and verify the applicability of this more unconventional product development pathway. The paper describes the integrated approach applied by BAOFOOD in more detail and also presents initial results of the agroforestry food product development work.

Keywords: Underutilized Trees, New product development, Community-based processing, Food security.

References:

1. Gebauer et al., 2016, Genet Resour Crop Evol, 377–399, DOI 10.1007/s10722-015-0360-1.
2. Meinhold et al., 2018, Ernährung im Fokus, 313-317.

L10.2_O.02

Can agroforestry enhance ecosystem services provision without reducing productivity?

Kuyah S.[1] (kuyashem@gmail.com), Whitney C.[2], Jonsson M.[3], Sileshi G.[4], Öborn I.[5], Muthuri C.[6], Luedeling E.[7]

[1] *Department of Botany, Jomo Kenyatta University of Agric & Tech, Nairobi, Kenya*; [2] *Department of Horticultural Sciences, Unversity of Bonn, Bonn, Germany*; [3] *Department of Ecology, Swedeish University of Agric. Sciences, Uppsala, Sweden*; [4] *University of KwaZulu-Natal, Pietermaritzburg, South Africa*; [5] *Department of Crop Production Ecology, Swedeish University of Agric. Sciences, Uppsala, Sweden*; [6] *World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [7] *Department of Horticultural Sciences, University of Bonn, Bonn, Germany*

Agroforestry (AF) is an important contributor to global efforts that seek to address climate change and maintain or increase ecosystem services. AF provides food and other products, while improving soil fertility, erosion control, water regulation and other regulating / maintenance ecosystem services, the supply of which varies from place to place and often includes trade-offs. Comprehensive evaluations of the overall effect of AF on ecosystem service provision in sub-Saharan Africa (SSA) are lacking and it is difficult to tell the degree to which different ecological conditions and management influence this potential. We conducted a meta-analysis to quantify effects of AF on crop yield, soil fertility, erosion control and water regulation in SSA. The analysis focused on 126 papers comparing AF and non-AF systems. Average crop yield was almost twice as high in AF as in non-AF; soil fertility improved by a factor of 1.2, control of runoff and soil loss was five and nine times better with AF, and infiltration was three times higher in AF compared to non-AF across all ecological conditions. We conclude that management of woody perennials in AF systems can provide multiple ecosystem services while improving productivity of crops.

Agroforestry provides woodfuel and other products that would otherwise be obtained from forests, reducing pressure on neighbouring forests and the time it takes to look for these commodities. Trees in agricultural landscapes also improve crop yield by regulating microclimate and improving soil fertility. Photo credit: Ylva Nyberg

Keywords: Agricultural productivity, Soil fertility, Runoff, Soil erosion, Trade-offs.

References:

1. Kuyah et al. 2017. in: Agroforestry: Anecdotal to Modern Science. Dagar JC., Tewari VP. pp. 797–815
2. Kuyah et al. 2016. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 12, 255–273.
3. Luedeling E., Shepherd K. 2016. Solutions 7:46-54

L10.2_O.03

Long-term effects of hedgerow intercropping on maize productivity in the Central Highlands of Kenya

Mugendi D.[1] (danielmnjiru@gmail.com), Ngetich F.[2], Mucheru-Muna M.[3], Njogu-Murithi E.[4], Mugwe J.[5]

[1] *Agricultural Resource Management, University of Embu, Embu, Embu, Kenya*; [2] *Land and Water Management, University of Embu, Embu, Embu, Kenya*; [3] *Environmental Science, Kenyatta University, Nairobi, Kenya*; [4] *Agricultural Resource Management, University of Embu, Embu, Kenya*; [5] *Agricultural Resource Management, Kenyatta University, Nairobi, Kenya*

Declining crop productivity is a major challenge facing smallholder farmers in central highlands of Kenya. This decline is caused by continuous cultivation of soils without adequate addition of external inputs in form of manures and fertilizers. With this background, an on-station trial was initiated at Embu in 1992 with the aim of evaluating the feasibility of using two leguminous shrubs; *Calliandra calothyrsus* and *Leucaena leucocephala* as hedgerow for improving food production. The objective of this study was to evaluate the long term effects of hedgerow intercropping on maize yields and soil fertility status. After over 20 years of implementation, the results indicate that, *Calliandra calothyrsus* and *Leucaena leucocephala* biomass transfer with half recommended rate of inorganic fertilizer treatments gave the best average yields of 3.3 Mg ha-1. *Calliandra calothyrsus* alley cropped with prunings removed treatment recorded the lowest maize yield of 1.2 Mg ha-1. Though treatments with *Calliandra calothyrsus* biomass transfer had similar yields compared to those of *Leucaena leucocephala* biomass transfer, all the treatments that were *Leucaena leucocephala* alley cropped did better than *Calliandra calothyrsus* alley cropped, both with prunings incorporated and prunings removed. On average, integration of organic and inorganic sources of nutrients gave higher yields compared to all the other treatments. Over time, the soil fertility parameters changed significantly with soil pH, Ca, Mg, P and OC decreasing in all treatments with the exception of K and total N where there was no significant change in their amounts. This might explain the reason why the hedgerow intercropping technology has been abandoned by many small scale farmers.

Keywords: Leguminous shrubs, biomass transfer, maize yields, Calliandra calothyrsus, Leucaena leucocephala.

L10.2_O.04

Effect of spacing on the yield in intercropping of poplar and alfalfa (case study: Alborz Research Station, Karaj, Iran)

Asadi F. (fasadi@rifr-ac.ir)

Research Division of Natural Resources, Mazandaran Agricultural and Natural Reso, Sari, Mazandaran, Iran

In recent years we were witnessing of decrease in people's interest towards poplar cultivations due to low income. It is so important for farmers to benefit the steady income from their farms. Therefore, a combination of poplar and agricultural crops is the best alternative. The aim of the study was to assess the efficiency of mixed Poplar cropping with alfalfa. In this study *Populus nigra* betulifolia seedlings were planted in a randomized complete block design with 3 replications and 4 mixed poplar and alfalfa treatments with tree spacing of 3×4, 3×6, 3×8, and 3×10 m as well as 2 control treatments with only alfalfa or only trees (planted at 3×4m). Plot size was 1200 m2. Ten distinctive growth attributes for poplar and alfalfa were recorded during the nine years. The data were analyzed using statistical methods. Results showed that the most volume growth appeared in mixed treatments at spacing of 3×4 and 3×8 m with 18.4 and 11.1 m3 respectively. The most dry weight production of alfalfa was obtained in the alfalfa alone, and 3×10 m with 7507 and 4788 kg per hectare, respectively. The recommended planting spacing for trees in the poplar/alfalfa intercropping system is 3×6m depending on the site conditions. Meanwhile, for some attributes, we observed significant differences among interaction between treatments and years. In order to reduce the dependency on forests, development of Poplar intercropping, was suggested as a beneficial way.

2-year-old trees with alfalfa (above) and same trees at age 4 (below)

Keywords: Hedgerow intercropping, Poplar, production, spacing.

References:

1. Burgess, et al, 2005, Agroforestry Systems, 157-169.
2. Misra, et al, 1996, Indian Forester, 65-68.
3. Rivest, et al, 2009, Journal of Environmental management, 432-440.

L10.2_O.05

Rubber-Based Agroforestry System in South China: Gaining Ground with Farmers

Padilla H. (hilpaddy@kfbg.org), Li J.

Kadoorie Conservation China, Kadoorie Farm and Botanic Garden, Hong Kong, Hong Kong SAR China

China is the world's largest natural rubber-consuming country and ranks 6th in production. Rubber in Hainan occupies 16% of the land. Almost every household in the mountains depends on rubber. Forests are cleared and planted with rubber. The biodiversity of the forests is lost, its ecological services diminished, and further degraded by chemicals. Ecologists call for diversification but identifying acceptable intercrops proved challenging. Luckily, high value crops in an Analog Agroforestry had been accepted by the profit-minded farmers. The medicinal *Alpinia oxyphylla*, dumpling leaves *Phrynium capitatum*, high value timbers *Aquilaria sinensis* and *Dalbergia odorifera* were intercropped with rubber. Chinese bee and stingless bees that pollinates the cardamom and increase its yield were integrated. Farmers are getting higher income from cardamom than rubber. Spraying was reduced. Trimmings from cardamom increased soil organic matter and water retention. The low-lying cardamom was critical in soil erosion. The adoption is gaining ground and we are mapping the adoption scale. This concept provides alternative to the mono-crop rubber plantations throughout Indochina.

Keywords: Rubber, Analog agroforestry, Hainan.

L10.2_O.06

Smallholders' oil palm agroforestry adoption: an opportunity to improve productivity and sustainability?

Budiadi B. (budiadi@ugm.ac.id), Ari S., Marhaento H., Imron M. A., Permadi D. B., Hermudananto H.

Faculty of Forestry, Universitas Gadjah Mada, Yogyakarta, Indonesia

Oil palm has become an important export commodity for Indonesia and has been cultivated by both smallholders and large scale companies mainly as monoculture plantations. Research suggested that this massive monoculture practices have led to adverse impacts to natural and social systems. Smallholders encounter difficulties to cope with the fluctuating commodity price and extreme climate events such as long dry seasons. We argue that agroforestry could become a promising and realistic alternative to deal with these problems. This is indicated by the voluntary adoption of oil palm agroforestry system by smallholders although this occurred at limited scales. This article aims at analysing the adoptability, productivity and sustainability of oil palm agroforestry practiced by smallholders. We employ a hybrid method which combines qualitative and quantitative analysis. This research suggests that the adoption of oil palm agroforestry decrease the household dependency on monoculture commodity and thus improve the household resilience in terms of income. However, our findings suggest that oil palm agroforestry has been challenged by the tendency of decreasing oil palm fresh bunch fruit production. Species selection and crop combination strategy become the key factors to improve the productivity of oil palm agroforestry. We suggest that long term and regular observations as well as longitudinal data are required to paint more comprehensive picture on the contribution of oil palm agroforestry to the improvement of ecosystem functions.

Keywords: oil palm agroforestry, Indonesia, adoptability, productivity, sustainability.

L10.2_O.07

30 years of agroforestry poultry system against climate change in Sarthe (West of France)

Guillet P. (philippe.guillet@pl.chambagri.fr), Lemarié C.

Sarthe, Chambre d'Agriculture Pays-de-la-Loire, Le Mans, France

One of the oldest poultry producer group is established in Sarthe at the West of France. Called "Les Fermiers de Loué", they are involved in trees' plantation since the seventies. Agroforestry system appeared obvious as trees enhance poultry health and welfare, poultry exit and poultry farming performance. Nowadays, climate change is making agroforestry poultry system more interesting. However, farmers and advisors are facing some issues. Firstly, trees species selection is far more difficult because of climate change (dryness, temperature, water regime and soil). Secondly, poultry farming management is evolving because of climate chang (shade, temperature). Thirdly, as a transversal issue, biodiversity conservation is taken into account (trees species diversity, native species, melliferous species). Finally, poultry agroforestry system is linked with other productions. Indeed, it contributes to agronomy performance and animal's food with fodder trees.

Looking back over 30 years of experiences, we notice an increase of obstacles condemning the development of poultry agroforestry systems. Firstly, we observe a lack of knowledge among farmers which makes more difficult creation and management of poultry agroforestry systems. Secondly, we have technical impediments. Actually, we are facing poor quality of young plants and poor soil preparation which prevent trees' regrowth and development. Thirdly, wood may not be remunerated properly as sale couldn't cover initial investment.

A poultry agroforestry system in Pays-de-la-Loire: chickens in the shade of trees

Keywords: agroforestry poultry system, climate change.

L10.2_O.08

Evaluation of chronological changes of trees and coffee bushes in permanent plots within a gradient of coffee management

Gómez-Martínez M. J.[1] (mjgomez@ut.edu.co), Ortíz-Ceballos G.[2], Cerdán C. R.[2]

[1] *Facultad de Ingeniería Agronómica, Universidad del Tolima, Ibagué, Tolima, Colombia*; [2] *Facultad de Ciencias Agrícolas, Universidad Veracruzana, Xalapa, Veracruz, Mexico*

The design of coffee agroforestry systems (CAFS), which simultaneously fulfill their function of conservation and production, requires a better understanding of how diverse tree species are interacting. Interactions would be either positive ones (facilitation), or negative ones (trade-offs), on the microclimatic and pedological conditions within plantations. It is quite important to access to real and constant data through permanent plots in farms of producers. We selected 15 coffee plantations with heterogeneous management, in the Coffee Region of Coatepec, Veracruz, Mexico, which is originally an area of cloud forest, with approximately 200 years of coffee introduction history. Plots were demarcated (50 m x 20 m), 3 transects were drawn (50 m x 2 m) and sampling points were located every 10 m (18 points plot^{-1}). The density of sowing, age of the crop, varieties and management of the plantation were registered. Additionally, the number of trees with DBH> 10 cm, crown area, height and plant species, number of strata, canopy percentage, area index of coffee trees and trees, and leaf litter percentage was counted. The variables were compared by type of AFS by ANOVA and mean comparison tests (LSD, $\alpha = 0.05$). The richness, abundance and diversity of the trees were calculated. 2265 coffee plants were measured, of the varieties Catimor (31.6%), Sarchimor (29.4%), Costa Rica (21.8%), Mundo Novo (10%), Arabica (4.4%), Caturra (2.2%) and Oro Azteca (0.6%). These varieties are preferred since they require little direct sunlight and can be grown in shaded environments. Coffee densities differed between CAFS and range from 3383 to 7800 plants ha^{-1}. A total of 178 tree individuals were registered, comprising 17 families, 24 genera and 33 species. The Fabaceae family stands out with 11 species that represent 60% of the abundance. The most common genus for its richness is *Inga*, with 6 species and with 45% of the arboreal individuals. As the management of coffee plantations intensifies, producers select varieties resistant to coffee rust and increase the abundance of the tree component, however, with less diversity. Contrary to traditional producers, who leave in their plots few but large trees, and whom manages a mixture of coffee varieties. The assembly of the tree species in the CAFS is influenced by the decisions of the producers regarding the productivity of their plots, who mainly direct their efforts to the productivity of the coffee trees, maintaining tree coverage, which is positive for the conservation of biodiversity and provision of ecosystem services. For example: the composition of tree species is crucial to provide some nutrients for the development of coffee trees, however, this will depend on the agro-ecological conditions of the area.

Keywords: Agricultural research, Agroforestry systems, Farm management, Knowledge information, University teaching.

L10.2_O.09

What Sustains Nepalese Agroforestry Practices?

Amatya S. M.[1] (swoyambhu_amatya@yahoo.com), Nuberg I.[2], Cedamon E.[2]

[1] *Faculty of Forestry, Agriculture and Forestry University, Kathmandu, Nepal*; [2] *Faculty of Forestry, University of Adelaide, Adelaide, Australia*

Farmers in the hills of Nepal have practiced agroforestry for centuries. For much of this time, farmers grew trees to meet subsistence farming needs, but the nature and extent of these practices depended on the size of their land and the accessibility of fuelwood and fodder from community forests. Over the last decade, much has changed in the rural areas of the Middle Hills. Household livelihood expectations have changed, many families have individuals working in cities or outside Nepal which has increased household income and reduced labour availability. Throughout this period, the role of agroforestry in Nepalese farming system has remained important, but the need for improved agroforestry systems and better knowledge of the various agroforestry options and market possibilities has increased.
In order to examine the current agroforestry systems and practices in Nepal, and what factors are responsible to sustain a given practice, a survey was carried out in Eastern, Central and Far-western districts of Nepal. The survey showed that number of practices has increased since the 1999 when agroforestry as science was just new in Nepal.
The survey also showed that agroforestry practices would further scale up if the selection of tree species from among some three dozen indigenous and one-dozen successful exotics vis-à-vis their silvicultural characteristics and local suitability is known and practiced accordingly. Proper choice of shrubs and herbs of economic value for commercial and general purposes, such as, medicine, essential oil, fibres, floss, and food could be encouraging for agroforestry practitioners. Capacity building should focus on skill development, market and its linkages and optimal use of available resources, optimal use of spacing, livelihood development and their enhancement. The role of Local and International Non-Governmental Organizations are very effective in capturing new innovations in agroforestry practices.
This study shows that conducive policy, peoples' friendly legislative act and regulations are very important in sustaining agroforestry practices. Marketing of agroforestry products and scale of economy are also very important in sustaining it.

Keywords: Agroforestry, Sustainability, Marketing, NGOs/ INGOs, Policy/ Act.

References:

1. Amatya, S. M. 2018 Banko Janakari, Vol. 27. No.2, 33-45
2. Amatya S. M., Nuberg, I., Cedamon, E., and Pandit, B. H. 2015.Small-scale and Community Forestry and
3. Amatya S. M., Nuberg, I., Cedamon, E, 2018. 181. Agriculture and Forestry University (Book)
4. Amatya, S. M. 1996. Banko Janakari, Vol. 6, No. 2,
5. Amatya, S. M and Lamsal, Prakash, 2017Journal of Forests and Livelihood15 (1)

L10.2_O.10

Evaluating factors influencing heterogeneity in agroforestry adoption and practices within smallholder farms in Kenya

Nyaga J.[1] (J.Nyaga@cgiar.org), Barrios E.[1], Muthuri C.[1], Oborn I.[1], Matiru V.[2], Sinclair F.[1]

[1] *World Agroforestry Centre, Nairobi, Kenya*; [2] *JKUAT, Nairobi, Kenya*

Understanding the structure, densities and utilization of tree populations in agricultural landscapes is useful in determining the species influencing agroecosystem function. Our study evaluated agroforestry adoption and practices within smallholder farms in a former large-scale maize growing area of Trans Nzoia County, Rift Valley Province, Kenya. This was followed by investigation of factors influencing heterogeneity in the adoption and practices. The factors include: household resource endowment, land tenure and time under current management. Five settlement schemes which were formerly large estates dominated by maize mono-cropping were selected for the current study. Tree inventories of the farms were obtained through transect walks across each settlement. A total of 123 farms were assessed representing households of different resource endowment levels, tenure and number of years under current management. Different analyses were carried out including farm size and tree number, tree density, tree diversity and utilization of the dominant tree species. In total, we identified 44 tree/shrub species, 24 of which were indigenous and the rest exotic. However, the exotic tree species dominated strongly in abundance with *Eucalyptus spp*. being the most frequent taxon and constituting 34.6% of all trees. Species richness was found to be low compared to other agricultural landscapes in the region. Resource constrained households were found to prefer fruit tree species and maintained high tree diversity on their farms. Households with secure tenure had higher tree diversity than those without who had higher species richness and opted for fast growing fodder and fertilizer/firewood trees. Younger farms had fewer trees but higher species richness than older farms. The study, therefore, explains heterogeneity in agroforestry adoption in terms of variation in household resource endowment, land tenure and time under current management levels.

Keywords: Tree diversity, Resource endowment, Land tenure, Time under current management, Small-holder farmers.

L10.P.01

Effect of selective pruning and thinning on tree diversity and biomass productivity in fallows of Sudanian woodlands

Assédé E. S. P.[1] (assedeemeline@gmail.com), Azihou F. A.[2], Mariki S. B.[3], Geldenhuys C. J.[4]

[1] *Université de Parakou, Parakou, Benin Republic*; [2] *University of Abomey-Calavi, Abomey-Calavi, Benin Republic*; [3] *Sokoine University of Agriculture, Morogoro, Tanzania*; [4] *University of Pretoria, Pretoria, Republic of South Africa*

Background
In fallow systems, woodlands stands of Sudanian zone are under different management regimes, including total protection and controlled use with mitigated results.
Aims
This study aims to determine the effect of selective pruning and thinning on i) tree species richness, and ii) potential production of standing biomass in fallows of Sudanian woodland stands.
Method
In Sudanian woodland of Benin, three random blocks (repetition) of 20 m x 20 m each were demarcated in homogeneous stands and divided into three treatment plots of 10 m x 10 m each i) T1: no harvesting, ii) T2: 30% thinning and pruning, iii) T3: 60% thinning and pruning. Tree species richness and growth in height of individual ≥ 1m were measured each 6 months between 2015 and 2016.
Results
The plant species richness and composition varies with treatment and woodland development stands. Whatever the treatment applied, there was a deficit of 68.28 % to 85.59 % in biomass to cover local population need estimated in biomass at 9,515,850.22 kg/year. The best tree height (Figure 1) and biomass production (3,018,736.25 kg/year) were obtained with 30 % thinning and pruning (T1). Compared to T1, the biomass produced with no thinning and pruning and with 60 % thinning and pruning increased the deficit in biomass respectively by 17.31 % and 4.83 %.
Conclusion
Moderate thinning gives the best result in early woodland's development stands, while more severe thinning gives the best result at later development stands.

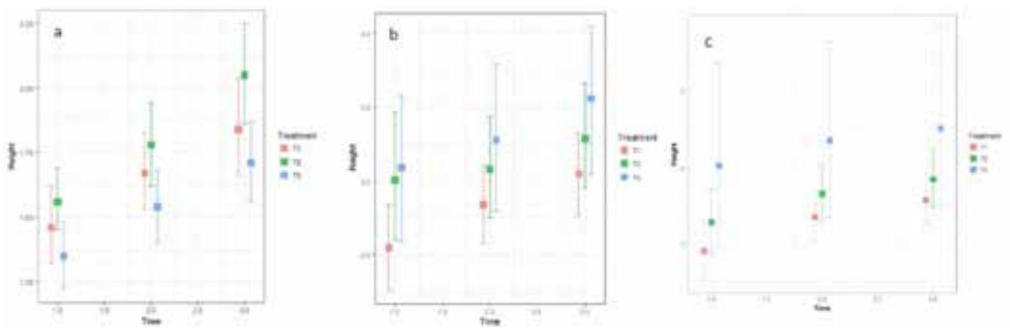


Figure 1. Effect of treatment on tree height growth in woodland development stages/stands:
a: stage 1; b: stage 2; c: stage 3.

Keywords: Biomass, tree diversity, thinning and pruning, Sudanian woodland, Benin Republic.

L10.P.02

Impact of land use type on demographic and spatial structures of *Adansonia digitata* in the semi-arid region of Benin

Assogba D.[1] (doris1assogba@gmail.com), Salako V.[2], Fantondji B.[2], Assédé E. S. P.[3], Assogbadjo A.[4], Chirwa P.[1]

[1] *Department of Plant & Soil Sciences, University of Pretoria, Pretoria, South Africa*; [2] *Faculty of Agronomic Science, UAC, Laboratory of Biomathematics and Forest, Calavi, Benin*; [3] *Faculty of Agronomy, University of Parakou, Parakou, Benin*; [4] *Faculty of Agronomic Science, UAC, Laboratory of Applied Ecology, Calavi, Benin*

Background

Baobab (*Adansonia digitata* L.) is an important plant species to people's livelihoods through provision of food, fibre and medicine. Baobab products are increasingly being commercialized and exported around the world which calls for an understanding of the status of the species natural stands.

Main

This study was conducted to assess the extent of conserve stands of baobab in different land use type in the semi-arid region of Benin, West Africa.

Data collection

The study was conducted within the Sudan agro-ecological zone of Benin specially in the Pendjari National Park (PNP), and surrounding farmlands, and Controlled Occupation Zones (COZ). Tree girth, tree total height, number of seedling and sapling was measured in 12 sample plots of 250m x 250m. Additionally, all baobab individuals irrespective of their size and all other trees exceeding 5 cm in diameter at breast height (dbh ≥ 5 cm) were mapped.

Data analysis

Tree density, diameter and height were computed and compared among the four sites using one-way analysis of variance followed by Fisher's LSD test. Diameter size class distribution (SCD) slope obtained from the regression analysis was used as indicator of the population structure. Population stability was assessed with three metrics: the Simpson index of dominance (S), permutation index (P) and the quotient (Q) between successive size classes. Univariate and bivariate pattern of trees were studied with the pair-correlation function.

Results

The farmlands had high number of young trees and adult tree densities (stem.km-2) (181.3 ± 155.4 and 453.3 ± 190.9), followed by COZ (16.0 ± 16.0 and 106.7 ± 33.3) and PNP (32.0 ± 16.0 and 85.3 ± 24.4). Tree diameter and the total height did not differ significantly among land use types ($p > 0.05$). All land-use types had negative SCD slope showing that there were more individuals in smaller size-classes than in larger size-classes. However, the flattest of slope (between -0.001 and -0.006) suggests low recruitment. Values of Simpson dominance (> 0.1) and permutation (> 0) indices in addition to the fluctuations of the quotients of the density of successive size classes suggest unstable stands with episodic recruitment and mortality, particularly in the COZ. In general, *A. digitata* showed a random spatial distribution for both young and adult trees, irrespective of the land use types.

Conclusion

This study showed that higher density of baobabs occur outside protected areas and the populations are mostly unstable, calling for active conservation in protected areas and promoting domestication of baobab in farmlands.

Keywords: population structure, protected area, farmland, spatial distribution, Pendjari National Park.

References:

1. Benot et al., 2013. Journal of Ecology, 101: 626–636
2. Munthali et al., 2013. Agroforestry Systems, 87: 117–130
3. Venter et al., 2013. Forest Ecology and Management, 303: 113–120
4. Fandohan et al., 2011. Genet. Resour. Crop. Evol. 58: 299–309
5. Assogbadjo et al., 2009. Agrofor Syst 75 : 157–165

L10.P.03

Innovative model of herbs production, processing and distribution in Zielawa Valley in Poland

Baj Wójtowicz B. (barbara.bajwojtowicz@bodleian.ox.ac.uk)

Taylor Institution and EIP-AGRI Group, Oxford University and EIP-AGRI Group, Oxford, United Kingdom

"Innovative model of herbs production, processing and distribution in Zielawa Valley" the project run by EIP – AGRI group "Agroforestry in Zielawa Valley" presenting Poland's first agroforestry cultivation model. The aim of the project is to develop and implement a new comprehensive model for the cultivation and harvesting of herbal plants, farm and production management as well as a new herbal processing model. It combines the cultivation of the following plants: a) elderberry with pulmonaria and heath speedwell (Veronica officinalis); b) rugosa rose (Rosa rugosa) and dog rose (Rosa canina) with cloudberry in agroforestry systems. Introduction to the cultivation of several wildly growing species such as, for example, cloudberry, cabbage thistle, pulmonaria, heath speedwell (Veronica officinalis), and nettle is possible thanks to a specific growing technics developed during the project. The EIP – AGRI group through the outcomes this project aims also at bringing a change in Polish legislation resulting in recognition of agroforestry systems and additional financial support for farmers introducing these practices. Also, a gap in the market has been identified wherein there is a lack of food products with a health-enhancing effect produced from quality herbal plants grown in the sustainable environment of agroforestry system. Therefore the project will conclude with the launch of Innovative model of herbs production to the market: herbal teas and spices.

Keywords: Innovative model of herbs production, cultivation of wild plants, sustainable environment of agroforestry system, food products with a health-enhancing effect, farm and production management.

L10.P.04

Developing agroforestry decision-support tools: lessons learned

Bentrup G.[1] (gbentrup@fs.fed.us), Stein S.[2]

[1] *USDA National Agroforestry Center, U.S. Forest Service, Lincoln, NE, United States*; [2] *USDA National Agroforestry Center, U.S. Forest Service, Washington, DC, United States*

Incorporating agroforestry into U.S. agricultural operations has the potential to achieve numerous environmental, economic, and social objectives desired by producers and society. Realizing this potential is a challenging task of determining what opportunities, limitations, and trade-offs exist in each situation. This challenge can be greatly facilitated by the use of decision-support tools. The USDA National Agroforestry Center has developed several decision-support tools that can be used individually or in conjunction to aid in planning and designing agroforestry systems. Examples include:

AgBufferBuilder: A GIS-based program for designing agroforestry buffers around agricultural fields for water quality enhancement.
Design Guidelines: Illustrated field guide for designing multifunctional agroforestry buffers.
NTFP Calculator: A spreadsheet for providing general estimates of income potential from producing non-timber forest products from an agroforestry planting.
Tree Advisor: An online plant selection guide to help planners identify better species of trees and shrubs to achieve a suite of user-defined purposes in the U.S. Great Plains region.

Using an action research approach to evaluate these tools, the USDA National Agroforestry Center has identified several key principles that can be useful to consider when developing effective agroforestry decision-support tools. This presentation will provide lessons learned from this research and evaluation.

Keywords: decision-support, tool, design, guidelines, agroforestry.

L10.P.05

Agroforestry innovations in Poland

Borek R. (rborek@iung.pulawy.pl), Gałczyńska M.

Dpt. of Bioeconomy and Systems Analysis, IUNG-PIB, Pulawy, Poland

Agroforestry (AF) is still not recognised and accepted farming practice in Poland, although it has long tradition. Notwithstanding, lack of unequivocal definitions considering trees on agricultural lands, particularly trees management rules discourage farmers to plant them. More knowledge about agroforestry, and collaboration between experts, local decision makers and practitioners is needed in order to develop local markets of innovative AF products.
In the AFINET project, regional stakeholders identified 32 AF innovations would be useful for Poland. Among them we can define: i) rotation cattle farming in traditional orchards, improving animal welfare, diversifying farmer income and not hampering crops productivity in the same time; ii) beef cattle farming on wooded pastures, improving biodiversity, optimized species composition of grassland, animals health, forest management efficiency and restoring marginal non-used land for agricultural production, in the same time providing good-quality beef, demanded by consumers; iii) production of shade tolerant herbs/medicinal plants under canopy of fruit bushes, particularly adapted to organic farming, allows reducing the impact of summer droughts; iv) planting mid-field microclimate windbreaks, most effective on distances of 12-18h (height of trees), depending on water deficit; composed of high tree species with crown leaf density not exceeding 60-70% during summer and of shrub belt beneath them stopping nozzle effect; v) Forest garden, the system based on companion planting, including forgotten native species and species from other climatic zones to be adapted to the region and used for medical or culinary purposes.
Output of the AFINET project are factsheets, videos and guidelines presenting identified AF innovations that could help rural areas in Poland to be more climate-smart and economically resilient, increase soils and animals productivity and counteract abandonment of agricultural lands.

Keywords: Innovation, Income diversification, Restoring lands to agricultural production, Microclimate, Wooded pasture.

L10.P.06

Moringa oleifera (Lam): a promising species for agroforestry under a changing climate

Boumenjel A.[1] (boumenjel19@gmail.com), Pantera A.[2], Ammari Y.[1]

[1] *Forest Ecology Lab, INRGREF, Ariana, Tunisia*; [2] *Forestry & NEM, AUA, Karpenissi, Greece*

Moringa oleifera (Lam) is a fast growing tree that is gradually getting more attention for its numerous uses. It is often called a «miracle tree» because of its many nutritional, medicinal and industrial potentialities (Leone et al 2015). It is one of the 13 species of the Moringaceae family of shrubs and trees, native to India, getting through time more attention around the world for its great economic importance (Leone et al 2015). It can represent an ideal intercrop for many silvopastoral and silvoarable systems under a changing climate (Mosquera-Losada et al 2018), in particular to locations with limited resources (Fig 1). It grows under a wide range of precipitation and temperature from 250 mm to 1500/2000 mm and from 25 oC to 35 oC respectively but it has been also reported to withstand 48oC in the shade, drought, light freeze (Foidl et al., 2001) and other adverse environments (Price, 2007). A unique feature of this species is that all of its parts (leaves, roots, seed, bark, fruit, flowers and immature pods) are used for different purposes with the medical ones being more popular in traditional and modern medicine (Leone et al 2015). Among its alimentary uses prevails oil production but it can also be used for water purification (Price, 2007). Its wood is excellent for the production of paper pulp, blue dye with its bark used for mats and rope. Its leaf extract contain growth factors which, when sprayed on other plants, increase their yield by 25-30% (Fuglie, 2001).

Fig 1. Moringa plants (14 months old) growing with Phaseolus vulgaris in an arid location in Tunisia

Keywords: silvoarable, multiple uses, Tunisia, Mediterranean, medicinal plant.

References:

1. Foidl et al 2001. The miracle tree: the multiple attributes of Moringa.-Wageningen : CTA; Dakar: CWS
2. Fuglie, 2001. The miracle tree: the multiple attributes of Moringa.-Wageningen : CTA; Dakar: CWS.-17
3. Leone et al., 2015, Int. J. Mol. Sci. 16: 12791-12835
4. Mosquera-Losada et al, 2018, Land Use Policy 78, 603-613
5. Price ML 2007, The moringa Tree. ECHO technical l note. Revised edition

L10.P.07

A low input high density mulberry forage bank contributing to the autonomy of a beef cattle farm in Ariège (France)

Bounab M.[1] (eliel.gonzalez-garcia@inra.fr), Authier M.[2], Brout S.[1], Cadudal M.[1], González-García E.[3]

[1] *Chambre d'agriculture de l'Ariège, Ariège, France*; [2] *Beef Cattle farmer, Espinoux 09500 Mirepoix, France*; [3] *SELMET, INRA, Montpellier SupAgro, CIRAD, INRA Occitanie-Montpellier, Montpellier, France*

Achieving the forage autonomy is a huge step in the goal of agroecological transition of farming systems. It's a priority in the current context of climate change, economic crises and the fluctuations of prices in raw materials and concentrates used for livestock supplementation. The objective was to evaluate, under the conditions of Ariège (France) a high density mulberry (*Morus alba*; 25 000 plants/ha) forage production technology, previously evaluated with very good results in tropics (see references). In collaboration with a voluntary farmer, a 0.2 ha pilot paddock was planted under real life beef cattle production, after previous conventional soil preparation and early stage plant growth in a nursery phase. A monthly monitoring was scheduled during the first-establishment year (i.e. from planting in April 2017 to the first-harvest –standardization cut-, in April 2018). Afterwards, the distribution to animals started. Mulching with on-farm produced straw between rows, and manure allowed efficient weed control and organic fertilization, with a zero-input approach. The plant growth and survival, biomass yield (total and edible forage) as well as its nutritive value and cattle voluntary intake are promising. The first results in agronomic and animal performance demonstrate the feasibility of establishing this technology under temperate conditions with this fodder specie, widely distributed in Europe. However, further efforts are required and the study will continue.

Illustration: After a one year establishment period, the high density mulberry forage bank is ready to support a frequent harvest regime. The forage is harvested at 45-50 cm of height. Several mechanised alternatives still being evaluated. Following a strategy of substituting the expensive concentrate, the high quality on-farm produced forage may be distributed as a whole branch or chopped, which increase ingestion, digestibility and animal performance. A direct controlled grazing system could be also envisaged, even if it has been demonstrated some negative effects on the plantation uniformity, resistance to regrowth and resilience.

Keywords: Forage bank, farm autonomy, Concentrate substitution, on-farm biomass production, Intake and performance.

References:

1. González-García and Martín-Martín, G, 2017, Grass and Forage Science 72, 248–260.
2. Alpízar-Naranjo et al., 2017, Tropical Animal Health and Production 49, 537–546.

L10.P.08

Paludiculture: Agroforestry to support peatland restoration

Budiman I.[1] (ibnu.budiman@wri.org), Wicaksono S.[2]

[1] *Science and Research, WRI Indonesia, Jakarta Selatan, DKI Jakarta, Indonesia*; [2] *Forest, WRI Indonesia, Jakarta Selatan, DKI Jakarta, Indonesia*

Peatland restoration is an important environmental agenda in Indonesia, to combat fire hazards and to reduce GHGs emission. Implementing restoration by enforcing protected areas or blocking drainage canals without addressing socio-ecological relationship and the livelihood needs of local communities, will almost certainly result in failure. This point implies the need to link or integrate three steps on restoration, which are revitalization of livelihood, revegetation, and rewetting to increase water table. Agroforestry appears as one of effective options in revegetation and revitalization of livelihood within restoration. One of the agroforestry systems applied in the peatland restoration is Paludiculture. This research aims to analyze the effectiveness of paludiculture as alternative livelihoods for peatland community, to what extent it can reduce the pressure on communities to clear new lands and increase the likelihood of success of any peatland conservation effort. This research utilizes case study of the implementation feasibility of paludiculture in peatland ecosystem in OKI regency, South Sumatera province.

Keywords: agroforestry, peatland, indonesia, revegetation, revitalization.

References:

1. Gunawan, Haris. 2018. “Indonesian Peatland Functions: Initiated Peatland Restoration and Responsible
2. Medrilzam, Medrilzam, Paul Dargusch, John Herbohn, and Carl Smith. 2014. “The Socio-Ecological Drive

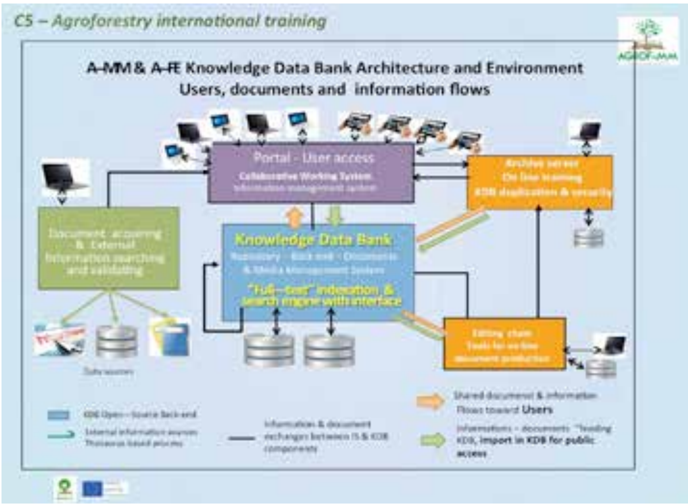
L10.P.09

Knowledge Data Bank, to support Education,Trainings and Development

Burriel C.[1] (charles.burriel@educagri.fr), Herdon M.[2], Escurat J.-M.[3], Tamas J.[4], Balaguer F.[5], Varallay L.[2], Botos S.[2]

[1] *Eduter, Agrosup Dijon, Fontaine les Dijon, France*; [2] *College of Agriculture, Debrecen University, Debrecen, Hungary*; [3] *EPLEA Vosges, Mirecourt, France*; [4] *Forestry and Enviroment, Debrecen University, Debrecen, Hungary*; [5] *AFAF, Montpellier, France*

Agroforestry Education and Development based on the Agrof-MM KDB.
1) Différences between data base and knowledge data bank
The different types of contents : data, figures, .. are stored in data bases, without public access or with poor interfaces. Same for articles, monography,… stored in documentary bases or in repositories, few are allowing on-line access to plain text. And very few are open to documents issued from farmers, educators, … Surely the issue of quality and content validation, like AFAF do, must be considered as a condition of KDB development
2) From data base, documentary bases, … to KDB:
The Document Enrichement process: Professional Thesaurus (from Agrof-MM) : adding validated metadata; Interface developed in multi languages; Full text engine for indexation and search inside KDB;
Open access (but protected) documents with on-line consultation, with user training and assistance.
3) How the KDB can be used ;
As support of Tr. activities, repository of Ed. matérial, for self training; in Development (agroforestry for farmers), repository of documented case studies; in Professional Information (advisoring); as documentation for lawmakers, autorities, ... to support Agroforestry policies and development.
Conclusion and perspectives: The scientific & professional knowledge must be acccesssible ! How to make it real ? Through the KDBs. Next step would be the thesaurus development adding glossary, issued from an international agroforestry ontology.



Agrof-MM Knowledge Data Bank Architecture & Environment

Keywords: Knowledge Data Bank, Enrichment, Fulltext index, search Engine, Education.

References:

1. Charles Burriel, Herdon Miklós, Tamás János, Várallyai László: Knowledge databank and repository ser
2. LENGYEL Peter, HERDON Miklós, PANCSIRA János, RÁTHONYI Gergely, FÜZESI István: THE E-LEARNING SYSTEM
3. erdon M, Botos Sz, Várallyai L: Decreasing the Digital Divide by Increasing E-Innovation and E-Readi
4. erdon Miklós, Burriel Charles, Tamás János, Várallyai László, Pancsira János: ICT based innovative s
5. Sz Botos, M Herdon, L Várallyai: Readiness for Future Internet Services in Rural Areas, PROCEDIA ECO

L10.P.10

Complexity of agroforestry cropping systems in the undergrowth of Guadeloupe

Chaigneau R.[1] (jean-louis.diman@inra.fr), Hammouya D.[1], Tormin P.[2], Bezard M.[2], Drillet E.[2], Castro Nuñes T.[1], Diman J.-L.[1]

[1] *PEYI, INRA, Petit-Bourg, Guadeloupe, France*; [2] *SYAPROVAG, Petit-Bourg, Guadeloupe, France*

In this study, SYAPROVAG and its partners in the VALAB initiative (Integrated ecosystemic valorization of the agrobiodiversity in the forest of Guadeloupe) surveyed the current diversity of complex agroforestry cropping systems in the forest undergrowth of Guadeloupe.
For more than 3 centuries, Guadeloupeans cultivate many species in the undergrowth. High value-added heritage crops such as vanilla, coffee and cocoa, which can be classified as high quality and exportable, can be distinguished from other food, fruit, aromatic or medicinal crops intended for local households. All these species are cultivated in the heart of the natural rain forest, in complex agroforestry systems (AFS), the associated spontaneous forest species serving sometimes as shading, sometimes as support for cultivated species such as vanilla (*Vanilla planifolia* and *Vanilla pompona*) or the different yams (*Dioscorea* ssp) when they are not valued directly for some of these (production of various oils and resins) such as red wood carapate (*Amanoa caribea*), incense wood or white oak (*Dacrydes exelcasa*).
Five main AFS have been identified in the Guadeloupe forests, a secular endogenous construction that has been produced by the history of the archipelago, with today two main orientations: the AFS based on heritage crops only on the one hand, and those combining heritage crops and food crops, accounting for 5 to more than 20 cultivated species, current declensions of forest gardens that tend to disappear.
These various AFS are characterized by several common points. First of all, cropping techniques come from ancient know-how. Thus, chemicals and mechanization are missing. As a result, these systems are respectful of the environment and contribute to the conservation or the improvement of the biodiversity of the forest area. On the other hand, the labor intensity of these agroecosystems, coupled with the high cost of labor, limit the area cultivated by asset and the productivity of land and labor. On farm processing of high value-added crops for niche markets, or direct sales, are strategies developed to overcome this structural constraint by increasing income generation.
Overall, it remains difficult today to live only with these AFS in Guadeloupe. Only the diversification of individual activities (pluriactivity) and / or the diversification of farms activities (agro-processing, agri-tourism ...) make it possible to make viable these systems of activity that nevertheless attract many candidates for farming installation.

Keywords: Cropping systems, undergrowth, Guadeloupe, farms viability, added value.

References:

1. Chaigneau R., 2018, Identification, caractérisation et évaluation des systèmes de culture, INRA, 95p
2. Durand M.,et al. 2016, A viability model of farming systems, the case of FWI. 52nd meeting of CFCS
3. Fanchone A., et al. 2018. The development of the circular economy open farm... CFCS 54th meeting
4. Dominici, T., 2016. Valorisation du sous en Guadeloupe par l'agriculture... SYAPROVAG, 75p.
5. Castro Nunes, T., 2018. Entre tradition et innovation. Diagnostic socio-économique... INRA, 44p.

L10.P.11

Delivering Agroforestry in the UK outside of CAP – a partnership between farmers, a hotel chain and the Woodland Trust

Chesshire H. (helenchesshire@woodlandtrust.org.uk)

Conservation, Woodland Trust, Grantham, Lincs, United Kingdom

In the UK agroforestry is a relatively unknown and little understood practise with the exception of boundary hedgerows, wood pasture and parkland. It accounts for approximately 3.3% of the utilisable agricultural area den Herder et al., (2017). The UK is a densely populated country with approximately 70% of the land area being farmed. A land management approach is required that avoids the potential trade-offs between food production and public goods. Agroforestry has the potential to deliver multiple benefits for productive, resilient and environmentally integrated farm systems. Since 2013 the Woodland Trust has been offering farmers across the UK advice and funding support to help them set up agroforestry schemes. This has been made possible by our partnership with the PUR Project and funding from the Accor hotel chain. Over the last 5 years we have helped implement a wide variety of agroforestry schemes in the UK planting 90,000 trees on farms. Table 1 summarises agroforestry planting in the UK funded by the Trees on Farms scheme. This poster will describe, via short case studies, the benefits and challenges of implementing agroforestry and how these examples are being used to share best practice, increase uptake in the UK and influence future land management policy. Examples include: saving soil on an arable farm, tree fodder for dairy cows, shelter on upland sheep farm, woodland eggs mean better business and alley cropping to improve economic returns.

Summary of agroforestry planting in the UK from 2013/14 to 2018/19 funded by Trees on Farms[1]

Funding	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Total
Planting season	2013/2014	2013/2014 2014/2015	2014/2015	2014/2015 2015/2016	2015/2016	2015/2016 2016/2017	2016/2017	2016/2017 2017/2018	2018/2019	
Trees funded	6500	8000	8000	8000	7500	12000	14000	20000	13,000	97,000
Trees planted	6105	6027	5760	7587	5775	12877	8580	12,514	25,382	90,607[2]
No of farms	7	10	7	7	6	6	6	9	15	73
Type of farm										
Conventional	5	5	3	3	4	4	5	7	13	49
Organic	2	5	4	4	2	2	1	2	2	24
Type of land tenure										
Owner occupier	7	8	6	7	5	5	5	7	14	64
Tenant		2	1		1	1	1	2	1	9
Objectives of planting[3]										
Alley Cropping	2		2	1	4	2	2	4	6	23
Shelter & shade	3	5	2	5	2	2	1	3	2	25
Browse		1	1					1	1	4
Resource protection		3	2	1		1	2		2	11
Biodiversity	1									1
Wood fuel	1	1							2	4
Hedgerows & wood pasture						1	1	1	2	5

[1] Woodland Trust (WT) is the UK delivery partner of the Pur project which is a social business supported by Accor Hotels. The WT receives a fixed sum towards each tree
[2] There is a lag between trees being funded and schemes being planted and some schemes are planted over two seasons
[3] Only listed the primary objectives for each scheme, each scheme often had several secondary objectives too

Table 1. Summary of agroforestry planting in the UK from 2013/14 to 2018/19 funded by Trees on Farms

Keywords: planting, UK, practical, experience, hotel.

References:

1. den Herder et al., 2017, Agriculture, Ecosystems and Environment, 241, 121-132

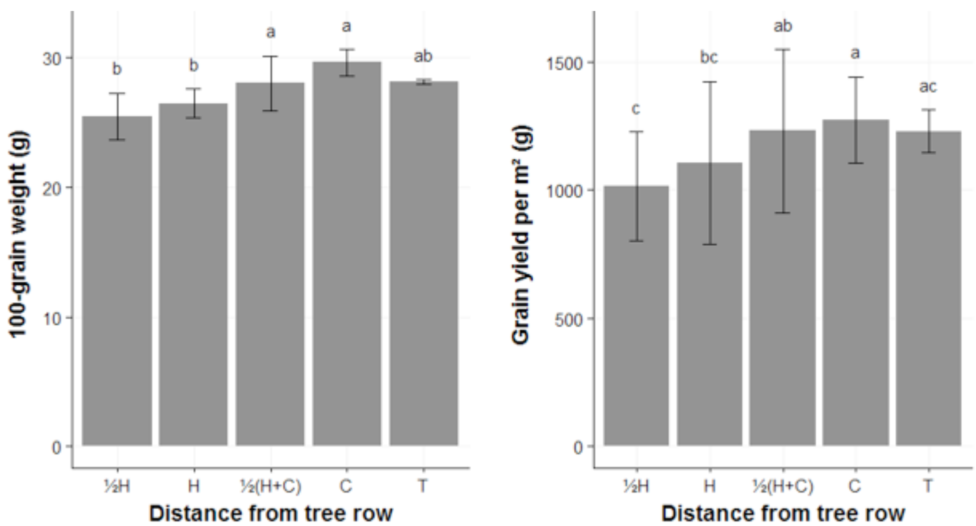
L10.P.12

Widely spaced tree-based intercropping systems: effect on soil microclimatic conditions and crop yield

Cogliastro A.[1] (alain.cogliastro@ville.montreal.qc.ca), Rhéaume-Gonzalez F.-A.[2], Carrier M.[3], Olivier A.[4], Rivest D.[3]

[1] *Sciences biologiques, Institut de Recherche Biologie Végétale, Montréal, Québec, Canada*; [2] *Sciences du bois et de la Forêt, Université Laval, Québec, Québec, Canada*; [3] *Institut des sciences - forêt tempérée, Université du Québec en Outaouais, Ripon, Québec, Canada*; [4] *Département de phytologie, Université Laval, Québec, Québec, Canada*

Tree-based intercropping (TBI) systems, which offer many benefits for society and the farm enterprise, are not very common in eastern North America. An experimental network of widely spaced 4 to 6 year-old TBI systems (25-40 m between tree rows) that are adapted to large scale annual crops was established in southern Quebec. Realistic estimates of the effects of these TBI systems on crop yields and microclimatic conditions are clearly needed if their widespread adoption is to occur. Soybean (*Glycine max*), corn (*Zea mays*) and wheat (*Triticum aestivum*) yields, weed density, soil moisture and soil temperature were studied at four distances from a tree row (½ H, H, ½ (H+C) and C, where H= average tree height and C= distance between the center of the cropped alley and the tree row) and in control plots over the 2017 growing season across four sites (4, 6, 6, 6 and 21 years old). In all sites the distance from the tree row significantly affected weed density. TBI systems did not affect the soil temperature and soil moisture measured at 15 cm depth. In all cases, integrated crop yields (all distances combined, where only the space occupied by the crop is considered) were not different from the control. Our results suggest that the effects of widely spaced tree rows on soil microclimatic conditions and crop yields are negligible in young TBI systems.



Corn 100-grain weight and grain yield per m² in function of the distance from the tree row where H= height of trees, C=center of the alley, T=control. Means not sharing the same letter are significantly different. P<0.05.

Keywords: intercropping, yield, soil moisture, weeds, hardwood.

References:

1. Thevathasan et al. In Agroforestry - The Future of Global Land Use. Nair & Garrity D. 247-283
2. Rivest et al. 2013. J.scitotenv 51-60. doi10.1016/j.scitotenv.2013.05.071
3. Bouttier et al. 2014. Agrofor Sys 693–706. doi10.1007/s10457-014-9721-6
4. Alam et al. 2014. Agrofor Sys 679-691. doi10.1007/s10457-014-9681-x

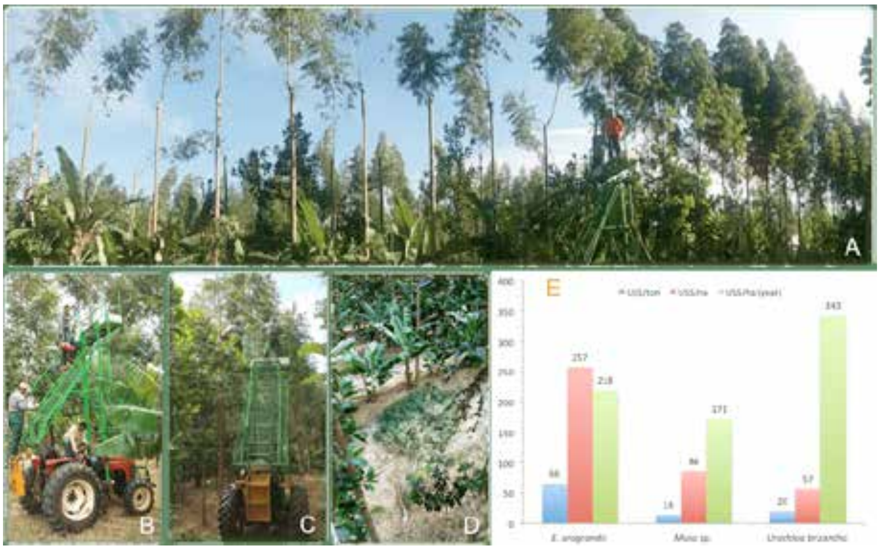
L10.P.13

Plan-Do-Check-Act (PDCA) cost reduction method in apical pruning operations for eucalyptus biomass production, in Brazil

Costa P.[1] (paula.costa.agroforestry@gmail.com), Ziantoni V.[2]

[1] *Agroforestry R&D, PRETATERRA, São Paulo, SP, Brazil*; [2] *Agroforestry R&D, PRETATERRA, Timburi, SP, Brazil*

Syntropic agroforestry in Fazenda da Toca is seeking best cost-benefit and less carbon-demanding model for system self-sufficiency in biomass. Study evaluated pros & cons of apical annual pruning for biomass deposition in *E. urograndis*, while conducting a PDCA for improvements. Operational costs were evaluated (Jan-Oct 2017), and 3 main operations were monitored weekly: (1) biomass pruning, (2) gridding and (3) distribution. Standardized unit was tree canopy harvested at 6 m height (68.3 Kg and 35% humidity). Several compartmentalized time-motion studies were conducted with PDCAs being severely tested. For apical pruning 3 main modalities and arrangements were tested. For biomass gridding and distribution (combined) 4 modalities were tested independently. Further information is shown in figure 1. PDCA process responded for a cost reduction of 43.2%. Process unit was US$ 1.57/tree (3.4 min), representing US$ 0.07/Kg of biomass grinded and distributed. Apical pruning accounted for 34.72% and grinding for 65.27%. Arrangement necessary to fulfill a constant production for 100 ha was 2 tractors (4x4 25 hp), one tower, 1 grinder, 2 chainsaws and 7 workers. Qualitative features of biomass, other sources and adapted machinery are object of ongoing tests. Process is still expensive. It's mandatory to develop better machinery to reduce risks and costs. Lignified material provided by *Eucalyptus* represents an excellent soil cover and nutrition material for tropical agroforestry systems.



(A) Apical pruning operation in the eucalyptus test area with one branch left per tree;
(B and C) Tractor tower used in the operation; (D) Tree-top pruned and (E) Cost-benefit comparison of 3 different sources of biomass used in Fazenda da Toca

Keywords: Syntropic agroforestry, PDCA agroforestry, Biomass production, Apical pruning, Fazenda da Toca.

References:

1. Soares, in: Manejo da copa diminui fator de afilamento em E. urophylla. 2017, ESALQ-USP, p. 29-45.
2. Pinkard, et al. 1999. Tree Physiology. 1-12. https://doi.org/10.1093/treephys/19.1.1
3. Youkhana, et al. 2009, Soil biology and biochemistry, 2527-2534. https://doi.org/10.1016/j.soilbio.2
4. Maruta, 2012, Knowledge and process management. 203-214. https://doi.org/10.1002/kpm.1396
5. Steenbock, in: Agrofloresta - Aprendendo a Produzir com a Natureza, 2013, CNPq, 12 - 81.

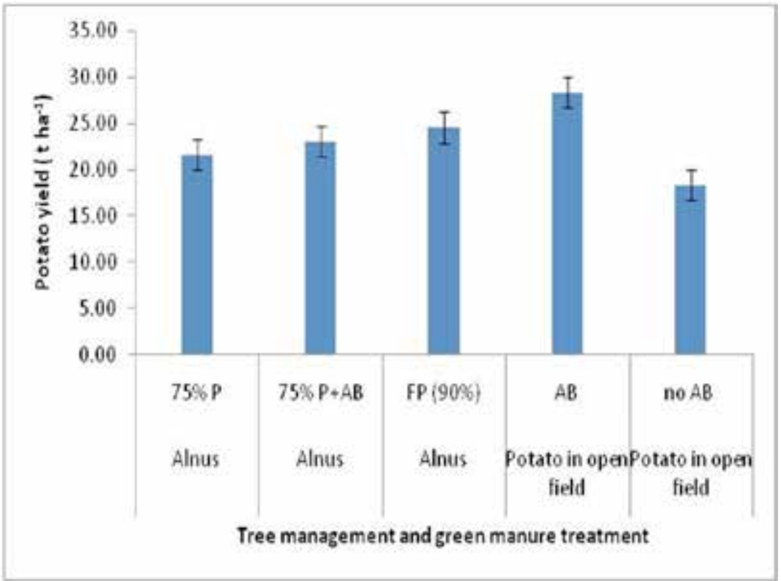
L10.P.14

Alnus acuminata: an effective fertilizer tree for smallholder farmers in sub humid region of Rwanda

Cyamweshi A.[1] (rusacyamweshi@gmail.com), Muthuri C.[2], Mukuralinda A.[3], Shem K.[4]

[1] *Jomo Kenyatta Univ of Agric and Technol, Nairobi, Kenya, Kenya*; [2] *ICRAF, Nairobi, Kenya*; [3] *ICRAF, Kigali, Rwanda*; [4] *Jomo Kenyatta Univ of Agric and Technol, Nairobi, Kenya*

Potato (*Solanum tuberusum* L.) is an important food and cash crop cultivated in the highlands of Rwanda. Its yield is low to meet market demand due to inadequate use of mineral fertilizers which appear an expensive input. This research assessed potato yield response as affected by the application of *alnus acuminata* green manure and pruning managements in the tree long term trial of Tamira research station in the sub-humid highlands of Western Rwanda. *Alnus acuminata* with two management treatments involving two pruning levels (75% pruning and farmer practice corresponding to 90% pruning) and an open field with no trees were used. Potato, Kirundo variety was conisidered as crop test. Before planting, each pruning treatment plot was divided into two to accommodate two sub treatments of *Alnus acuminata* green manure (7 t/ha dry matter and 0 t/ha). Results indicated that all treatments with green manure performed better than those without green manure. Moreover, alnus green manure significantly increased potato yield (28.4 t/ha) in the open field compared to other treatments. Farmers' pruning treatments recorded the highest yield compared to the 75% branch pruning although there was no significant difference; however, trees were more vulnerable to wind due to excessive pruning in farmer practice. These results show that *Alnus acuminata* trees pruned at an appropriate pruning level (75%) are of potential use by farmers as green manure for improved potato crop productivity in Rwanda.



75% P: 75% pruning; FP (90%): farmer pruning practice corresponding to 90% pruning; AB: Alnus acuminata green manure; No AB: No green manure incorporated

Keywords: Alnus acuminata, green manure, Tree pruning.

References:

1. Wajja-Musukwe TN, Wilson J, Sprent JI, Ong CK, Deans JD, Okorio J., 2008,Tree physiol.,233
2. Akinnifesi F.K., Makumba W., Kwesiga F.,2006,Exp. Agr. 441–457
3. Chirwa P.W., Black C.R., Ong C.K., Maghembe J.,2003, Agroforest. Syst, 265–277
4. Buresh R.J., Tian G.,1997, groforest. Syst, 51–76
5. Oluyede C.A., Frank P., Akinnifesi FK. and Sileshi, GW., 2011,International Journal of Agric.129-136

L10.P.16

Agroforestry systems in Eastern Himalayas, Sikkim, India

Deshmukh H.[1] (hkdeshmukh1@rediffmail.com), Bhattacharya P.[2], Patnaik S.[3], Dobriyal M.[1]

[1] *Silviculture and Agroforestry, Navsari Agricultural University, Navsari, Navsari, Gujarat, India*; [2] *Uni School of Environment and Management, GGSIU, Delhi, India, Delhi, Delhi, India*; [3] *Ecosystem Forestry, IIFM, Bhopal, Bhopal, MP, India*

Sikkim a state of India located in the Eastern Himalayas region with an area of 7096 sq.km. About 80% of the population depends on agricultural land for their livelihood. Trees are planted in farms along with agriculture and crops over the length and breadth of Sikkim Himalaya is an age-old practice with a considerable effect on the natural systems of this region. The local people possess broad knowledge on the tree-crop combination and their role in conservation of resources and in livelihood .There is need to gather such knowledge and incorporating into our resources education system, technical training and development plan. In view of this present study was conducted with the objectives, to study the different agroforestry systems in south and west Sikkim and to record the perception of the farmers regarding function of different agroforestry components in conservation of natural resources and role in livelihood. Three villages each were selected from south and west district of Sikkim. A list of 60 respondents were prepared using different tools such as; semi-structured interviews, group discussion, and social mapping. Agroforestry area survey was conducted to identify the agroforestry systems and to understand the components and composition of the agroforestry systems.
Ten different Agroforestry systems were recognized on farmers land in South and West Sikkim, which are rich in tree-agriculture crop diversity. The study shows that the farmer's have considerable knowledge about farming and its contribution to natural resources and finding were recorded by White (2001) and Chauhan and Dhyani (1990).
As per the perception of farmer, the Agroforestry systems plays both productive and protective role. The functional unit like agricultural crops, vegetable, fodder crops, fruit trees plays productive role where as large cardamom, multipurpose tree species, pastures, fruit trees and apiculture plays productive as well as protective role for the farmer (Table 2). Agrisilvipasture, agrihorticulture, agrihortipasture, livestock based mixed farming systems, apiculture and kitchen garden are more beneficial and mostly preferred by farmers. Eight different agroforestry components have been observed in agroforestry systems. In total 96 species i.e. functional unit were recorded in agroforestry systems of Sikkim Himalayas of which 85 percent plants species are native (Table 2). Similar finding were recorded by Chauhan and Dhyani (1990).
The study reveals that the agroforestry is an age old practice in Sikkim and has been way of life and livelihood for centuries. The farmers of South and West Sikkim presently practicing ten traditional agroforestry systems which plays both productive and protective role to farmers' subsistence and conservation of local germ plasma. However Research on choice of species, tree crop interaction, spacio temporal dynamics needed to be undertaken to maximize the socio-economic and ecological benefits of the Agroforestry systems.

Keywords: Agroforestry system, productive, protective, functional unit.

References:

1. Chauhan, D.S. and Dhyani, S.K 1990. Traditional agroforestry practices in north-east Himalayan regio
2. White, J.C. 2001. Agriculture. In: The Gazetteer of Sikkim, Risley, S.S, Low price publications, Del

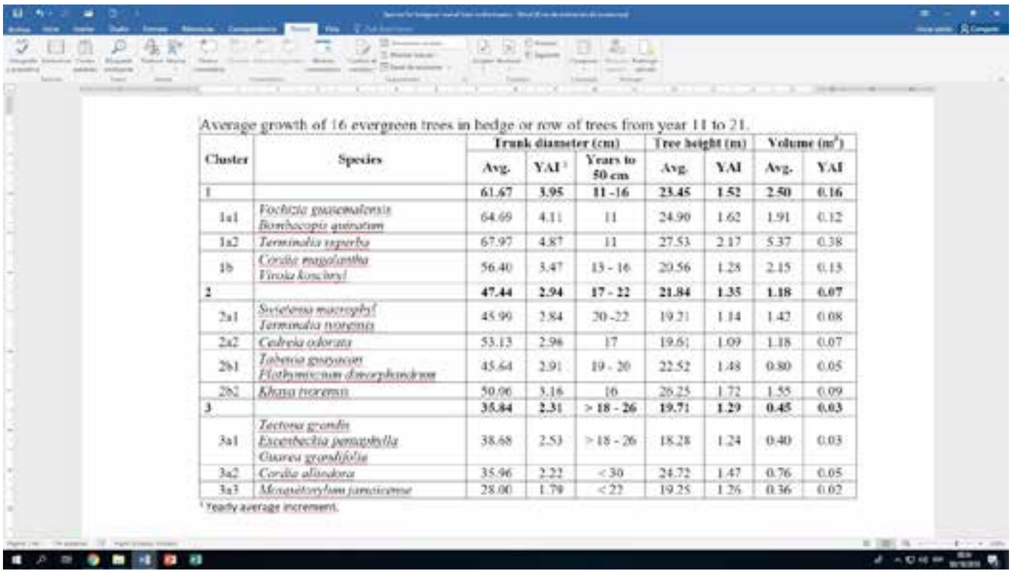
L10.P.17

Hedge rows of Mahogany, Spanish cedar and other species as powerful reforestation alternative of humid tropical lowlands

Diaz J. (javier_diaz@fhia-hn.org), Sanchez J., Dubon A.

Cocoa and Agroforestry, FHIA, La Lima, Cortes, Honduras

The alarming deforestation in the tropics continues for lack of alternatives to stop, slow or revert the trend. Culturally accepted hedge or row of trees foster reforestation and deters burning among other ecological and socioeconomic benefits. To determine adequate options, yield and revenue of tree species for the humid tropics, in 1987 the Honduran Agriculture Research Foundation (FHIA) began planting 16 different species, integrating it into its 50-ha cacao experimental center in La Masica, Atlántida at 20 meter above sea level with a tropical rainforest climate, on low fertility, deep alluvial soils with drainage. Multivariate cluster analysis of annual trunk diameter, plant height and wood volume, aggregates species in three groups. Highly marketable *Swietenia macrophylla* (Mahogany) and *Cedrela odorata* (Spanish cedar) show mid-growth rates with wood volume of 1.14 and 1.77 m3/tree at 22 to 24 years which represent a gross income of $ 12,980 and $ 15,432 of a 100 m row. High and very high growth rate trees produced 4.32 and 7.77 m3/tree at 22 and 17 years, *Cordia magalantha* and *Terminalia superba* respectively. Slow growing trees have yet to have a 50 cm diameter. We have established that hedge or row of trees under the edaphic and climatic conditions of this study 70% of the species have good adaptation as expressed by their growth. This reforestation alternative should be promoted for sustainable economic development in the humid tropic regions.



Average growth of 16 evergreen trees in hedge or row of trees from year 11 to 21.

Cluster	Species	Trunk diameter (cm)			Tree height (m)		Volume (m^3)	
		Avg.	YAI[1]	Years to 50 cm	Avg.	YAI	Avg.	YAI
1		**61.67**	**3.95**	**11 -16**	**23.45**	**1.52**	**2.50**	**0.16**
1a1	*Vochizia guatemalensis* *Bombacopis quinatum*	64.69	4.11	11	24.90	1.62	1.91	0.12
1a2	*Terminalia superba*	67.97	4.87	11	27.53	2.17	5.37	0.38
1b	*Cordia magalantha* *Virola koschnyi*	56.40	3.47	13 - 16	20.56	1.28	2.15	0.13
2		**47.44**	**2.94**	**17 - 22**	**21.84**	**1.35**	**1.18**	**0.07**
2a1	*Swietenia macrophyl* *Terminalia ivorensis*	45.99	2.84	20 -22	19.21	1.14	1.42	0.08
2a2	*Cedrela odorata*	53.13	2.96	17	19.61	1.09	1.18	0.07
2b1	*Tabebuia guayacan* *Platymiscium dimorphandrum*	45.64	2.91	19 - 20	22.52	1.48	0.80	0.05
2b2	*Khaya ivorensis*	50.96	3.16	16	26.25	1.72	1.55	0.09
3		**35.84**	**2.31**	**> 18 - 26**	**19.71**	**1.29**	**0.45**	**0.03**
3a1	*Tectona grandis* *Excenbechia pentaphylla* *Guarea grandifolia*	38.68	2.53	> 18 - 26	18.28	1.24	0.40	0.03
3a2	*Cordia alliodora*	35.96	2.22	< 30	24.72	1.47	0.76	0.05
3a3	*Mosquitoxylum jamaicense*	28.00	1.79	< 22	19.25	1.26	0.36	0.02

[1] Yearly average increment.

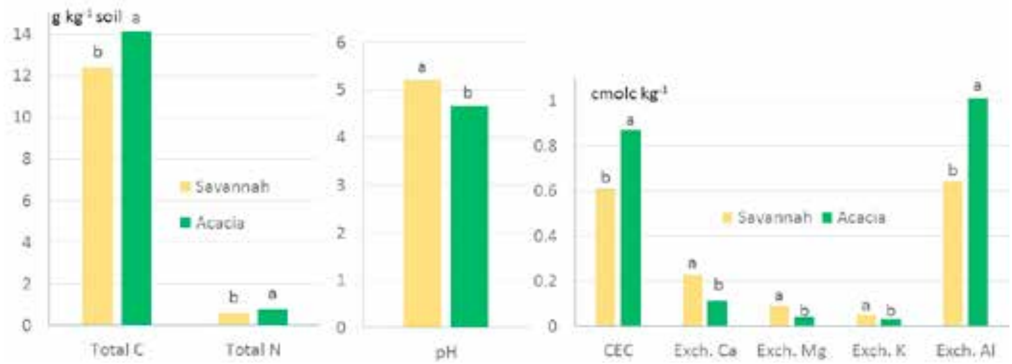
L10.P.18

Evolution of soil chemical properties in the rotational agroforestry system with *Acacia auriculiformis* for 22 years, DRC

Dubiez E.[1] (emilien.dubiez@cirad.fr), Freycon V.[1], Marien J. N.[1], Peltier R.[1], Harmand J. M.[2]

[1] *UPR Forests and Societies, CIRAD, Univ Montpellier, Montpellier, France*; [2] *UMR Eco&Sols, CIRAD, ICRAF, Yaounde, Cameroon*

To produce charcoal and prevent the deforestation around Kinshasa (Gond et *al.*, 2017), 7,700 ha of *Acacia auriculiformis* were planted on savannah ecosystems, in 1987 (Bateke Plateau, DR Congo). Since 1995, the plantation was managed using the rotational woodlot system alternating agricultural and charcoal production on the same area (Kimaro et *al.*, 2007). The 7,700 ha produced a large amounts of charcoal, cassava and maize during many years (Bisiaux et *al.*, 2009).
However, farmers have observed for a while a decline in wood and crop productivity. The aim of this study was to compare chemical properties of soils in six acacia stands in two farms having undergone different agroforestry trajectories: - one 22-year-old acacia stand, never-harvested; 4 stands in their 2nd rotation after 1 cropping cycle; and 1 stand in its 3rd rotation after 2 cropping cycles - and soils in the native control savannah.
Compared to the original savannah, all acacia stands showed an increase in soil C, N and N-NO3- contents, but a decline in soil pH and exchangeable cations, and an increase in exchangeable Al and CEC (Fig 1).
To maintain the sustainability of the system, we recommend different practices in order to improve the nutrient balance and decrease the soil acidity. Such practices are the debarking of tree stems before carbonization, the restitution of small branches and charcoal residues to the soil, and the supply of natural rock phosphate (Dubiez et *al.*, 2018).



Total carbon content, total nitrogen content, pH in water, Cation Exchange Capacity (CEC), Exchangeable Ca, Mg, K and Al in the soil at a depth of 0-20 cm in the savannah and the six acacia stands. Letters indicate differences (ANOVA; $p < 0.05$) between the savannah and the Acacia stands.

Keywords: Bateke plateau, Agroforestry, Charcoal production, Shifting cultivation, N2 fixation.

References:

1. Bisiaux et al., 2009, Bois et Forêts des Tropiques, n°301 (3) : 21-32, https://doi.org/10.19182/bft2
2. Dubiez et al., 2018, Agroforest Syst, 1-12, https://doi.org/10.1007/s10457-018-0222-x
3. Gond et al., 2016, Bois et Forêts des Tropiques, n°327 (1) : 19-28, https://doi.org/10.19182/bft2016
4. Kimaro et al., 2007, Agroforest Syst, 175-184, https://doi.org/10.1007/s10457-007-9061-x

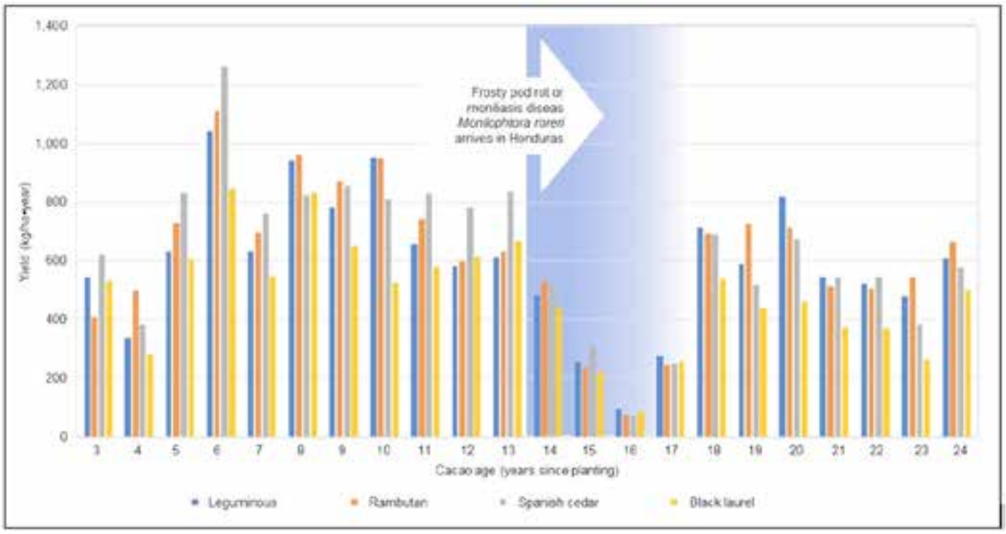
L10.P.19

Cacao yield in agroforestry systems with non-traditional income earning shade trees

Dubon A. (a.dubon10@gmail.com), Sanchez J., Diaz J.

[1] *Cocoa and Agroforestry, FHIA, La Lima, Cortes, Honduras*

Native legume trees *Gliricidia*, *Erythrina* and *Inga* are found in cacao-based agroforestry systems offering suitable and manageable shade, soil improvement and fire wood, yet provide no addition income for impoverished small farmers. Thus, FHIA has proposed fruit or tropical timber as shade trees and set out to determine their effect on cacao yield. In 1987 on a site close to sea level with tropical rainforest climate, on low fertility alluvial soils, cacao was planted with black laurel (*Cordia megalantha*), Spanish cedar (*Cedrela odorata*), rambutan (*Nephelium lappaceum*) and a legume control in a 0.25 ha plot each with four replicas in a randomized complete block design. The analysis of variance of average yearly yield gave a high significant difference between years and systems ($p<0.0001$, $r2=89$, C.V.=13.5%). Mean test ($p<0.05$) show no difference of the total 22-year yield of cacao grown with traditional legumes, rambutan or Spanish cedar, 13.1, 13.6 and 13.9 t/ha, respectively, all different to black laurel with 10.5 t/ha. We have demonstrated additional income from fruit or timber shade is possible since cacao yield is not affected compared to traditional legumes except for some fast-growing competitive trees like black laurel.



L10.P.21

Radial growth of pollarded hybrid walnut trees in a mediterranean agroforestry system

Dufour L. (lydie.dufour@inra.fr), Gosme M., Dupraz C.

UMR System, INRA, Montpellier, France

In temperate agroforestry systems, crop yield is reduced mainly by light competition (Dufour et al, 2013). Dramatically reducing tree canopy by pollarding may alleviate both light and water competition. Pollarding provides an additional production (branch biomass) but may affect timber production negatively. To assess this tradeoff, we compared the trunk radial growth of pollards and control trees in a cereal–based alley-cropping plot.
In December 2013, fifty 22-year-old hybrid walnut trees were cut back at 4m height. Each pollard was paired with a control tree, always pruned up to 4 m high, with the same initial height and trunk diameter. Pollarding was repeated in October 2017. We monitored tree diameter growth with microdendrometers during 5 growing seasons.
Pollarding reduced trunk growth in spring but increased summer growth 2, 3 and 4 years after cutting (figure1). The mean growth of pollards was 5.9±0.8 mm year-1 *vs* 6.3±0.7 mm year-1 for controls during 2014-2017; but only 2.6±0.8 mm for pollards *vs* 9.6±1.0 mm for control after the second pollarding.
Ghahramany et al. (2017) evidenced that long term pollarding had a positive effect on the diameter increment of oaks. In contrast, we observed that the strong reduction the first year after pollarding was not totally compensated by the boosted growth during the subsequent years, while the second pollarding was impressively detrimental to trunk growth.

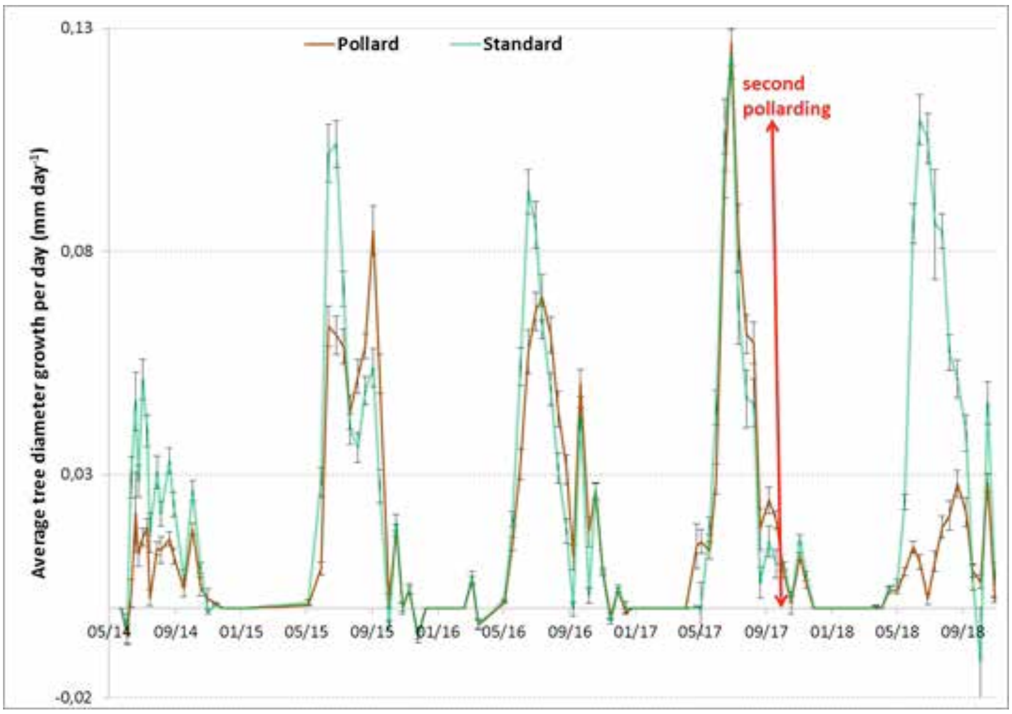


Figure 1: Diameter at Breast Height growth per day of pollards (brown) and control trees (green) as a function of time. The bars indicate ± standard error

Keywords: timber production, seasonal growth, adult trees.

References:

1. Dufour L et al, 2013, Journal of Agronomy and Crop Science, 217-227. DOI: 10.1111/jac.12008
2. Ghahramany L. et al, 2017, Agroforestry Systems, 741-748. DOI: 10.1007/s10457-016-9944-9

L10.P.22

Activity analysis of coffee growers in complex agroforestry systems, understanding the farmers' practices

Durand L.[1] (l.durand@istom.fr), Azéma G.[2], Justes E.[3], Leblanc S.[2], Lamanda N.[4], Allinne C.[5]

[1] *UMR SYSTEM, CIRAD, Turrialba, Costa Rica*; [2] *LIRDEF, Université de Montpellier, Montpellier, France*; [3] *UMR SYSTEM, CIRAD, Montpellier, France*; [4] *ISTOM, Angers, France*; [5] *CATIE, Turrialba, Costa Rica*

In coffee based agroforestry systems, biodiversity management by farmers is a promising lever for innovation to promote system sustainability and increase income. We hypothesized that the co-design of agroforestry cropping systems based on ecological process, and on implementation of innovative practices have to take into account the reality of the technical work as well as the farmer concerns and the knowledge leading to the actual plot management. The aim of this study is to examine how coffee farmers understand the diversity of their agroforestry systems and how do they manage it through their practices.
We have developed an original methodology based on the activity analysis applied to the study of the shade trees regulation practices in the agroforestry coffee plot by coffee growers. The activity analysis is interested in human activity with a view to transforming and designing work situations. According to Theureau (2010), considering enaction paradigm, activity is considered as a dynamic of asymmetrical interaction between an actor and his environment[1]. Thus, human action is not considered to the actual achievement of a predetermined program resulting from the application of decision rules[2]. First, semi-structured interviews were conducted to understand the systems and the cropping practices drivers. Then, practices were studied in real situation, through participant observation and the use of methods of verbalization during practice, of self-confrontation and farmer-guided practice[1]. This study took place in Costa Rica (Turrialba). Agroforestry systems consists of coffee (C*offea arabica*) and various types of shade tree species.
Our results highlight each action carried out by the coffee grower, associated with farmers indicators, considered as the factors that farmer take into account in the agroforestry environment against the background of his concerns, knowledge or habits. These indicators inform about complexity of interactions between the coffee grower and his environment. This interaction occurred at several levels: for a systemic management (to favor the ecological processes like disease regulation), for an ergonomic management (to favor movements, or reduce risk of injury), for a personal management (based on an affective relation with the biotope). In that respect, shade tree regulation is not only intended to increase the incident light energy received by coffee, but also driven by other motivations. The re-design of innovative and sustainable cropping systems has to take into account the interaction between diversity of human situations and the agroforestry system complexity. In this context, how can practices be transformed? How can we support farmers to think about their own practices and initiate changes specific to them? The activity analysis is an efficient framework to nourish the thinking on current management practices and a promising way to support their progressive transformation in complex agroforestry systems.

Keywords: co-design, agroforestry system, coffee growing, activity, farmers indicators.

References:

1. Theureau, 2010, Revue d'anthropologie des connaissances, 290, doi: 10.3917/rac.010.0287.
2. Astier et al., 2003, Recherche & Formation, 121-122, doi: 0.3406/refor.2003.1833.

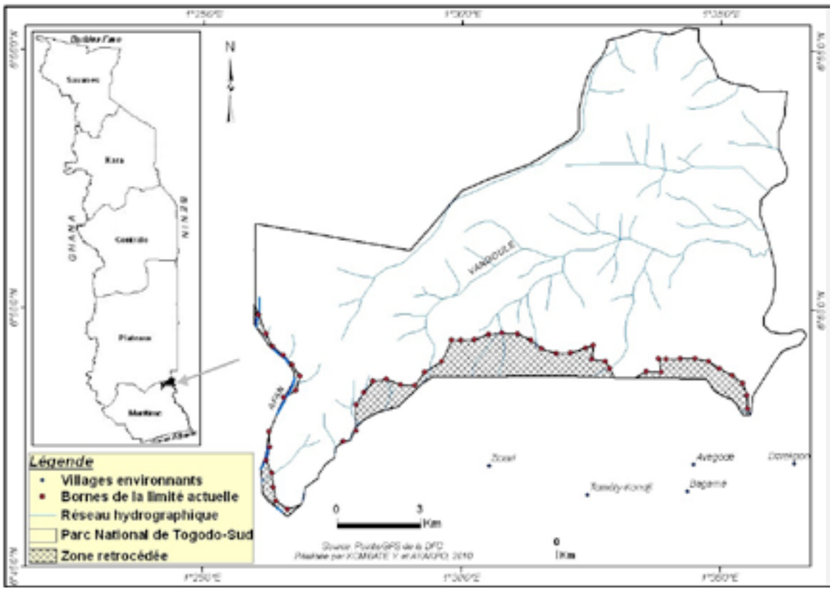
L10.P.23

National Park South Togodo part's retrocession/valorization: deforestation reduction by Togolese Traditional Chiefdom

Edah K.[1] (Togbuiedahkoffi@gmail.com), Koudouvo K.[2], Ohouko O. F. H.[3], Afidegnon A.[1], Abbe M.[4], Danhossou A.[5], Akpodo M. K.[1]

[1] *Union des Chefs Traditionnels de Yoto, Lome, Togo*; [2] *Faculty of Sciences, University of Lome, Lome, Togo*; [3] *University of Abomey-Calavi, Abomey-Calavi, Benin*; [4] *ADAV/OCDM, Lome, Togo*; [5] *AVGAP, Lome, Togo*

Background: The National Park Togodo-South (PNT-S), Yoto/TOGO (Fig1), a significant reserve of biodiversity's conservation/protection, is subjected to drastic anthropic pressure due to demographic expansion (Kokou *et al*., 2005; Akakpo, *et al*., 2012).
Aims: This study aims to set up a process of permanent dialogue between Togolese government and the bordering populations of the PNT-S for the retrocession of part of the Park.
Material: Dialog boxes and video projector for sensitizing, cameras, GPS and questionnaires were material used.
Methods: Semi structured Interview, meetings in focal groups, cartography realization of the PNT-S and reassigning of its part, and networking owners of the reassigned part, were the methods used (Kokou *et al.,* 1999; Akako *et al*., 2012).
Results: 3000 hectares of ground of PNT-S were reassigned. Owners Network in 3 bordering cantons (Gboto, Sédomé Tométy-Kondji) was created. 825 farmers, awards of the reassigned grounds, valorizing 71% of them, were listed. 21 different agricultural cultures were practiced bringing back about 450.000 FCFA(692 Euro)/hectare/an. Moreover, nine groups of 5 volunteers each, for the permanent supervision of the PNT-S, were constituted.
Conclusion: Retrocession of 3000ha of the PNT-S cultivated at 71% (2130 ha), networking of owners and constitution of comminatory volunteers supervisors of the Park, constitute synergic factors which contribute durably to protect the park and fight against deforestation and poverty.



National Park of Togodo-South and the reassigned part

Keywords: National Park of Togodo-South, YOTO/LOME, retrocession/valorization, deforestation, Togolese Traditional Chiefdom.

References:

1. Akakpo in Mémoire de Diplôme d'Ingénieur des Travaux, 2010, Bobo Dioulasso , 82p
2. Akakpo in Communication XVème Journée Scientifique Internationale de Lomé (JSIL), 2012,UL –Togo,
3. Kokou et al., 2005, Vertigo, DOI : 10.4000/vertigo.2456
4. Kokou et al., 1999; J. Rech. Sci. Univ. Bénin,91-104. DOI : 10.4314/jrsul.v3i2.16991

L10.P.24

Intra-annual diameter increment and seasonal leaves nutrients in cork oak species under 3 understory management options

Faias S. P.[1] (soniapf@isa.ulisboa.pt), Paulo J. A.[1], Firmino P.[1], Tomé M.[1], Moreno G.[2]

[1] *Instituto Superior de Agronomia, Centro de Estudos Florestais, Lisboa, Portugal*; [2] *Universidad de Extremadura, INDEHESA, Plasencia, Spain*

Cork oak is an important species in the Mediterranean agroforestry systems. There are few studies outcomes providing knowledge on the impact of different understory management practices, on the tree and cork growth.

Monthly diameter increments, monitored with band dendrometers, and the seasonal variation of the specific leaf area (SLA) and N, P and K content of current-year leaves, were collected during two consecutive years from an uneven-aged cork oak pure stand that included debarked trees at two different years. This dataset provided information to study how trees respond to three distinct understory management alternatives (UMA): spontaneous understory vegetation maintenance (NUR, as control); understory removal with biomass incorporation into the soil (RUI); and understory removal with simultaneous NP fertilization (RUF).

A parametric approach was performed to identify seasonal patterns for the leaves variables, and differences among UMA and debarking ages. Differences were found between UMA and for the combined effect with different debarking years, where the P content was higher in the 2nd year on RUF. A difference on RUF was also revealed in the 1st year for the diameter increment. A linear mixed model was performed for the diameter increment, which allows simultaneously considering the UMA effect and its interaction with climate and distance-dependent competition indices. A positive correlation with precipitation was expectedly found regardless the UMA.

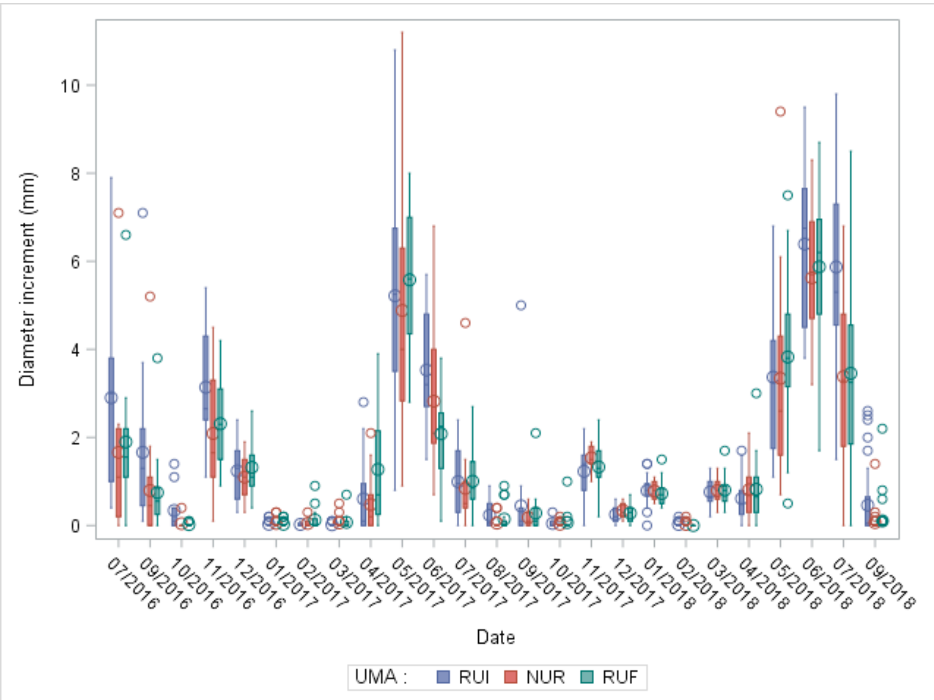


Figure 1. Tree diameter increment (cork+wood) pattern during two consecutive years after performing understory management alternatives (UMA) operations.

Keywords: Montado, dendrometers, spontaneous shrubs, fertilization, cork growth.

L10.P.25

Indigenous Knowledge in Agro-forestry Practices: A Strategy for livelihood Sustainability, in the Mt.Oku Region, Cameroon

Foncha J. N. (jacinta_foncha@yahoo.com), Azinwe A. G.

Development Studies, Pan African Institute for Development, Buea, south West, Cameroon

Forests provide adjacent communities with livelihood opportunities; during periods of uncertainty, shocks and stress, indigenous knowledge is used for alternate livelihoods. This study focused on the use of indigenous knowledge by local communities in the creation of agro-forestry alternatives amidst conservation programs in the Mount Oku Forest, North West Region, Cameroon. Based on frontline and secondary villages, five communities were randomly selected from the three tribes (Nso, Kom, Oku) that make up the forest. Selected Participatory Rural Appraisal tools were used to collect relevant data. Resources extracted from the forest were ranked; trees extracted from forest and planted in farms were identified, farm produce before and after the practice of agro-forestry was assessed. The paired sample t-test was used to test differences between agricultural productions from farms and livelihood opportunities before and after agro-forestry practices. The results indicated that there was a positive and significant difference ($p < 0.05$) in agricultural production and livelihood opportunities, viz-a-viz forest cover. Though there was diversification in livelihood opportunities, the lack of incorporation of basic scientific approaches of agro-forestry was a major limitation. There is need for a blend of indigenous and scientific knowledge and training of farmers, in the practicing of agro-forestry practices for forest sustenance and livelihood assurance in the Mt Oku area.

Keywords: Forest, Agroforestry, Livelihoods improvements, indigenous knowledge, sustainability.

L10.P.26

Effect of different types of organic manure on production of *Lepidium sativum* under Morus based agroforestry system

Gautam K. L. (krishanlalgautam99@gmail.com), Bishist R., Namgial J.

Department of SAF, Dr Y S P U of Horticulture and Forestry, Solan, Himachal Pradesh, India

The present investigation was conducted at the experimental field in the Department of Silviculture and Agroforestry, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during 2017-2018 to evaluate the effect of different types of organic manure on yield and biomass production of *Lepidium sativum* under *Morus* based agroforestry system. The present investigation consisted two structural and functional components *Morus alba* fodder tree as woody perennial and *Lepidium sativum* as intercrop. In addition, the impact of three types of organic manure on performance of *Lepidium sativum* was observed under *Morus* and open conditions.There were eight treatments *i.e.*T1: Lepidium + *Morus* +FYM@ 4tonnes ha-1 (3.2 Kg plot-1), T2: Lepidium + *Morus* +Vermicopost@ 1.12 tonnes ha-1 (0.9 kg plot-1), T3: Lepidium + *Morus* +Jeevamrut@ 500Litre ha-1 (0.4Litre plot-1), T4: Lepidium + *Morus* +No Manure, T5: Lepidium + FYM @ 4tonnes ha-1 (3.2 Kg plot-1),T6: Lepidium + Vermicompost @ 1.12 tonnes ha-1 (0.9 kg plot-1), T7: Lepidium + Jeevamrut@ 500Litre ha-1 (0.4Litre plot-1), T8: Control (without *Morus* and no Manure). The present study revealed that the tree proximity, significantly affected growth and yield parameters of *Lepidium sativum* where *Lepidium sativum* in open condition resulted in better growth and yield parameters as compared with *Lepidium sativum* under *Morus* based agroforestry system. The results of the study indiacted that the highest plant height at harvesting (69.71 cm) was recorded with the application of Jeevamrut@ 500Litre ha-1 under Open condition. Highest number of branches (23.60 plant-1), number of main stem (1.56 plant-1), number of pods (2192.96 plant-1), Fresh aerial biomass (28.65 g plant-1) dry aerial biomass (17.85 g plant-1), Fresh root biomass (1.74 g plant-1) dry root biomass (0.95 g plant-1) and yield parameters *viz.* number of seeds per pod (2.60), seed yield per plant (4.89 g), Seed yield (1613.07 kg hectare-1) was observed in treatment T6 *i.e.* Lepidium + Vermicompost @ 1.12 tonnes ha-1 (0.9 kg plot-1) while the lowest was recorded in treatment T4 *i.e.* Lepidium + *Morus* +No Manure. From the economical point of view, the maximum cost of cultivation (73306.79 Rs ha-1) and gross return (145700.3 Rs ha-1) were recorded in T2 (*Morus*+ Lepidium+Vermicompost) where 1.12 tonnes hectare-1 vermicompost was applied as organic manure. The treatment T3 ((*Morus*+ Lepidium+Jeevamrut) resulted in higher net return (85186.06 Rs ha-1) and B:C ratio (2.44) when 500 litre hectare-1 Jeevamrut was applied as organic manure.

Keywords: Lepidium; Organic manures; Jeevamrut;.

References:

1. Thakur P S and Kumar R. 2006. Indian Journal of Agroforestry 12-21.
2. Singh B, Singh V, Singh R P and Srivastava B K. 1997.Indian Journal of Horticulure 320-326.
3. Kumbar B and Devakumar N. 2016. Advances in Life Sciences 3619-3623.

L10.P.27

Evaluating the Sustainability of Agroforestry systems in five different countries of Europe using Emergy evaluation

Gliga A.[1] (gligaadrian@gmail.com), Sandor M. S.[1], Smith J.[2], Ghaley B. B.[3], Pisanelli A.[4], Augusit A.[4], Wawer R.[5], Borek R.[5], Smith L.[6]

[1] *Environment and Plant protection, USAMV, Cluj-Napoca, Romania*; [2] *ORC, Berkshire, United Kingdom*; [3] *University of Copenhagen, Taastrup, Denmark*; [4] *National Research Council, Porano, Italy*; [5] *ISSPC, Pulawy, Poland*; [6] *ORC, Royal Agricultural University, Berkshire, United Kingdom*

Resource use and environmental impacts of six different agroforestry systems from five European countries were assessed using emergy evaluation (Table 1). Emergy is a widely used method for the assessment of energy efficiency and sustainability within agroforestry systems that expresses and accounts for different forms of energy on a common physical basis. Each system consisted of a farm with an integrated food and non-food production system. The on-farm resource use, production and inputs of different types like sunlight, fuel, machinery, human labour and economic services were converted into a common unit of solar equivalent Joules (seJ). After accounting for emergy in each system we used emergy indices to compare different systems in terms of ecological and economic efficiencies to assess sustainability. Emergy-based indices calculated in this study are: output (Y), total emergy use (U), solar transformity (U/Y), fraction of local renewable resource use, emergy yield ratio (EYR), environmental loading ratio (ELR), and emergy sustainability index (ESI). Compared to conventional systems were more than 90% of resources (seJ) were used for supporting labor and service, less than 50% of resources are used in agroforestry systems for the same purpose.

Table 1.

Studied farms, location and size

No.	Agroforestry farm	Study location	Size
1	Livestock silvopastoral system with wooded semi-natural grasslands	Petrova Municipality Romania	94 ha
2	Organic farm with willow and hazel alley cropping system, mixed species timber and apple system, hedgerows	Wakelyns Farm, Suffolk, UK	22 ha
3	Experimental Combined *F*ood and *E*nergy system, integrating food and fodder crops with mixed stands of willow, alder and hazelnut.	Taastrup, Denmark	11 ha
4	Organic farm comprised of olive orchard with natural weed between the tree rows	Orvieto Municipality, Italy	7 ha
5	Conventional farm, of which 22 ha are managed as olive orchards with periodical soil harrowing	Orvieto Municipality, Italy	207 ha
6	Livestock farm with wooded grasslands, hedgerows and forest	Beskid Mountains, Poland	200 ha

Keywords: Agroforestry, Emergy, Integrated food and non food.

References:

1. Ghaley & Porter, 2013, Ecol. Indic., pp. 534-542.

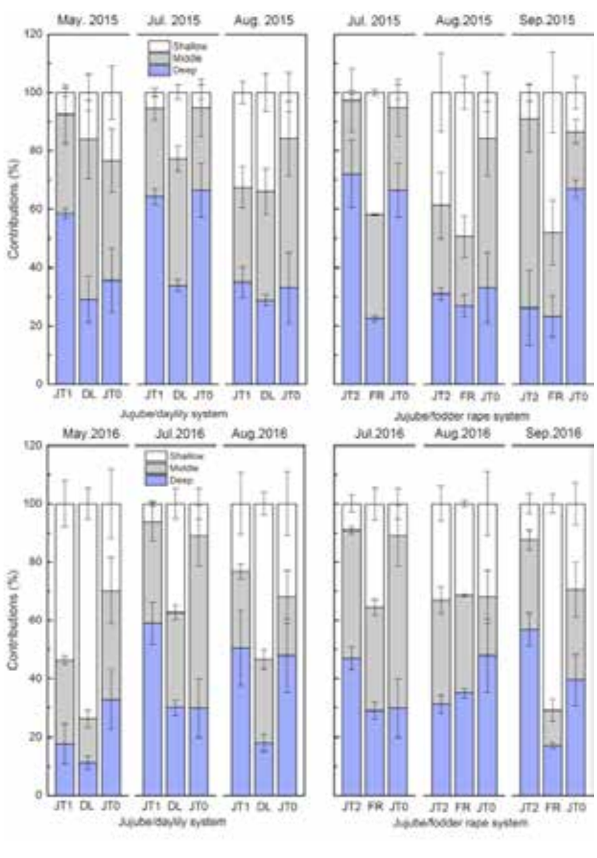
L10.P.28

Soil water effect and interspecific relations of a semiarid agroforestry in Northwest China

Huo G. (huogp527@nwafu.edu.cn)

Northwest A&F University, Yangling, Shannxi, Select a Stat, China

Agroforestry is a widely advocated adaptation strategy for enhancing agricultural resilience to extreme climates. Here we describe studies on jujube agroforestry regimes using two different cash crops: the annual fodder species rape (Brassica napus) and the perennial daylily (Hemerocallis fulva). The jujube agroforestry systems were characterized with respect to their interspecific water interactions and their responses to extreme natural drought using stable isotopic techniques and in situ soil water observations. We found that agroforestry altered the jujube trees' water sources but its impact depended on soil wetness: compared to monocultures, jujube trees in agroforestry systems generally shifted to deeper water under dry conditions but to shallower water under wet conditions. Complementary water use between jujube trees and crops was observed on most sampling dates, but there was clear evidence of water competition in the shallow layer under relatively wet conditions. Furthermore, it was found that facilitative interspecific interactions were clearly enhanced in both agroforestry systems during extreme drought. In addition, jujube yields in agroforestry systems were clearly higher than in monoculture. These findings demonstrate that agroforestry is a climate-smart agricultural system and can increase the resilience of semiarid jujube plantations to extreme real-world drought.



Seasonal patterns of contribution of soil water at different layers to xylem water under different treatments in 2015 (upper) and 2016 (lower). The error bar represents one stand error. JT0, JT1 and JT2 denote jujube tree in the jujube monoculture, jujube/daylily system, and jujube/fodder rape system, respectively; DL: daylily; FR: fodder rape.

Keywords: intercropping, water use, stable isotopes, interaction, Bayesian mixing model.

L10.P.29

Scaling up Assisted Natural Regeneration to intensify agroecologically agrosystems productivity

Issoufou H. B.-A.[1] (hassanebil-assanou.issoufou@ird.fr), Daouda B.[2], Sitou L.[3]

[1] *Crops Sciences, University Dan Dicko Dankolodo of Maradi, Maradi, Niger*; [2] *Directorate of the Environment, Environmental Office, Aguié, Niger*; [3] *Economy and Rural Sociology, University Dan Dicko Dankolodo of Maradi, Maradi, Niger*

As an agroecological intensification technique, the scaling-up of tree assisted natural regeneration (ANR) protects agrosystems and ensure crop production in Sahelian context of increasing population and climatic variability. This study aims to evaluate agronomic, environmental and economic performances of agroforestry parkland arising from a local community innovations in tree resources management (**Jouve & Banoin 1998**) to support their ongoing scaling-up. Study sites are located in central-south of Maradi region (Niger). Average annual rainfall is 600 mm. This parkland is derived from ~ thirty years of trees ANR practice (**Larwanou & Saâdou 2011**). Pearl millet is the main cereal grown usually associated with cowpea, sorghum or groundnut. Soil moisture and soil bulk density in ANR and non-ANR areas were measured on samples collected during rainy and dry seasons at depths of 0.5, 1.0, 1.5 and 2.0 m. Millet growth and grain yield were measured in 100 m^2 (10x10m) plots (50 plots in ANR and 50 non-ANR areas). Results showed that the two areas have the same composition for dominant woody species but the mean tree density is higher in the ANR than in non-ANR areas. Tree density is lower in fields in the vicinity of the village than those that are far away irrespective to the two areas. Soil moisture in uppermost horizons is higher in ANR areas under -and out of canopy than in non-ANR area. However, in deep horizons up to 1.0 m, soil moisture is higher in ANR areas (under and out of canopy) than in non ANR areas. Apart from seeding density ($F = 1.20$, $P\text{-}value = 0.2756$), all agronomic parameters are significantly higher in the ANR than in the non-ANR area. This study showed that the ANR improve crop production in a sustainable manner through the increase of crop yield. With the increase of tree density, additional direct incomes could be expected to smallholders through wood exploitation.

Keywords: Agroforestry, Demographic pressure, Land saturation, Sahel, Sustainability.

References:

1. Jouve et al., 1998, Bois et forêts des tropiques, 31-44.
2. Larwanou et al., 2011, J Arid Environ, 194–200, doi:10.1016/j.jaridenv.2010.09.016

L10.P.30

Forest windbreaks serving a function of the agricultural land shield from the negative effects of wind

Josimovic B. (bosko@iaus.ac.rs), Milijic S., Bezbradica L.

Inst. of Arch. & Urb. & Spatial Planning, Belgrade, Serbia

Out of 88,361 km^2 of the Republic of Serbia's territory, 53.76% is agricultural land, amounting to 47,502.173 km^2. Considerable part of that land is situated in the Autonomous Province of Vojvodina (APV) (19.69 %, or 17,397.92 km^2). Its terrain mostly consists of lowlands belonging to the Pannonian Basin, intersected by numerous rivers and canals. About 7% (exactly 7.1%) of land in APV is covered by forest (compared to 29.1% in the Republic of Serbia), while that percentage in the eastern parts of the province, where the effect of the southeastern wind called Košava is the greatest, goes between 1.5 and 7.7%. Lowland terrain and the climate there make this area susceptible to wind erosion, i.e. degradation of the agricultural land. The negative effect is two-fold: deflation of fertile soil particles, and deposition of infertile material over fertile agricultural land. Degradation of the agricultural land due to the wind erosion, salinization of the soil caused by irrigation and flooding, spreading of infrastructure and similar negatively affect the area of land convenient for agriculture. The paper points to all the adverse effects that lead to the decrease of arable land areas in APV, making it vital to protect and preserve the most fertile zones. As a priority measure, raising forest windbreaks is suggested so as to provide a long-term protection of the degraded agricultural land and preserve the existing agricultural land, along with the crops raised there. The purpose of this paper is to analyze the need for, the types of and the techniques of forest windbreaks on the territory of the Autonomous Province of Vojvodina, in the Republic of Serbia, as well as to establish other positive impacts of planting and maintaining forests. It also presents a comparative analysis of the change in the ration between agricultural and forested areas based on CORINE Land Cover – CLC database, illustrating natural and both positive and negative anthropogenic effects on the protection and degradation of the said areas.

Keywords: agricultural land, forest windbreaks, land degradation, wind erosion, protection.

L10.P.31

Attaining food security through forest-farming in the mid-hills of Nepal: opportunities and challenges

Karki R.[1] (rahul@forestaction.org), Paudel N. S.[1], Nuberg I.[2], Adhikari A.[1], Bashyal M.[1]

[1] *ForestAction, Lalitpur, Nepal*; [2] *University of Adelaide, Adelaide, Australia*

Forests play an integral role in securing livelihoods of the rural poor in Nepal. Large population, which does not have adequate land to cultivate, has been benefitting from common pool resources especially community forests. Management of community forests and sustainable use of diverse forest products, has significantly contributed to food, fiber, medicine and income. Drawing on the lessons learnt from community forestry in Nepal, this paper shows how strengthening forest-farm interface creates opportunities for securing food security of the people dependent on forests. The evidences were gathered during the five years of action research supported by Australian Centre for International Agricultural Research (ACIAR) in Lamjung and Kavre districts of Nepalese hills. It is evident that timber, fodder, grass, and non-timber forest products (e.g. tea, coffee, fruits) that are grown in close association with community forestry hold a significant share of income and livelihood of the people. However, the existing policies, regulatory framework and forestry institutions are not fully embracing these realities and still tend to be inclined to timber-centric management, thus overlooking the diverse existing and potential strategies for supporting rural food security. Strengthening forest-farm interface will not only help in achieving food security, but also contributes to check deforestation through reduced demand for agricultural expansion.

Cardamom plantation in Phagarkhola community forest of Chaubas, Kavre district, Nepal

Keywords: agriculture-in-forest, food security, forest-farm, Nepal, policies.

L10.P.32

Agroforestry-appropriate forms of land and capital

Keeley K.[1] (keefe@savannainstitute.org), Wolz K.[1], Richards J.[1], von Tscharner Fleming S.[2], MacFarland K.[3], Straight R.[3]

[1] *Savanna Institute, Madison, Wisconsin, United States*; [2] *Greenhorns, Pembroke, Maine, United States*; [3] *National Agroforestry Center, Lincoln, Nebraska, United States*

Appropriate land and capital access are critical for wider adoption of agroforestry. In the U.S. 39% of farmed land is non-owner operated. One-year cash rent leases designed for annual crops most commonly govern use of this land. Long-term secure agroforestry arrangements could better meet many landowner objectives and public interests, e.g. improved property values and ecosystem functions. Conventional agricultural financing, too, may suit annual systems, but agroforestry-appropriate capital accords conditions as such. Access to land and capital are common barriers for beginning farmers—key potential agroforestry adopters. Bringing together multiple parties – farmers, landowners, and sources of capital – in suitable land and business arrangements represents a potential strategy for stimulating adoption of agroforestry. In this paper, we (1) outline the principles of agroforestry-appropriate land and capital (2) highlight exemplary cases of agroforestry on non-owner operated land via multi-party arrangements, including with institutional landowners, (3) develop best practices and potential pitfalls for successful multi-party agroforestry arrangements, (4) assess potential for expanding use of multi-party agroforestry arrangements, and strategies for how it might be realized by collaboration among academics, policy makers, government agencies, civil society organizations, businesses, institutional and individual landowners, and agroforestry practitioners.

Roles & Responsibilities	Citizen Group for Parks Planning & Use	Savanna Institute	Farmer/Contractor	Municipal Parks Department
Land Ownership	Long-Term Lessee	None	None	Land Owner
Fundraising	Primary responsibility for funding project	Assist with fundraising	None	Capital expenses of establishment
Planning & Stakeholder Engagement	Goals drive planning process	Facilitate	None	None
Installation	Main responsibility for installation	Assist with installation	May contract labor/equipment	None
Ongoing Management	Main responsibility for management	Little or none	May contract labor/equipment	None
Ownership of Products	Owner of all products produced	None	None	None
Research	As desired	Lead and coordinate collaborators	None	None
Education	Lead in educational programming	Assistant in educational programming	None	None

An example configuration of roles and responsibilities in a multi-party arrangement for a ~10 hectare silvoarable research and demonstration plot with a municipal landowner. Definitions of roles and responsibilities can be customized according to context and needs.

Keywords: Land tenure, Financial capital, Partnerships, Landowners, Case studies.

References:

1. USDA Economic Research Service. 2016. U.S. Farmland Ownership, Tenure, and Transfer. EIB-161.

L10.P.34

Tree survival does not always depend on soil water conservation-what and where matters: Lessons from East Shewa Ethiopia

Kinuthia R.[1] (R.Kinuthia@cgiar.org), Mugwe J.[2], Muthuri C.[1], Danga B.[2]

[1] *Systems science theme, World Agroforestry Centre (ICRAF), Nairobi, Nairobi, Kenya*; [2] *Agriculture Resource Management, Kenyatta University, Nairobi, Nairobi, Kenya*

Efforts to scale agroforestry in the arid and semiarid areas in Ethiopia are constrained by the high rate of tree mortality. These areas have low tree cover despite concerted efforts of tree planting by both governmental and non-governmental institutions. To enhance tree survival in East Shewa zone of Ethiopia, two micro catchments: micro basins and trenches were introduced in four districts: Adami Tulu, Dugda, Lume and Bora. This study sought to assess the effectiveness of the micro catchments in enhancing survival of three tree species: *Cordia africana, Grevillea robusta* and *Mangifera indica* through soil moisture retention. The study also sought to assess other factors that influence survival of trees from farmers' perspective. Survival of the trees grown in the micro catchments was compared with trees grown in the conventional planting pits (control). Tree survival data was collected through six-month assessment from planting time up to 36 months while data on farmers' perceptions was collected through a household survey involving 110 farmers who had planted at least one tree species for the past five years. Using SPSS, descriptive statistics and ANOVA were used to analyse the data. A low survival rate (<30%) was observed for the three species after 36 months with no significant differences between trees in the micro catchments and those in the control. The highest mortality rate was observed between 6 and 12 months. Trees that had survived past 18 months survived up to 36 months. Survey results showed farmers had planted a total of 33 different species. *Mangifera indica* was planted by all households in Bora and Dugda. *Melia azedarach* was planted by 100% and 85% households in Lume and Adami Tulu respectively. Only 9 species were common across all the sites. Of these, a significant difference (P=0.0014) in survival was observed in the four sites, the highest survival rates being recorded in Lume. Water scarcity was reported to be the main cause of tree death in all the sites (>30%). Livestock damage was the second main cause in Adami Tulu (25%) and Dugda (20%), insects and pests attack in Lume (33%) and Bora (29%). The study further revealed differences in tree management activities and access to water for trees across the sites. The study concluded that: in isolation, micro catchments may not adequately address the low tree survival rate in East Shewa. Not only is tree survival influenced by other factors such as inadequate soil water but also by livestock damage and attack by insects and pests; early stages of tree establishment are critical in overall tree survival; variations across sites in terms of tree species suitability and tree management influence performance of trees. The study recommends holistic approaches in addressing tree survival and further research into appropriate tree management practices suitable in the specific sites and for the different tree species, mainly focused at the early stages of seedling establishment.

Keywords: Trees, Survival, Water, Conservation, Management.

L10.P.35

K competition between crops and young oil palm in agroforestry systems in the Allada plateau smallholdings, Benin

Koussihouèdé H.[1] (hermionekoussihouede@gmail.com), Aholoukpè H.[2], Dubos B.[3], Barthès B.[4], Chapuis-Lardy L.[5], Amadji G.[1], Clermont-Dauphin C.[5]

[1] *Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, Abomey- calavi, Benin*; [2] *CRAPP, INRAB, Pobè, Benin*; [3] *UPR Systèmes de pérennes, CIRAD, Montpellier, France*; [4] *UMR Eco&Sols, IRD, Montpellier, France*; [5] *UMR Eco&Sols, IRD, Dakar, Senegal*

Beninese smallholders associate food or cash crops with young oil palm stands to reduce field maintenance costs and gain income before the oil palm comes into production. However, little is known about the effects of these agroforestry systems on nutritional and growth status of the tree at end of its juvenile phase although it is well known that the tree production could be affected by the management in juvenile phase. We selected 15 plantations where the crop succession associated with the trees was mostly based on maize, cassava, tomato and pineapple respectively. Nutrient contents in soil and tree leaves, and the vegetative growth of the tree were examined at end of juvenile phase. We found that N and P nutrition of young palms was satisfactory but K nutrition was deficient in all systems especially in tomato and pineapple ones. There was a significant correlation between K contents in soil and palm tree leaves. In the pineapple- and tomato-based systems, the amount of K fertilizer did not compensate the exportations by the crop. We concluded that competition for K are particularly important in pineapple- and tomato-based systems although fertilizer inputs were the highest. Trade-offs between profitability of these associated crops and the productive performance of the tree could be sought. A better adaptation of mineral fertilization could help in satisfying these compromises.

Figure: Main oil palm agroforestry systems developed by smallholders in the Allada region (Southern Benin). Oil palm tree associated with: A (top-left), Pineapple; B (top-right), Tomato; C (bottom-left), Maize; D (bottom-right), Cassava. The annual crops are maintained no longer than the immature period of the trees. © H. Koussihouèdé

Keywords: mineral nutrition, growth, oil palm smallholdings, family farming, Southern-Benin.

L10.P.36

Decreasing crop diversity leads to food insecurity and off-farm food reliance and varies with land degradation status

Kuria A.[1] (A.Kuria@cgiar.org), Pagella T.[2], Muthuri C.[1], Sinclair F.[1]

[1] *Systems Science Theme, World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [2] *School of Natural Sciences, Bangor University, Bangor, Gwynedd, United Kingdom*

Food security remains a critical development priority within the 2030 Sustainable Development Goals (SDGs) agenda. One of the main challenges facing global policy makers is the inability to meet all food security dimensions due to lack of customized local indicators and metrics for assessing food security needs across heterogeneous smallholder landscapes. This leads to the design of blanket food policies across different context informed by top-down approaches, without understanding local needs or adapting interventions to local context. This results in food insecurity due to inappropriate, non-inclusive and unsustainable interventions. The aim of this study was therefore to assess local drivers and indicators of food insecurity by land degradation status. Local knowledge was elicited using systematic knowledge-based systems approach (AKT5) from 150 smallholder farmers through paired catchment assessment of three landscapes along a land degradation gradient in Western Rwanda. Data was analysed using R statistical software. Results showed a decrease in annual crop diversity or complete disappearance of some annual crops between 1995 and 2015, which 76% of farmers attributed to Crop Intensification Policy launched by the government of Rwanda in 2007 that led to specialization in a few 'high-value' crops. About 83% of farmers reported being food insecure, with the main indicator of food insecurity being food shortage during certain months of the year (mainly July to November) when the high value crops were not mature for consumption. This resulted in most farmers outsourcing food. Over time, farmers have become more dependent on the market, with food produced on-farm supporting them for an average 6.6 months annually in 2015 compared to 10.1 months in 1995. The main coping mechanism currently employed by 55% of farmers experiencing food insecurity was off-farm (paid labour). The frequency of mention of all the above parameters varied with land degradation status, but there were no gender differences. Inversely, there was an increase in perennial crop diversity between 1995 and 2015, mainly attributed to access to quality germplasm (66%) and tree propagation and management skills (34%), with farmers noting that tree food crops played a key role in filling food gaps during 'food -insecure months. Results demonstrate the role of local knowledge acquisition in complementing science through understanding food security and crop diversity dynamics. This study concludes that food security policies should promote crop diversity as opposed to specializing in a few crops; and should match food interventions to local context informed by local indicators to ensure the promotion of diverse and appropriate food interventions that enhance livelihood and ecological resilience of smallholder farming systems throughout the year.

Keywords: local knowledge, crop diversity, food security, land degradation, smallholder farmers.

L10.P.37

Agroforestry practice in Latvia

Lazdiņa D. (dagnija.lazdina@silava.lv), Bārdulis A.

Short rotation coopice, LSFRI SILAVA, Salaspils, Latvia

Agroforestry is well known and is becoming more popular as a sustainable farming method. In Latvia there is agroforestry, but it is not mentioned in local legislation. There are two main farming methods which could be also be classified as agroforestry, they are short rotation coppices, which is counted as agroforestry in some countries because trees are grown on agriculture land and have been managed like an agriculture crop. In 2018 in Latvia there were 220 ha of *Populus spp*., 442 ha of *Salix spp*. and only 3 ha of *Alnus incana* with the status of Short Rotation Coppice. It is becoming popular to cooperate between willow farmers and beekeepers because there are plenty of meadow species below the canopies in Short Rotation Coppice and Short Rotation Forestry trees, beside that willows are the first plant to bloom in spring (1,2).

The most suitable agroforestry system for Latvia farming traditions are silvopastoral systems because open arable land is too important for growing human food to be used for grazing. Instead the animals would graze in the transition zone between arable land and forest or water such as the sea, lakes or rivers or in forest belts and bush lands.

There are no available statistics on how many ha of forest and bush land are used for grazing. The official opinion and message to society are that silvopastoral systems in Latvia have disappeared, but it is because valuable habitat surveys are covering old forests where there is nothing to eat for cattle, cattle graze in middle age and young forests as well as on bush lands. In Latvia there are around 45 farms dealing with cattle for meat. There is a huge potential for human made silvopastoral systems where fast growing coppice trees (common for Short Rotation Coppice systems) are used for shelter of cattle. Shelter trees becoming more popular and important in terms of climate change as well – extreme weather conditions and as capturers of CO_2.

Keywords: fast growing trees, agroforestry, grazing, schelter.

References:

1. Pucka I., Lazdina D., Bebre I., 2016, Agronomy Research, 14(4), 1450-1466.
2. Kreslina V., Stikane K., Bebre I., Lazdina D., 2017. Acta Biol. Univ. Daugavp., 17 (2): 199 – 210.

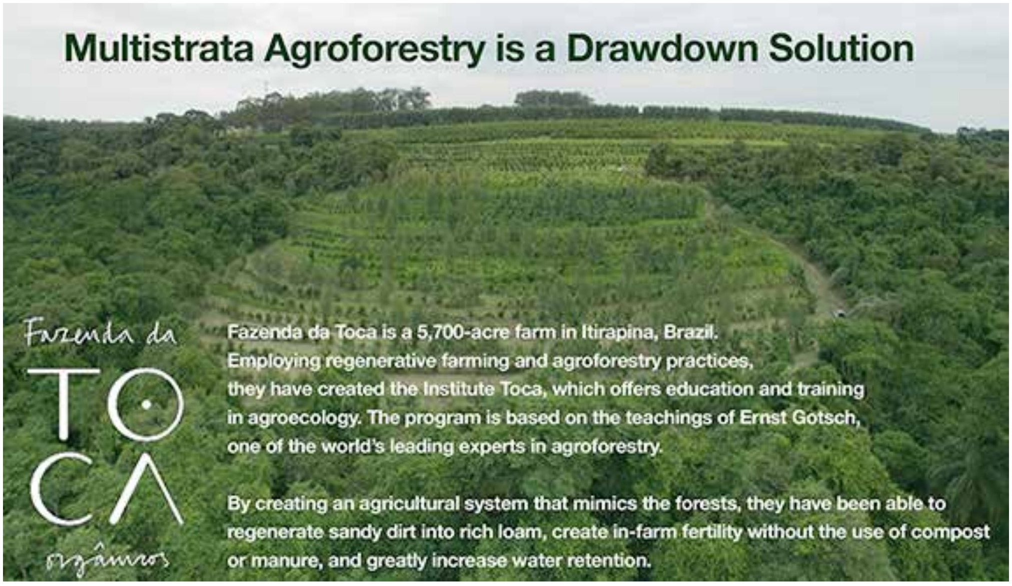
L10.P.38

Multistrata Agroforestry for Carbon Drawdown

Lea A. (igivetrees@gmail.com)

iGiveTrees, Seattle, WA, United States

Multistrata agroforestry takes its cues from this natural structure, blending an overstory of taller trees and an understory of one or more layers of crops.
Because multistrata agroforestry mimics the structure of forests, it can deliver similar environmental benefits. Multistrata systems can prevent erosion and flooding, recharge groundwater, restore degraded land and soils, support biodiversity by providing habitat and corridors between fragmented ecosystems, and absorb and store significant amounts of carbon.
Whether the crop being grown is coffee, cacao, fruit, vegetables, herbs, fuel, or plant remedies, the benefits of multistrata agroforestry are clear. It is well suited to steep slopes and degraded croplands, places where other cultivation might struggle.
The costs to establish such a complex system are high and without immediate returns. Though they are quite profitable once established, that investment may be out of reach for resource-poor farmers. That same complexity makes mechanization difficult, if not impossible. Tending and cultivating by hand means higher labor costs. And though resilience and longevity are superior, yields can be lower than with conventional approaches, as crops compete for water, light, and nutrients.
Multistrata agroforestry cannot be implemented everywhere, but where it can, it promises a sizable impact. In addition to their high rates of carbon sequestration, these systems of cultivation are among the most energy efficient in the world.



Keywords: multistrata, biodiversity, carbon, sequestration, drawdown.

References:

1. HAWKEN Paul, 2017 Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming p46

L10.P.39

Impacts of FMNR on the agricultural performance of smallholder farming s ystems at landscape scale in Senegal

Leroux L.[1] (louise.leroux@cirad.fr), Gbodjo J. E.[2], Djiba S.[3], Tounkara A.[4], Ndao B.[5], Diouf A. A.[5], Soti V.[6], Affholder F.[7], Tall L.[8], Clermont-Dauphin C.[9]

[1] *UR AÏDA, CIRAD - CSE, Dakar, Senegal*; [2] *UMR TETIS, IRSTEA, Montpellier, France*; [3] *UCAD, Dakar, Senegal*; [4] *Univ Thiès, Thiès, Senegal*; [5] *CSE, Dakar, Senegal*; [6] *CIRAD - CSE, Dakar, Senegal*; [7] *UR AÏDA, CIRAD, Montpellier, France*; [8] *LNRPV, ISRA, Dakar, Senegal*; [9] *UMR Eco&Sol, IRD, Dakar, Senegal*

Management of isolated trees as an integrated part of smallholder farming systems has long been a key food security strategy in Africa. Current knowledge on the impact of parklands structuring on agrosystems productivity is limited. Combining multisources remote sensing, landscape ecology and statistical modelling, this study aims at evidencing the contribution of FMNR to the agricultural performance of smallholder farming systems at landscape scale in Senegal. Agronomical surveys were conducted in 2017 and 2018 on 70 farmers' fields with heterogeneous trees composition. We assessed groundnut aboveground biomass (AGB) and millet grain yield (GY). Proxies for parklands composition and vegetation productivity were derived from remote sensing. Regression models were calibrated and model parameters were optimized using a random sample consensus method accounting for measurement uncertainties. For 2017, Green chlorophyll index over millet flowering phase and whole groundnut cropping cycle allowed estimating GY and AGB with R^2 of 0.76 and 0.67 respectively. Integrating information on tree cover structure (fraction of soil covered by trees) increased assessment accuracy by 7% for millet GY (R^2=0.83) and 22% for groundnut AGB (R^2=0.89). These promising results have to be strengthened with data from ongoing cropping season but they already indicate the need to integrate information on trees at landscape scale to better assess agricultural performance of smallholder farming systems.

Millet grain yield estimation (left) and groundnut aboveground biomass estimation (right) with a linear model and a random sample consensus algorithm applied to linear regression. Input variables are chlorophyll index, woody cover and phenological information derived from multisouces high spatial resolution remote sensing data.

Keywords: Parklands, Senegalese Peanut Basin, crop productivity, remote sensing, landscape.

L10.P.40

Identifying Systems Acceptable to Farmers: Hainan Rubber Agroforestry

Li J. (joanneli@kfbg.org), Padilla H.

Kadoorie Conservation China, Kadoorie Farm and Botanic Garden, Hong Kong, Hong Kong SAR China

Rubber is considered as China's strategic crop, it was largely promoted in tropical Hainan since 1970s. It is one of the most successful poverty alleviation programs in Hainan that almost every rural households depends on rubber.
Kadoorie Conservation China has been promoting rubber agroforestry in rural villages surrounding protected areas to diversify the agroecosystem and improving ecosystem services. We have been struggling to identify plants acceptable to farmers. Scientifically proven systems like rubber-tea, rubber-coffee and rubber-cocoa were rejected by farmers. However, in recent 5 years, rubber agroforestry systems are developing rapidly. High-value tree crops, native herbs and honeybees were identified and integrated into the systems, providing additional short-term and long-term incomes to farmers and improving their resilience to climate change and market fluctuation. Lesson was learnt from farmers' criteria for acceptance or rejection of different systems related to current and potential market.

Keywords: Rubber, Agroforestry, Hainan, China.

L10.P.41

Icosysteme : developping blended learning for agroforestry

Liagre F.[1] (liagre@agroof.net), Archambeaud M.[2], Girardin N.[1], Ori D.[1], Richard A.[3], Amar L.[4], Legallic H.[1], Marin A.[1]

[1] *Agroof, Anduze, France*; [2] *Icosysteme, Nantes, Country*; [3] *Grizzly Production, Paris, France*; [4] *Icosysteme, Anduze, France*

Training session is a key point for young future farmers or candidates for an agroforestry project. Traditionally, the training included actions in room, face to face, and visits or workshops in the field. The new technologies offer various perspectives which could be very efficient if they are well adapted to the farm and agroforestry context. Just like the rest of the world, agriculture is evolving rapidly, and the education tools just follow this evolution.

In this context, Agroof and two other associated (Matthieu Archambeaud Consulting and Arnaud Richard Communication) created ICOSYSTEME in 2016. The objective of ICOSYSTEME is to use the new technologies to propose new training programme and to explore new potentialities for agroforesters. Blended learning is an education program (formal or non-formal) that combines online digital media with traditional room or field methods The blended instruction could be more effective than purely face-to-face or purely online classes, without any instructor. By using a combination of digital instruction and one-on-one face time plus a field time, students and farmers can work on their own with new concepts which frees teachers up to support individual students and to launch innovations by new exchanges between the trainees. Blended learning also have the potential to go directly to key point when people meet together in room or in the field. On the platform used for the training, people can share experience, project, tools… before and after the training session. The collaboration between the facilitators and the trainees offer multiple advantages and offer a new challenge for the education in Agroforestry.

Another positive point for this new opportunity is to offer the possibility to farmers, often very busy, to join session without spending too much time outside their farm, but keeping the interactivity with other trainees or participants. In the same way, it's also the possibility to connect a same project with international partners… that encourages collaboration and shared learning.

Keywords: Training, Blended learning, icosysteme, webinary.

L10.P.42

Factors influencing on-farm tree seedling survival across various contexts in the eastern drylands of Kenya

Magaju C.[1] (c.magaju@cgiar.org), Crossland M.[2], Kuria A.[1], Winowiecki L.[1], Nyaga J.[1], Kiura E.[1], Phosiso S.[1], Muriuki J.[1]

[1] *World Agroforestry Centre, Nairobi, Kenya*; [2] *Bangor University, Wales, United Kingdom*

Trees on farms have the potential to improve the livelihoods of smallholder farmers. In addition to ecosystem services, they provide opportunities for generating additional income and contributing to household nutritional requirements. Despite these benefits, tree planting in the eastern drylands of Kenya has had many challenges, especially characterized by low seedling survival. This is partly due to erratic rainfall, planting of ecologically unsuitable tree species, poor quality seedlings, and poor tree seedling management practices. To support farmer learning to enhance tree seedling survival, 1600 farmers in Kitui, Machakos and Makueni Counties conducted on-farm planned comparisons to explore the performance of different planting and management practices on survival. The objective was to determine how different planting and management practices influence tree seedling survival across varying farm contexts. Farmers compared two sizes of planting holes with and without manure, and mulch. Seedlings of six tree species were planted in November 2016 and November 2017 and seedling survival was monitored six months after planting using electronic data entry. Data was analysed using R statistical software.

Results showed that of the six tree species, *Moringa oleifera* seedlings had the highest survival rate in Kitui County while *Carica papaya* and *Senna siamea* had the highest survival rate in Machakos and Makueni Counties respectively. Seedlings planted with manure had a higher survival rate across all species and Counties. *Azadirachta indica*, *Carica papaya*, *Mangifera indica* , *Melia volkensii*, and *Senna siamea* had higher survival with the addition of mulch across all the Counties while seedlings planted in a woodlot had a higher survival compared to those planted along the boundary, scattered in cropland, along the terraces, and home compound. Survival was highest with watering in Makueni County while survival was higher for seedlings planted without fertilizer in Machakos and Makueni Counties. Seedlings planted in the 90cm by 90cm by 45cm hole had a higher survival rate than those planted in the 45cm by 45cm by 45cm.

Survival was also higher in Kitui and Makueni Counties for seedlings planted in November 2017 compared to those planted in November 2016. Farmers reported that higher seedling survival was due to increased rainfall during the November 2017 planting season, improved farmer management of the seedlings due to practices learned during trainings, and changes in attitudes towards the value of tree planting which resulted in better management practices. Contextual variables affecting seedling survival include: household characteristics such as farm size, access to labour and inputs, and farm characteristics such as erosion status, soil quality and level of degradation.

Keywords: Trees on farm, Options by context, On-farm planned comparison, Tree seedling survival.

L10.P.43

Establishment of a 12-ha Cacao Agroforest in Côte d'Ivoire

Mancini A.[1] (agnese.mancini@mdlz.com), Crozier J.[2], Cryer N.[1], Gninahophin S.[3], González-Moreno P.[2], Kaminski A.[3], Gilmour M.[3], Stirling C.[1]

[1] *Mondelez International, Birmingham, United Kingdom*; [2] *CABI, Egham, United Kingdom*; [3] *Barry Callebaut, Zurich, Switzerland*

Many studies have demonstrated the advantages of cacao agroforestry systems. However, large scale, long-term field trials are not common, and the current body of knowledge is not sufficient to support farming recommendations. We are currently evaluating cacao agroforestry schemes at scale for an extended period (2015-2026) using a 12-ha agroforest in Côte d'Ivoire. The aim is to assess the economic and environmental benefits of large-scale cacao agroforestry. The experimental design is based on three agroforestry planting schemes and one control. Each agroforestry scheme has a different design comprising cacao intercropped with timber or fruit-trees, temporary & permanent shade (plantain and Gliricidia) with sufficient space for the growth of annual crops (maize and cowpea) during the establishment period of cacao. Scheme 1: double row cacao and teak. Scheme 2: double row cacao and coconut. Scheme 3: single row cacao and teak. Scheme 4 (control): single row cacao and plantain (typical small-holder's system). The trial has just completed the establishment phase. Measurements include i) economic performance: cost of inputs, labour and outputs, ii) agronomic performance: mortality, growth rates and yields and iii) environmental assessment: climate & microclimate data, soil chemistry, carbon sequestration and shade level. The establishment and early findings from the trial will be described.

Scheme 2: double row cacao and coconut. Tiassalé, Côte d'Ivoire, October 2018

Keywords: Cacao, Agroforest.

L10.P.44

Agroforestry systems in Arunachal Pradesh, North-East India practiced by indigenous people

Manpoong C.[1] (chowlani18@gmail.com), Tripathi S.[2]

[1] *Agriculture Sciences, Arunachal University of Studies, Namsai, Arunachal Pradesh, India*; [2] *Forestry, Mizoram University, Aizawl, Mizoram, India*

Arunachal Pradesh is rich in variety of agro-ecosystems. These ecosystems are being practiced by indigenous population representing 28 major and 110 sub-ethnic tribes. Agroforestry is one of the most commonly practiced farming systems in this humid sub-tropical climate. The poor small land holding farmers are mostly engaged in the agro-forestry systems and they adopted various cultivation strategies for their enhanced food security and better livelihood options. Out of various land use practices operated, the most common land use practices are Agri-silviculture, Agri-silvopastoral and Agri-horticulture in this foothill of Eastern Himalaya. Among these practices, home garden and shifting cultivation are the most prominent indigenous agroforestry systems extensively adopted for cultivation of variety of crops. Crops grown in home gardens are mainly selected by the tribes on the basis of their utility to the family for fulfilling day to day requirement of the family. These species includes variety species of trees, bananas, vines, vegetables, spices and diverse medicinally important herbaceous plants which are grown to make a dense canopy with random or spatial and temporal arrangements. Further, the dependency of the population is on age-old traditional slash and burn agriculture system which comprises variety of rice, maize, mustard, vegetables including various indigenous spices as major crops which played a vital role in meeting the basic family needs. Conservation of forest trees and bamboo in and around the agriculture fields adopted by the indigenous tribals provides resilience to the system at the landscape level. Besides agro-forestry practices, the region is endowed with rich and unique natural diversity of wild edible plants. However, expanding population and increasing cost of commodities are adversely affecting the sustainability of indigenous farming practices, which require attention from the policy makers and Government department to sustain such practices which should be ecologically balanced and economically feasible. It requires holistic approach of forest management in the tropics with emphasis on landscape management for sustainable management of resources, providing developmental benefits to local communities, based on equity and social justice.

Keywords: Indigenous farming, Homegarden, Shifting cultivation, Food security, Northeast India.

References:

1. Viswanath et al, 2018, Advanced Agricultural Research & Technology Journal, 18-29
2. Tangjang and Nair, 2016, International Journal of Environmental & Agriculture Research, 25-34
3. Dhyani et al, 2009, Indian Journal of Forestry, 181-190

L10.P.45

Experiencing the transition towards agroforestry in the Mediterranean: a new Long Term Experiment in Central Italy

Mantino A.[1] (a.mantino@santannapisa.it), Antichi D.[2], Coli A.[3], Sbrana M.[3], Pecchioni G.[1], Bosco S.[1], Cappucci A.[3], Mezzalira G.[4], Pelleri F.[5], Chiarabaglio P.[6], Carlesi S.[1], Moonen C.[1], Barberi P.[1], Mazzoncini M.[2], Ragaglini G.[1], Mele M.[2]

[1] *Institute of Life Sciences, Sant'Anna School of Advanced Studies, Pisa, Italy*; [2] *DAFE, University of Pisa, Pisa, Italy*; [3] *CIRAA, Centre for Agro-Environmental Research, Pisa, Italy*; [4] *Veneto Region Agency for Innovation, Legnaro (PD), Italy*; [5] *Forestry Research Centre, CREA-Forestry and Wood, Arezzo, Italy*; [6] *Intensive Wood Production, CREA-Forestry and Wood, Casale Monferrato (AL), Italy*

Agroforestry (AF) is considered to have a high mitigation potential and to be more resilient to climate changes compared with conventional cropping systems. However, the effectiveness of AF systems still need to be evaluated in the Mediterranean, where ongoing changes are exacerbating the interannual variability of climate, making farmers choices increasingly difficult. A multidisciplinary team is focusing on the establishment of a 40-ha Long Term Experiment (LTE), to support the transition towards AF in Tuscany. The purpose of the LTE is to assess the sustainability of rainfed AF compared with conventional arable and agro-pastoral systems. The LTE, started in 2018, is located in Pisa on clay loam soils (Fig.1). Two AF systems, silvo-arable (SA) and agro-silvo-pastoral (ASP), have the same linear tree system for timber production, with poplar and oak, but different crop rotations. In AS the rotation consists in durum wheat, sorghum and faba bean; in ASP the 3 crops are followed by a 4-yr meadow. Trees have been planted along one side of each field, 2m away from drainage ditches, with a density of 60 trees ha-1. The space between tree rows and ditches are managed as semi-permanent buffer strips to increase functional biodiversity and to limit nutrient leaching. The controls are the 2 rotations without trees, 2 pure stands of poplar and oak and a polycyclic plantation (oak, poplar, hazelnut and alder). The LTE will be the base for future research and demonstration activities.

Fig.1 Location and overview of the agroforestry Long Term Experiment (LTE) in Pisa, Italy

Keywords: Mixed farming systems, Sustainable intensification, Mitigation potential, Resiliency to climate change.

L10.P.46

Agroforestry Plantations: Improving returns while decreasing costs

Mejía Goellner C.[1] (carolina.mejia@12tree.de), Martinez L.[2], Hanke O.[3]

[1] *12Tree Finance Panama, PANAMA CITY, PANAMA*; [2] *12Tree Finance, BERLIN, Germany*; [3] *12Tree Finance, ZURICH, Switzerland*

This abstract is based on existing projects developed by 12Tree Finance in Latin America.

Cacao is a species native to the tropical rainforests of the Americas. The humid natural environment of cacao trees favors fungal diseases, which decrease the plants' productivity. To protect their investments, investors looked for drier climates to establish new large and capital-intensive commercial cacao plantations. However, these "superior" climatic conditions brought new challenges: water scarcity, lacking organic matter in the soil and adequate nutrition programs.
For most South American large-scale producers, the solution was to establish monoculture cacao plantations in dry climates with complex irrigation systems that supply the water demand and compensate the evapotranspiration rates in such conditions. However, with increasingly erratic climate patterns, these dry zone plantations will have less surface water available over time and at all of the times. As rainfall decreases and temperature increases, deeper wells and bigger water reservoirs are needed. These factors combined with a volatile commodity market, make a point for agroforestry economic and environmental resilience.
Agroforestry concepts used by 12Tree cacao provide moderate shade, while maintaining the environmental services of an agroforestry plantation; such as protection of younger plants from radiation and extreme heat, reduced evapotranspiration rate and increased organic matter in the soil over time.
By reducing evapotranspiration, the amount of water required by the main crop reduces significantly. A cacao plantation in a full exposure system may require up to double the water lamina than an agroforestry system, because of the reduction in evapotranspiration. Lower water requirements mean smaller investment in pumps, wells and reservoirs, and less energy consumption because of shorter irrigation turns. In other words, lower operation costs.
Using leguminous plants as primary shade, also decreases the amount of nutrients that must be provided by a nutrition plan, as leguminous plants help fixing nitrogen in the soil. The presence of shade substantially decreases the weed growth in a plantation; decreasing the cost of weeding. This ensures that the fertilization is more effective as there is less competition for nutrients between the commercial crop and the weeds. By using such profitable shade crops, the same plot of land can be used to produce two or more different crops that are linked to different commodity markets, which increases the economic resilience of a project as it diversifies revenues streams.Using Musaceae in the earlier stages of a cacao plantation is another good example how temporary shade crops contribute positively to financial returns[1]. Musaceae also attract Forcipomyia, a pollinator of cacao[2]. Having this pollinator in the plantation increases the pod production, thus increasing the returns[3].

Keywords: Agroforestry Systems, Cacao, Irrigation, Returns, Water scarcity.

References:

1. https://www.indexbox.io/blog/brazil-and-ecuador-are-the-major-banana-producers-in-central-and-south-
2. http://www.worldcocoafoundation.org/wp-content/uploads/files_mf/adjaloo2013genomics-physiologypolli
3. https://www.smithsonianmag.com/science-nature/you-wouldnt-have-chocolate-without-invisible-flies-and

L10.P.47

Oil palm agroforestry in the Brazilian Amazon: early lessons from demonstration sites in Tomé Açu, Pará

Miccolis A. (a.miccolis@cgiar.org), Ramos H. M., Silva J. A., Arantes A. C. V.

World Agroforestry Centre - ICRAF Brazil, Belém, Pará, Brazil

This study is part of the project *SAF Dende: Oil Palm Diversification: reconciling conservation with livelihoods*, an alliance between NATURA, EMBRAPA - Brazilian Agricultural Research Company, CAMTA , a farmer cooperative, and ICRAF - the World Agroforestry Centre, with support from USAID, in Tomé Açu, Pará State, Brazilian Amazon. The main goal of this wider initiative is to promote the adoption and upscaling of oil palm agroforestry systems that couple social and economic benefits with environmental services. The action research approach adopted in this study was comprised of: a participatory appraisal (using a tool developed by ICRAF called PLANTSAFs – Planning and Appraisal for Decision Making in Agroforestry Systems) Performed on 15 farms, this tool provided insights that fed in to a co-design workshop where farmers and technicians jointly designed systems tailored to each family's objectives and context, followed by technical visits and farmer exchanges. 11 new plots established in early 2018 are comprised of oil palm, cacao, açai palm (Euterpe oleracea), and a combination of other fruits, hardwoods, and fertilizer species, with a total of 33 species and average of 12 species per plot in innovative compositions. After 9-10 months, over 80% of areas have been managed properly, plant development has been satisfactory and farmer participation in demonstration sites and project activities has been high. Youth accounted for 54% of farmers directly involved in plot establishment and management, and women made up 45% of participants in project activities. Key constraints in initial establishment were low labor availability, significant losses of fertilizer species planted by cuttings, few short-cycle food crops in most of the systems, and insufficient planting materials to cover the whole site with some species. Given high labor requirements for more complex, biodiverse systems, it is highly advisable to establish smaller plot sizes than usually practiced for monocrop oil palm in the region, not exceeding 1 hectare per family per year in the case of family farmers. The prevalence of degraded lands and low ecological resilience where many of these new plots are being established calls for the wider use of fertilizer species. Overall, the greater use of short cycle crops and food species in the first year should also be encouraged to offset high initial establishment costs and enhance food security, thus spurring adoption. Constraints identified in the appraisal stage and confirmed in initial establishment also include the need for capacity-building and extension processes that build solutions with farmers, strengthening germplasm supply, and increasing access to the financial capital needed to cover high initial investment costs.

Keywords: oil palm, agroforestry, Saf Dendê, diversification, Brazil.

L10.P.48

Dynamic Agroforestry without burning for land preparation for annual and perennial crop production in the tropics

Milz J.[1] (j.milz@ecotop-consult.de), Jacobi J.[2], Velasquez F.[1]

[1] *ECOTOP, La Paz, La Paz, Bolivia*; [2] *Centre for Development and Environment, University of Bern, Bern, Switzerland*

Slash and burn practices are still one of the most common methods used by small and large-scale farmers for land preparation of bush and forest fallow for annual and perennial crop production in the tropics. The consequences are risks of uncontrolled bush fires, rapid loss of soil fertility, biodiversity loss, erosion, and high pressure by weeds, pests and diseases. Ecotop conducted an experimental study in the Alto Beni region in the lowlands of Bolivia during four years, producing upland rice, beans and maize while applying the principles of dynamic agroforestry processes as described by E. Götsch. In addition, within Ecotop's scope of participatory extension work with small farmers in Bolivia, Central America, Ivory Coast and Ghana, farmers are rapidly adapting non-burning field preparation. The slashed vegetation is chopped and the organic matter distributed uniformly on the ground. Dynamic agroforestry systems are also replicated elsewhere: In Ghana, a pilot phase of the renovation of unproductive cocoa plantations by implementing the principles of dynamic agroforestry started in 2016, and 450 ha of dynamic agroforestry systems are going to be established with small farmers as of 2019. In general, it is thought that the main reason for field preparation with fire is because of less labour requirement comparing with non-burning land preparation.
Nevertheless, on-field monitoring of labour investment for land preparation in the Alto Beni Region without burning indicated less requirement of working hours compared with the use of fire. Implementation costs are varying according to characteristics of existing vegetation, topography and land use history. Labour requirement for land preparation with and without burning included slash of fellow vegetation, chopping of branches, tagging for cocoa plantation of 4m x 4m, preparation of banana suckers, digging of holes for banana and cocoa planting, sowing of maize, beans and squash.
The average labour requirement was 513 working hours/ha for non-burning and 681 working hours/ha for land preparation with burning.
The main difference is that land preparation without fire for dynamic agroforestry systems requires the establishment within a timeframe of only 3 to 5 days. The planting of banana and by-crops have to be done before cutting and chopping the vegetation while land preparation with fire can be extended within a time frame of several weeks.
Throughout the four years of the upland rice field experiment in Bolivia, we achieved annual yields comparable to slash and burn plots on primary forest soils of around 1560 kg/ha of husked white rice without land rotation and any external inputs. Average yields of upland rice in the Alto Beni region are normally less than 1000 kg/ha. Further labour requirements for weeding in non-burning fields are considerably lower than in burnt fields and cocoa, banana and other crops are performing better than in burnt fields.

Keywords: Dynamic agroforestry, Non-burning land preparation, Upland rice in dynamic agroforestry, Bolivia, Ghana, Ivory Coast, cocoa production Ghana.

References:

1. Götsch, E. 1994. Break-through in agriculture. Rio de Janeiro, ASPTA.
2. Jacobi, J.,2016, Environmental Management DOI 10.1007/s00267-016-0805-0
3. Milz, J., 2009, IFOAM Guide to Biodiversity and Landscape Quality in Organic Agriculture, 3.4.3.
4. Milz, J., 2010, Biodiversidad y Ecología en Bolivia, (p 324-340)

L10.P.49

Yield safe: wheat and pasture production under Pinus Radiata

Mosquera-Losada M. R.[1] (mrosa.mosquera.losada@usc.es), Pérez-López C.[2], Ferreiro-Domínguez N.[1]

[1] *Crop Production and Project Engineering, University of Santiago de Compostela, Lugo, Galicia, Spain*;
[2] *Agroforestry Engineering, University of Santiago de Compostela, Lugo, Galicia, Spain*

Agroforestry are sustainable land management systems able to increase the production considering both the woody and herbaceous component. The Woody component economic return is usually produced when the stand is thinned and in the final harvest. However, the herbaceous production is usually negatively affected by the shade, but it also depends of the type of understory that it is grown. Yield SAFE is a biophysical model that allow to compare different crop production under different tree management options. The aim of this paper was to compare the herbaceous production of wheat and grassland in a tree less situation and a silvopasture system with low tree density (600 trees ha-1) developing four different scenarios. Wheat and grassland were sown at the beginning. Under treeless situation (Figure 1), wheat produces more than grasslands, but in extreme years with a high leve lof drougth the production of pasture is reduced in a lower degree or even not reduced. When the herbaceous component grows up under the tree, wheat diminishes more its productivy than grasslands. As a mean pasture under tree is able to maintain the 20% of the full sunlight situation grassland production, while the whea is below 5%. We can conclude that having grassland as part of the understory of a pinus radiata silvopastoral systems, farmers are able to have more forage than having wheat. Moreover, the resilience of pasture availability is higher when grassland is used in silvopastoral systems.

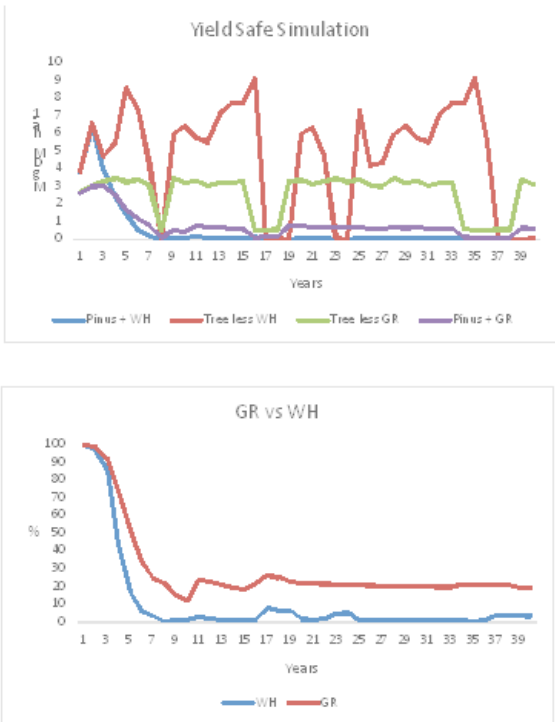


Figure 1. Yield safe understory production (DM and %) simulation in four scenarios.
WH: Wheat; GR: Grassland

Keywords: agroforestry, silvoarable, silvopasture, Monterrey pine.

L10.P.50

Silvopasture in Central New York, Galicia and Central Argentina

Mosquera-Losada M. R.[1] (mrosa.mosquera.losada@usc.es), Chatrchyan A.[2], Chedzoy B. J.[3]

[1] *Univ. Santiago Compostela, Lugo, Lugo, Spain*; [2] *Cornell University, Ithaca, New York, United States*; [3] *Cornell Cooperative Extension of Schuyle, Ithaca, New York, United States*

The Sierra Mountains of Central Argentina: Afforestations in Argentina converted some areas in silvopasture. Major benefits include: (i) Decreased flash flooding through increased precipitation infiltration (ii) Rapid improvements of soil health by OM and nutrient deposition(iii) increase rural employment (iv) Production diversification. (v) Higher stocking capacities than treeless areas (v) Silvopasture provides shelter for livestock during extreme weather events (vi) Improved silvopasture rotational grazing increases animal performance and health and plant richness.

Central New York: Livestock farms in New York are typically a mix of pasture and forest. Major benefits of silvopasture are: (i) Control tool of invasive forest plants (ii) Increase farmland use and diversification leading to a greater viability. (iii) Soil health improvement (iv) Improved water infiltration in soils (v) Reduced extreme weather events livestock exposure and animal confination (vi) Greater forage drought resilience(vii) Reduced pest issues (viii) Greater resilience.

Galicia: Silvopasture benefits in Galicia are (i) Feeding animals during shortage feed periods (ii) Increasing short, medium and long term productivity (iii)Reducing fire risk and GHG emissions (iv) Increasing biodiversity (v) Reducing water contamination in agricultural lands (vi) Improving soil water infiltration (vii) Improves landscape beauty (viii) Increasing productivity, rural development and community resilience.

Figure 1. Silvopasture plots in Galicia, Central Argentina and New York

Keywords: environment benefits, productive benefits, social benefits.

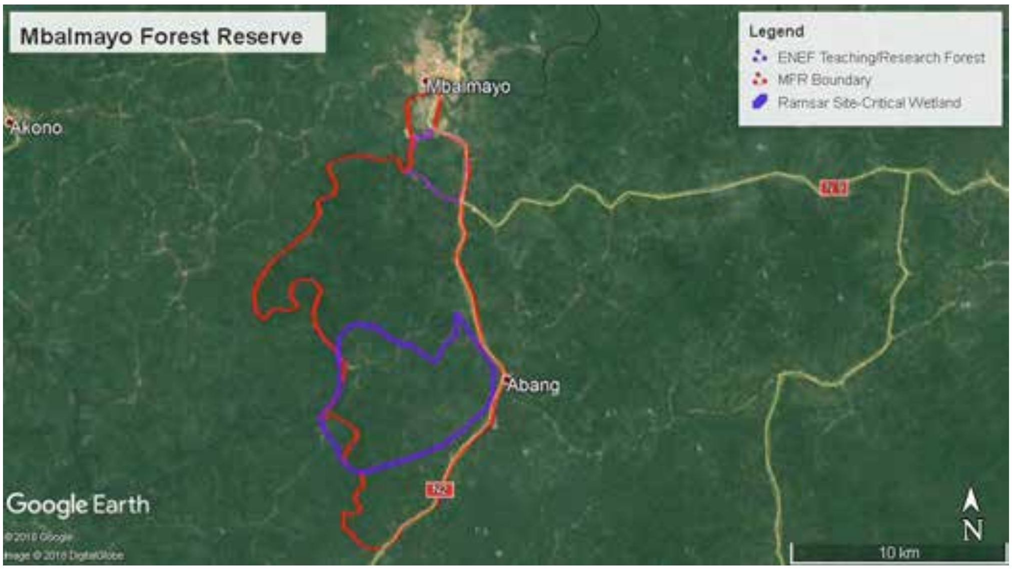
L10.P.51

Agroforestry Service Learning and Action Research in Cameroon's Mbalmayo Forest Reserve

Munsell J. (jfmunsel@vt.edu), Addlestone B.

Virginia Tech University, BLACKSBURG, VA, United States

L'Ecole Nationale des Eaux et Forêt/The National School of Water and Forests of Cameroon (ENEF) and Virginia Tech University's Department of Forest Resources and Environmental Conservation (FREC) are improving agroforestry science and community collaboration skills among ENEF students while protecting the Mbalmayo Forest Reserve. The reserve contains important wetland and forest habitat, and the ENEF teaching, training, and research forest. It also plays a critical role in regional water quality, wildlife, and farmer livelihoods, but degradative agriculture threatens its integrity. Previous efforts to manage the ENEF teaching forest and promote wetland conservation were top-down, forest-centered, and ultimately rejected by local farmers. Collaborative conservation and action research focused on agroforestry better balances student education, farmer buy-in, and environmental health. Through a combination of classroom and field-based interaction, students and farmers are gaining first-hand knowledge needed to work together in a transparent and scientific manner. This includes scientific research methodology and analysis, water quality and sediment monitoring, novel community engagement and citizen science techniques, site selection, and agroforestry technology design and management. Student/farmer interactions are studied using narrative- and activity-based methods, and field plantings and monitoring systems track impacts.



Keywords: Education, Mixed Methods.

L10.P.52

Effects of improved pigeonpea fallows on biological and physical soil properties and their relationship with maize yield

Musokwa M.[1] (mmusokwa@gmail.com), Mafongoya P.[1], Lorentz S.[2]

[1] *Agriculture, University of KwaZulu-Natal, Pietermaritzburg, South Africa*; [2] *Engineering, University of KwaZulu-Natal, Pietermaritzburg, South Africa*

Land degradation and declining soil properties, have affected agricultural productivity**.** Sub Saharan Africa (SSA) is experiencing the rapid increase in the percentage of rural households farming on degraded land as compared to other regions in the world. Use of legume trees such as pigeonpea improved fallows, is one of the agroforestry system that can restore degraded soils. The objectives of the study were to: Evaluate biological (soil macrofauna species diversity & richness) and physical soil properties (infiltration rate & aggregate stability) of the two-year-pigeonpea improved fallow compared to non-fertilized continuous maize crop and to relate maize grain yield to biological and physical soil properties. The study was conducted in KwaZulu-Natal Province at Fountainhill Estate (29°27'2» S; 30°32'42» E) and 853 m. A randomized complete block design replicated three times was used with 5 treatments, continuous unfertilized maize (T1), natural fallow- then maize (T2), pigeonpea intercropped with grass in (1st year) - then pigeonpea (2nd year) – then maize (3rd year) (T3), maize intercropped with pigeonpea (1st year) – then pigeonpea (2nd year) –then maize 3rd year (T4). Two-year pigeonpea fallow then maize on 3rd year (T5). Pigeonpea fallows were planted as pure stands at a spacing of 1 m by 1m, direct seeded in 2015/2016 season. The fallows were terminated in November 2017, and then maize was planted in all plots. Soil macrofauna was sampled using steel monoliths. Infiltration rate was measured using double rings. Aggregate stability was measured using a modified wet-sieving technique.Data was analyzed using Estimate S, Correlation and Regression analysis and GENSTAT C. Significant difference ($P<0.05$), were observed on soil macrofauna species richness and diversity as indicated by the order T5 (17.44**d**) >T4 (13.33**c**) ≥ T3 (10.56**bc**) ≥ T2 (9.67**b**) > T1 (6.00**a**) and T5 (1.75**b**) ≥ T2 (1.66**b**) ≥T4 (1.62**b**) > T1 (0.78**a**) ≥ T3 (0.98**a**) respectively. Significant differences ($P<0.05$) were observed on Infiltration rate (mm/hr) T5 (29.81**c**) > T3 (20.99**b**) ≥ T2 (19.11**b**) ≥ T4 (15.97**ab**) ≥ T1 (10.78**a**) and aggregate stability (mm) – T5 (11.45**c**) > T3 (10.13**bc**) ≥ T2 (8.99**b**) ≥ T4 (11.20**c**) ≥ T1(5.02**a**). Maize grain yield was significantly higher ($P < 0.05$) with the following order T5 (3787**d**) >T4 (2922**c**) ≥ T3 (2852**c**) ≥ T2(2294**b**)>T1 (993**a**) kg/ha. Positive correlation was observed between infiltration rates ($r2 = 0.73$), soil aggregate stability ($r2 = 0.92$), soil macrofauna species richness ($r2= 0.99$) against maize grain yield. Increase in aggregate stability and infiltration can increase potential for rapid capture of rainfall. This will also decrease the potential for runoff, erosion, and evaporation leaving more water available for maize crop use. This ultimately leads to a more sustainable viable system and under climate change variability maize crop may go under dry spell, hence it will create resilient maize cropping system.

Keywords: aggregate stability, agricultural productivity, agroforestry, infiltration rate, soil macrofauna.

L10.P.53

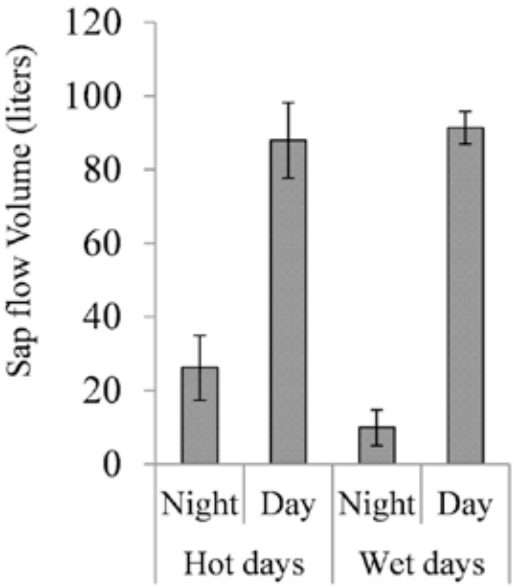
The impact of tree pruning on *Grevillea robusta's* water use and maize productivity in semi-arid Rwanda

Ngoga T. (ngogatenge@gmail.com)

Research, Rwanda Agriculture and Animal Resources, Kigali, Kigali, Rwanda

The integration of tree on smallholder farmers' fields in semi-arid conditions have been reported to cause competition for resources. Prunning is a proven way of managing competition but farmers in Bugesera do not commonly prune *Grevillea robusta,* a popular agroforestry tree in the area. This study aimed to investigate the effect of pruning on water uptake in *Grevillea* and productivity of associated maize. Sap Flow Meters were installed on *Grevillea robusta* trees from July 2014 to November 2016 and the Heat Ratio Method (HRM) was followed for water uptake analysis. The split split plot design was used to assess maize grain yield response and sap flow. Pruning reduced water uptake from an average of 59 lday-1 to 23 lday-1. The nighttime sap flow during dry season was higher compared to the wet season sap flow while the seasonal daytime was the same. Pruning increased maize grain yield from 2.375 tha-1 to 2.978 tha-1 during 2015 long rains and from 1.909 t ha-1 to 2.234 tha-1 during 2016 short rains. The corresponding percentage increase in yield was of 25.4% and 17%; respectively. The study clearly quantifies the volumes of water taken up by Grevillea and that pruning is critical in reducing these amounts to the benefit of accompanying maize. Besides, through pruning the farmers get firewood an important tree product in the area. It is recommended that tree pruning should be popularised in the region.

Key words: Pruning, Sap flow, Maize grain yield, Grevillea robusta



Keywords: Pruning, Sap flow, Grevillea robusta, Maize grain yield.

References:

1. Smith et al., 1999. Functional Ecology. 13, 256–264
2. Lott et al.,1996. Tree Physiology, 16, 995–1001
3. Muthuri et al., 2005. Forest Ecology and Management 212, 23–39
4. Burgess et al., 2001. Tree physiology. 21, 589–598
5. Wang et al., 2012. Journal of Plant Ecology. 5, 294–304

L10.P.54

Food Forest and Forest Garden: Italian Study Cases. Cataloguing varieties and practices in Italian Food Forests

Nicola L.[1] (l.nicola@studenti.unisg.it), Migliorini P.[1]

[1] *Sustainable and Organic Agriculture, University of Gastronomic Sciences, Pollenzo, Bra, Italy, Italy*;

The Food Forest as part of Agroforestry approach seems to give convincing results in term of marginal land management, reduction of inputs, sustainable production and ecosystem services, even though it is still little studied and known. It is based on the prevalent use of perennial varieties and the design takes place according to the creation of an ecosystem, based on self-fertilization, the close cycle of nutrients typical of a forest and the constant coverage of the soil. All these factors create a model with very low energy and care needs but highly fertile and biodiverse, and therefore resilient.

This article is an attempt to describe the phenomenon of the "Food Forest" in the Italian scenario, researching design methods, purposes and specific characteristic of the forest creation. 6 case studies from 5 Italian regions were visited and interviewed in 2017 to registered plant species and varieties, the gastronomic use and potential ecosystem services.

According to the results, the formation of these 6 food forests are quite recent with similar aims (mainly educational and self-sufficiency) on experimental base. In small areas (3000 m2 as average) 113 species/varieties of vegetables and 2 animal species were identified in total. The species were chosen for different productive roles, ecosystems functions and characteristics. Many results are already tangibles but productivity, animal interactions, consolidation and enlargement of surface are goals for the near future.

Tab. 4

Aims and goals at the beginning	
Improving soil fertility	A;B;D;E;F
Improving biodiversity	A;B;C;F
Uncertain timing	A;B;C;E
Self-sufficiency	A;B;D;E;F
Creating educational models	B;C;F
Resilience	A;B;D;E;F
Self-sufficient wood production	A;B
Experimentation	B;C;D
Social aggregation	C;E
High quality produces	D;F
Gradual expansion possibility	D;E;F
Forseeing climate change	F

Tab.5

Results	
Limited by climate change	F
Improved fertility	B;D;E;F
Improved biodiversity	B;C;D;E;F
Improved production	B;D;E;F
Good educational model	A;B;C;E;F
Partial self-sufficiency	A;B;E;F
Healthy plants	A;B;E
Good melting pot	C

Tab.6

Future goals	
To improve production	B;D;E;F
Interaction with breeding	B
Improving spaces	C;D;E
Inserting new practices and expermenting	B;C;D;E;F

Tab.7

SWOT Analysis				
	Helpful		Harmful	
Internal Origin	Strenghts		Weaknesses	
	Healthy plants	A;B;D;E	Productivity	B;D;F
	Resilience	A;B;D;E;F	Limited Spaces	B;C;D
	Soil fertility	A;B;C;D;E;F		
	Productivity efficence	A;B;D;E;F		
	Territorial implication	A;B;C;D;E;F		
External Origin	Opportunities		Threats	
	Education	A;B;C;D;E;F	External activities	B;C;F
	Tourism	D;E;F	Burocracy	B;D;E;F
	More interest	A;B;C;D;E;F	Climate change	A;E;F
	Improving production	A;B;D;E;F	Instituzions	B;E;F
	Sustainability	A;B;C;D;E;F	Little spread	A;B;C;D;E;F

Keywords: Food Forest, Forest Garden, Sustainable Agriculture, Italy, Resilience.

L10.P.55

Safeguard of *Faidherbia albida* based on phytochemical study of parts used in Phytomedicine of Benin, Niger and Togo

Ohouko O. F. H.[1] (ohoukofrjus@yahoo.com), Garba I. A. R.[2], Koudouvo K.[3], Adakal H.[4], Dougnon T. J.[1], Agbonon A.[3], Aguiyi J. C.[5], Gbeassor M.[3]

[1] *University of Abomey-Calavi, Abomey-Calavi, Benin*; [2] *Ministère d'Agriculture et de l'élevage, Niamey, Niger*; [3] *University of Lome, Lome, Togo*; [4] *Université Dan Dicko Dankoulodo, Maradi, Niger*; [5] *University of Jos, Jos, Nigeria*

Background: Faidherbia albida (FA) is one of the plants that could be threated due to its parts used to feed animal and curing livestock's/human diseases in phytomedicine.
Aims: This study aims to compare through a phytochemical screening, secondary metabolites present in fruits (F), leaves (L) and stem bark (SB) of FA for good practices in the identification of best part to use for safeguard and conservation of FA.
Materials: The GPS helped to locate the species in Togo, Benin and Niger. The F, L and SB of FA were used to carry out the screening.
Methods: The three parts of FA were collected in the North of Togo at Dapaong. Phytochemical screening established by Houghton (1998) and described by Houngbeme *et al.* (2014) was the comparative method used. Sustainable part of the plant's identification and the threat evaluation followed technics of Koudouvo *et al.* (2017).
Results: Ten of the 18 secondary metabolites evaluated were present variably in L, F and SB of FA (Table 1). Coumarins, Gallic Tannins, Leucoanthocyanes, Mucilage and Saponosides were present in the three parts, Anthocyanes only in L and SB: Possibility of substitution of the SB by F and L. Flavonoids and Reducing compounds, present in SB were absent in F and L: Impossibility of substitution of SB.
Conclusion: Due to the presence of these common secondary metabolites in F, L and SB, the usage of L and F in replacement of SB in veterinary phytomedicine could contribute to safeguard FA from biodiversity threat.

Table 1: Comparison of the secondary metabolites present in fruits, leaves and stem bark of *Faidherbia albida*

	Chemical compound																	
F. albida parts	Al	TAC	TAG	Fl	Ant	Leu	Qn	SP	Tp	St	Cy	Mu	Cm	Cr	HL	O-H	C-H	H-C
Stem bark	-	-	+	+	+	+	-	+	-	-	-	+	+	+	-	-	-	-
Leaves	+	-	+	-	+	+	-	+	+	-	-	+	+	-	-	-	-	-
Fruits	+	-	+	-	-	+	-	+	-	-	-	+	+	-	-	-	-	-

Green: Possibility of substitution of the stem bark by fruits and/or by leaves
Red: Impossibility to substitute of the stem bark
Yellow: Substitution of the stem bark can't be decided
+ : Presence of the compound; - : Absence of the compound

TAG: Tanins galic; TAC: Tanins catechic
Al: Alkaloids; Fl: Flavonoides; St: Sterols
Tp: terpenes; Leu: Leucoanthocyanes; Ant: Anthocyanes
Mu: Mucilages; O-H: O-Heterosides; CH: C-Heterosides
HL: Heterosides free; Cr: Reducing compound
Cm: Coumarins; Hc: Heterosides cardiotonics
Qn: Quinones; Sp: Saponosides; Cy: Cyanogenic derivatives

Stem of bark of *F. albida* Leaves of *F. albida* Fruit of *F. albida* Plant of *F. albida*

Keywords: Faidherbia albida, Safeguard, Phytochemical screening, Biodiversity, Togo, Benin, Niger.

References:

1. Koudouvo et al., 2017; J. of Agri. and Eco. Res. Int., 1-9
2. Houghton in Laboratory handbook for the fractionation of natural extracts, 1998; Ed Chapman and Ha
3. Houngbeme et al., 2014; Int J Pharm Sci Res, 1739-1745.

L10.P.56

Comparison of five shea tree (*Vitellaria paradoxa* C. F. Gaertn.) regeneration techniques in Burkina Faso

Ouoba Y. H.[1] (herman249@yahoo.fr), Bastide B.[2], Kaboré S. A.[1], Ganaba S.[3], Boussim I. J.[1]

[1] *Laboratory of Plant Biology and Ecology, University Ouaga 1 Pr Joseph Ki-Zerbo, Ouagadougou, Burkina Faso*; [2] *Department of Environment and Forests, INERA, Bobo-Dioulasso, Burkina Faso*; [3] *Department of Environment and Forests, INERA, Ouagadougou, Burkina Faso*

Shea tree (*Vitellaria paradoxa* C. F. Gaertn.) is a highly utilitarian species whose growth is slow. This study focuses on the comparison of five regeneration techniques. Its objective is to propose appropriate techniques to rejuvenate and restore at low cost the shea tree parklands in the areas of disappearance / reduction, in order to ensure a good dynamism of the species in Burkina Faso. Four sites distributed along a climatic gradient were selected for tests : Kakoumana (Sudano-Guinean zone), Noumoudara (South-Sudanian zone), Gonsé (North-Sudanian zone) and Bouria (sub-Sahelian zone). Three repetitions were performed per site in fields and/ or fallows. 90 planted subjects, 150 transplanted subjects, 300 seedlings, 150 seedlings in bushes and 270 subjects for assisted natural regeneration (ANR).
The plantation is very efficient in terms of survival rate ranging from 13% in the sub-Sahelian zone to 90% in the Sudano-Guinean zone. Seedlings in bushes are less successful but provide survival rates from 15% in the sub-Sahelian zone to 31% in the south-Sudanian zone. Free seedlings offer relatively low rates from 4% in the sub-Sahelian zone to 29% in the Sudano-Guinean zone. The transplantation have also low survival rate from 3% in the sub-Sahelian zone to 32% in the Sudano-Guinean zone. Survival rate vary from 60% in the sub-Sahelian zone to 95% in the Sudano-Guinean zone for ANR.
Plantings and seedlings in bushes are therefore the two techniques recommended to the farmers for the regeneration / restoration of their shea tree parklands in Burkina Faso. ANR is also an advisable technique because it protects and supports spontaneously established seedlings that ensure optimal growth with a low cost.

Keywords: Shea tree, ANR, plantation, transplantation, seedling.

References:

1. Fontes et al.,1995, Instit. Internat. de la Végét. Labo. d'Ecologie Terrestre (UMR 9964), 67p.
2. Kaboré et al., 2012, Bois et forêts des tropiques, N°313 (3)
3. Lafleur M., 2008, Rapport de stage OCI, 110 p.
4. Serpentié G., 1996, C. Floret (éds), pp 55-57

L10.P.57

Current state and possibilities of selected agroforestry systems in Central Europe

Pástor M.[1] (michalpastor65@gmail.com), Jankovič J.[1], Houška J.[2], Lojka B.[3], Kotrba R.[3], Borek R.[4], Vityi A.[5]

[1] *Forest Research Institute, National Forest Centre, Zvolen, Slovakia*; [2] *Department of Landscape Ecology, The Silva Tarouca Research Institute, Brno, Czech Republic*; [3] *Faculty of Tropical Agri-Sciences, Czech University of Life Sciences, Praha, Czech Republic*; [4] *Institute of Soil Science and Plant Cult, Pulawy, Poland*; [5] *Institute of Forest and Environmental Te, University of Sopron, Sopron, Hungary*

Central European countries have a strong potential for agroforestry application in practice, which has become a rediscovered land use system of mainly family and small-scale farmers and foresters in the last years. The main aim of the study was to give a general overlook of the role and potential of agroforestry in Slovak Republic, Czech Republic, Poland and Hungary with special attention on selected agroforestry systems. One of the most traditional agroforestry systems in Slovakia is represented by juniper pastures. Current findings from the mapping of juniper localities occurrence in Slovakia confirm the assumption that vital juniper stands suitable for fruit production can be most effectively exploited as agroforestry systems combined with livestock grazing. In the Czech Republic several traditional systems had occured until the begining of the 20th century, however slowly disappearing starting from the second half of 19th century due to intensification and collectivization in agriculture. Mainly hedges on the borders of particular properties, homegardens and pasture in forests were the most frequent in this period. Relicts of traditional agroforestry practices remains in some areas, especially in montane regions (silvopasture, «Streuobst»), such as White Carpathians Mts. Nowadays, the development of small farms based on family enterprises tend to re-establish these traditional elements (hedges, windbreaks, Streuobst, etc.) in the landscape as well as establish new agroforestry systems (e.i. alley cropping) in some areas. The estimated proportion of total territorial area based on LUCAS data is 0.6 %. In Poland, there is slowly growing interest among farmers (particularly organic, but not exclusively) in planting mid-field trees rows (including lime, ash, elm, black locust, willow or traditional varieties of fruit trees) for biodiversity conservation (green infrastructure concept), protection against wind impact on grazing animals and honey production. There are number of different social actions aimed at planting trees on rural areas carried out by NGOs (e.g. Eco-Development Foundation, Agri-Natura Foundation, Polish Agroforestry Association) or landscape parks (e.g. Landscape Park Complex the Wielkopolskie voiovodship). Despite many campaigns and local workshops, lack of unequivocal definitions considering trees on agricultural lands, particularly trees management rules discourage farmers to plant them. Wood pastures have been present in Hungary for thousands of years. According to the recent surveys, there are about 33, 000 hectares of wood pastures in Hungary, 90 % of which is located in protected or EU Natura 2000 areas. Today, large areas of wood pastures are overgrown with shrubbery and trees, causing serious problems at farm level. The restoration of abandoned wood pastures is a key issue for developing the natural and cultural value of the rural region, and also for the profitability of the livestock industry.

Keywords: Central Europe, agroforestry practice, traditional systems, wood pastures, hedges.

L10.P.58

Complementarities or complexity? The case study of Horticultural Agroforestry Systems

Paut R. (raphael.paut@inra.fr), Boury-Esnault A., Sabatier R., Tchamitchian M.

Ecodeveloppement, INRA, Avignon, France

Among agroforestry systems, the intercropping of fruits and market gardening (Horticultural Agroforestry System – HAS) is innnovative and attracts more and more new entrants to farming (Burgess et al. 2018; Léger et al. 2018). Although HAS meet environmental and social challenges, particularly with regard to diversified and local food consumption, their management is challenging because of species diversity and the complexity of fruit and vegetable management practices (Lauri et al. 2016).
The present study aims to understand how labor organization and management practices are impacted by the agroforestry configuration.
A framework co-developped with farmers was implemented to record workload in market gardening and orchard activities. Regular follow-ups and semi-structured interviews in 9 farms made it possible to acquire data on workload for fruit-trees and vegetable management practices and to highlight *frictions points* between these two activites.
The results reveal (i) an increase in the overall workload induced by the management of two activities; (ii) numerous *friction points* between orchard and market gardening management practices (Fig.1); (iii) innovative strategies developed by farmers to address this increasing complexity.
Often very promising on paper, HAS are sometimes more difficult to set up in the field (Eksvärd 2016). The present work points out the main antagonisms related to the simultaneous implementation of fruits and vegetables in an agroforestry design.

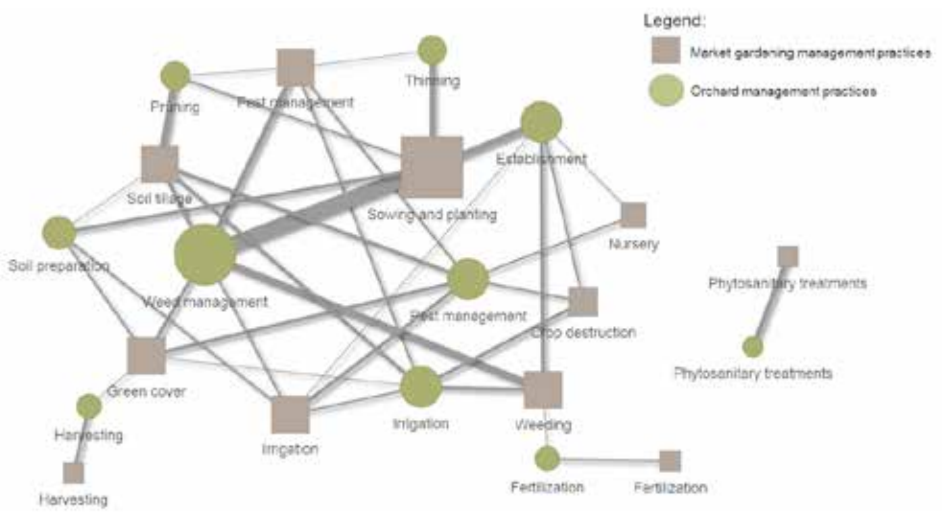


Figure 1: Network of “friction points” between orchard and market gardening management practices. Square nodes (□) represent market gardening management practices; circle nodes (•) represent orchard management practices. Node size is proportional to the number of interactions in which they are involved. Edges thickness is proportional to the intensity of the interaction between two nodes (number of occurrence among farmers).

Keywords: Fruit-trees, Market gardening, Management practices, Intercropping, Horticulture.

References:

1. Burgess et al. 2018. Advances in European agroforestry: results from the AGFORWARD project [...]
2. Eksvärd, K., 2016. EIP-AGRI Focus Group Agroforestry - Dicussion paper.
3. Lauri et al. 2016. Fruit-Trees in Agroforestry Systems - Review and Prospects for the temperate [...]
4. Léger et al. 2018. Agroforestry market gardening: a strategic choice to improve sustainability [...]

L10.P.59

The Chitoumou dilemma: how to reconcile fruit and insect production in Sahelo-Sudanian agroforestry parklands

Person S.[1] (forestgoodsgrowing@gmail.com), Payne C.[2], Lantieri Jullien R.[3]

[1] *Forest Goods Growing, Montpellier, France*; [2] *Dept of Zoology, University of Cambridge, Cambridge, United Kingdom*; [3] *Polistes, Paris, France*

Agroforestry is a land management system in which trees are cultivated among crops or pasture. Tree products, such as fruit or nuts, are one of the outputs of this system; the other output(s) are in the form of plant crops and/or livestock. It is found on every continent, using a range of cultivars. In the Sahelo-Sudanian zone of Africa, agroforestry is the dominant land management system. The two key tree cultivars are shea (*Vitellaria paradoxa*) and nere (*Parkia biglobosa*). The main products from these trees are the fruits, and these are important both as a source of nutrition and as a commodity that farmers may sell at market. The importance of these products is particularly high for more marginalised and vulnerable communities that rely on subsistence smallholder farming.

Across the African continent, many rural communities also use insects for food and income. Until recently, this was limited to the harvesting of insects from wild land and agricultural fields. There are now a few initiatives that promote farming edible insects in enclosed systems, but most are still in the pilot phase.

In the Sudano-sahelian zone, the edible caterpillars *Cirina butyrospermi and Cirina forda* are harvested widely from both wild and cultivated areas. Their abundance is partly due to their food preference: the shea tree. They do not appear to cause damage to shea fruit production, though evidence for this is not conclusive. The caterpillars are sold in rural and urban markets, but recently in Burkina Faso a company has responded to urban demand by processing and packaging the caterpillars in a way more palatable to the high-end consumer, and distributing these in supermarkets at a high price. This strategy could generate additional income for the collectors of the caterpillars.

The purpose of this paper is to explore some concrete examples of possible solutions. It is possible to combine the production of several commodities, and this is the basis of the management of other multipurpose tree species in agroforestry parklands. Specifically, double-end species are common and the differentiated management practices (eg. Of *Adansonia digitata, Parkia biglobosa*…) implemented by rural communities could be a source of inspiration. Thus, certain individual or stand-level management (offset harvest, pruning and pollarding techniques, differentiated management) could increase and spread foliar production over time. The development of insect farming could also, like certain old practices (sericulture) or recent initiatives make it possible to manage this resource more sustainably.

In many regions, finding a means of protein production that is compatible with the maintenance of tree cover is a major issue. Thus, better management of foliar production in agroforestry systems as an aerial forage resource specifically dedicated to insect farming opens important perspectives in terms of diversification and the promotion of new agroforestry practices.

Keywords: entomophagy, Parkia biglobosa, Cirina forda, agroforestry parklands, Cirina butyrospermi.

References:

1. PAYNE C. L. R. & al. (2017) Insects 8(1):24
2. PERSON S. & al. (2015) Mémento du forestier tropical Editions Quae – CIRAD 1198 p.

L10.P.60

Biomonitoring of agroforestry systems - application of smart beehives

Rétfalvi T.[1] (retfalvi.tamas@uni-sopron.hu), Lakatos F.[1], Kovács Z.[2], Rétfalvi-Szabó P.[1], Eredics A.[1], Vityi A.[1]

[1] *University of Sopron, Sopron, Hungary*; [2] *NAIK ERTI, Sárvár, Hungary*

Nowdays' environmental interest is greatly focused on evaluation of the effects of anthropogenic pollutions. Finding the appropriate and representative indicators, which are able to reveal interactions between the pollution and the environmental elements is the key issue of our research. Besides the conventional environmental examinations investigation of different organisms and their produced materials is a novel, progressive point of view. Honey bees (*Apis mellifera*) play appreciable role not just in the agriculture sector, but in the global ecosystem by pollination of plants. Furthermore they produce various products, such as pollen, honey, propolis with high economic value. Understanding their communication, following their life cycle and measuring their collected products provide valuable information regarding to environmental status. Due to these benefits our aims are to establish the basic parameters and the methodology for an environmental biomonitoring system for environmental review of shelterbelt system based on bee families.

The project includes two main parts. On the one hand we set smart beehives into pilot agroforestry area (optimised for beekeeping) of EFOP project running at University of Sopron, Hungary. Beehives are equipped with sensors, in order to measure the temperature, humidity and CO2, VOC concentration. The date are transferred into server periodically by mobile network, which provides possibility to follow life activities of bee families.

On the other hand analysing different bee keeping products allows an indication method of various anthropogenic pollution impacts. Novel protocol was developed applying by different analytical techniques.

Keywords: biomonitoring, beehives, anthropogenic pollution, hive products, agroforestry.

L10.P.61

Rehabilitating degraded lands in Groundnut basin of Senegal using Famers' Managed Natural Regeneration

Sanogo D.[1] (sdiami@yahoo.fr), Kamara M.[2], Badji M.[3]

[1] *CNRF, ISRA, Dakar, Senegal*; [2] *ISFAR, Université de Thiès, Thiès, Senegal*; [3] *BV, UCAD, Dakar, Senegal*

Farmer Managed Natural Regeneration (FMNR) is gaining momentum as a low cost technique to restore the vegetation cover by local communities in the Sahel. The present study evaluated the effect of this technique on the reconstitution of woody vegetation in comparison with total exclosure. Woody plant diversity was assessed through inventory on two different plots: FMNR from 2011 to 2018 versus exclosure from 2008 to 2018. Seven-year (2011 - 2018) of FMNR led to a diversity increase from 7 families and 10 species to 10 families with 15 species. Species such as *Ziziphus mauritiana, Acacia senegal, Azadirachta indica, Bauhinia rufescens* and *Calotropis procera* of great nutritional values for both human and livestock re-established in FMNR plots. Tree density increased from 47 ± 2.79 to 366 ± 28.49 individuals ha-1 in exclosure plots and from 41 ± 3.09 to 43 ± 4.83 individuals ha-1 in FMNR plots. The tree demographic structure displayed a L form for the exclosure whereas for the field with FMNR, it is a «bell» distribution with a diameter 20 cm larger compared to the denser exclosure plots. It is expected that the increased diversity and density will generate a range of products and ecosystem services that could improve the livelihoods of the local communities. This study showed that few years of FMNR is enough for substantial increase in biodiversity and biomass revealing the potential of this practice to rehabilitate agricultural degraded lands in the Sahel. Key words: Sahel, degraded lands biodiversity, FMNR, regreening, adaptation

Keywords: Sahel, degraded lands, Biodiversity, FMNR, adaptation.

References:

1. BADJI et al., 2015, La Régénération Naturelle Assistée (RNA) comme un moyen de reverdir le bassin ar
2. BADJI et al., 2014. Dynamique de la végétation ligneuse des espaces sylvo-pastoraux villageois mis e
3. BADJI et al., 2013 Effet de l'âge de la mise en défens sur la reconstitution de la végétation ligne
4. SAMAKE et al., (2011). Régénération naturelle Assistée. Gestion des arbres champêtres au Sahel. Manu
5. BOTONI et al., 2010. La régénération naturelle assistée (RNA) : une opportunité pour reverdir le Sah

L10.P.63

Co-design and on-farm experimentation of practices combining conservation agriculture and agroforestry

Sieffert A.[1] (andre.sieffert@adaf26.org), Morinay A.[1], Zniber T.[1], Canet A.[2], Lavoyer S.[3], Maïzi-Moity P.[4], Sabatier R.[5], Paut R.[5], Tchamitchian M.[5]

[1] *Association Drômoise d'Agroforesterie, 26160 Pont-de-Barret, France*; [2] *Arbre et Paysage 32, 32000 Auch, France*; [3] *French Agroforestry Association, 32 000 Auch, France*; [4] *Institut des Régions Chaudes, Montpellier SupAgro, 34000 Montpellier, France*; [5] *Unité Ecodéveloppement, INRA, 84140 Montfavet, France*

Agroforestry (AF) studies tend not to take much into consideration the different options available for the management of crops per se, generally taking into account classical techniques. However, in these single farming systems, reduced or no-tillage methods using mulch or cover-crops defined as Direct seed Mulch based Cropping systems (DMC) are gaining momentum. According to recent studies, DMC systems result under specific conditions in an enhancement of biological activity of soils and optimization of soil-plant-microorganisms interactions which in turn can enhance the resistance of crops towards plant pathogens. DMC systems have however been rarely combined with AF systems. A straightforward explanation lies in the high level of expertise needed to follow each of the two approaches, which makes their combination highly complex. But more fundamental issues such as the difficulties to manage root competition between trees and vegetables without ploughing are also at stake.
The objectives of our work is (1) the co-design and co-implementation with farmers of DMC and AF systems, (2) the study on how these systems and their combination affect the farming system in its whole and (3) the continuous diffusion of the results of this study. We focus on a co-design which is a result from a thorough collaboration between the farmers and our partners which are AF structures and experts in different fields. We started our work in 2016 and are currently collaborating with a network of 34 farms (arable crops, breeding and horticulture) in the South-East of France which are using or developing DMC and/or AF systems (e.g. vegetable-orchards, agroforestry in arable crops) since 2007 and up. Ndoli (2018)[1] has already shown that under specific conditions the combination of DMC and AF systems can lead to a reduced productivity as in the case of maize grown under trees. Hence, one of our aims is to identify technical and design options optimizing the combined management of crops and trees in DMC systems and allowing the success of the farming system in the long run. We direct this identification into an iterative process with the co-design of the farms.
The co-design of the DMC and AF systems is implemented based on the diagnosis of the farming system at various levels associated to the farmer's objectives. On-farm experiments are then processed by the farmers in order to test the viability of the design. The ADAF carries out with the farmer and in relation with the technical partners the monitoring and evaluation of various parameters which assess the agronomic, environmental and socio-economic performances of the farm as well as the soil and crops conditions. Focus is also made, through a systemic approach, on the specific linkage between crop culture and tree management (e.g. workforce repartition and adaptation in vegetable-orchards).

Keywords: co-design, conservation agriculture, on-farm experimentation, systemic approach, participatory development.

References:

1. Ndoli A. (2018) Farming with trees : A balancing act in the shade. PhD Thesis, Wageningen University

L10.P.64

What enables agroforestry? Understanding watershed restoration, political dynamics and 'Free Labour' in Tigray, Ethiopia

Sigman E. (emily.sigman@yale.edu)

Forestry/Global Affairs, Yale University, New Haven, CT, USA

The Free Labour Contribution Period (FLCP) is a common feature of rural society in the Tigray Region of Ethiopia. During this period, typically lasting between twenty and sixty (20-60) days, community members volunteer substantial hours of intensive labor towards large-scale projects, frequently directed at watershed restoration. Many agroforestry initiatives in Tigray rely on the FLCP—often unwittingly—to realize projects, and as such, the FLCP is a force that animates much 'community-led participatory agroforestry' in the region.

Despite the centrality of the FLCP to these projects and practices, there is little scholarship or systematic treatment of the FLCP within programming, publications, or evaluation schemes. This research dimentionalizes a case study in Abreha we Atsbeha, a qebele (village) known for successful restoration and agroforestry efforts[1], through the lens of the FLCP. In so doing, it aims to initiate academic documentation the FLCP and identify key factors that motivate community participation in FLCP-based agroforestry.

This interdisciplinary case study relies on three types of data collected via the following methods: (1) ethnographic qualitative data collected through participant observation, focus groups, and interviews (2) quantitative labor data collected at the woreda (regional) level and (3) historical data synthesized from previous publications, analyses and archives.[2] The data was analyzed using conceptual mapping to identify loci of decision-making within the community, and assess the degree of participation afforded within this loci to community members across different metrics.

The results suggest a high degree of heterogeneity among different community stakeholders in their attitudes, motivations, and perceptions surrounding the FLCP. Moreover, results reveal that while many community members understand the economic and environmental benefits of their work, participation in the FLCP is also motivated by fear of punishment. Notably, political party affiliation appears to play a substantial role in determining a community member's ability to participate in FLCP decision-making, which in turn may negatively impact their perception of both the FLCP and the projects undertaken during the FLCP.

The study concludes that a lack of political diversity historically enables the FLCP, making possible the mass movements and large-scale projects central in Abreha we Atsbeha's success. This political monoculture may render Abreha we Atsbeha—and communities seeking to emulate it—vulnerable to political shocks and stressors across scales. The study offers an improved sampling methodology to assist future researchers model and survey the unique political organization of rural communities in Tigray and beyond. Ultimately, this knowledge can help integrate agroforestry within political frameworks, and steer community interaction with intensive agroforestry initiatives towards more durable, equitable, and resilient outcomes.

Keywords: dryland agroforestry, socio-ecological resilience, political ecology, participatory restoration, human-nature systems.

References:

1. United Nations Development Programme, 2013, Equator Initiative Case Studies, 1-12.
2. Rahmato, The Peasant and the State, Addis Ababa University Press, 2009, ix-109, 181-205

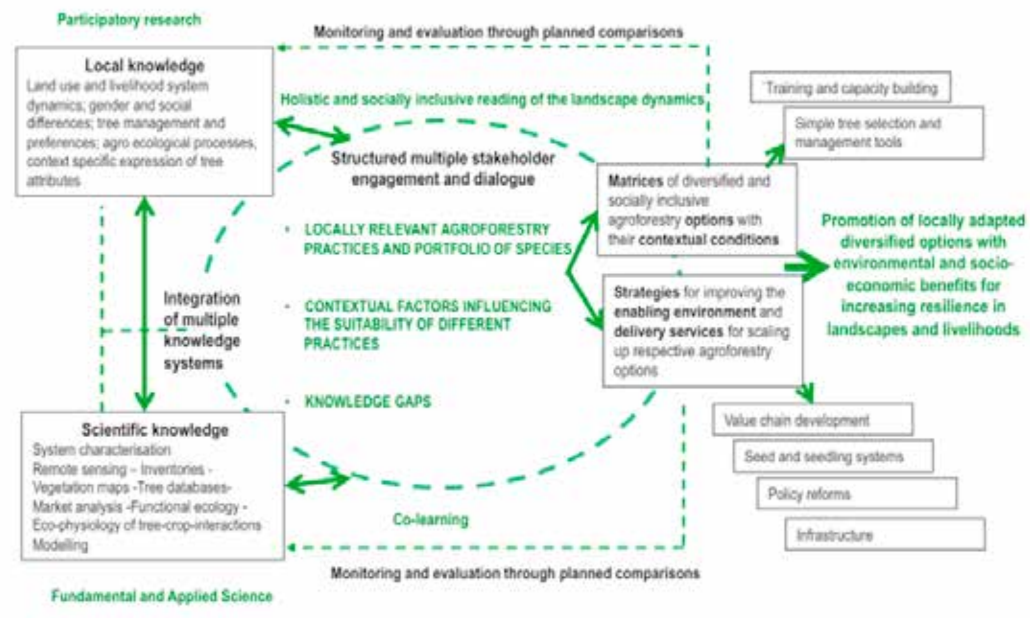
L10.P.65

Investing in resilience: how co-learning with local people leads to more diverse and inclusive agroforestry options

Smith Dumont E.[1] (e.smith@cgiar.org), Sinclair F. L.[1], Pagella T.[2]

[1] *Systems, World Agroforestry Centre, Nairobi, Kenya*; [2] *SENRGY, Bangor University, Bangor, Wales, United Kingdom*

Agroforestry can generate multiple ecosystem services underpinning human wellbeing while maintaining environmental integrity but rather than promoting silver bullet technologies across large areas, menus of options need to be tailored to local context. There are knowledge gaps in scientific understanding about how to enhance tree cover to deliver a range of ecosystem services. We present insights on how to do this from participatory action research across contrasting farming contexts in sub-Saharan Africa. In all cases, farmers had knowledge of a wider range of tree species than was available scientifically or promoted by extension services. This knowledge can be used in tree planting or regeneration initiatives to include a diverse range of tree species, largely unknown to science but important in farmers' practice. Doing so results in agroforestry options that are more inclusive, with different options suiting different people. Drawing from these experiences we propose a co-learning framework that integrates multiple knowledge systems through the facilitation of stakeholder engagement to identify agroforestry options for different contexts, alongside interventions required in the enabling environment for them to be realised. Co-learning continues beyond the design phase to drive iterative evaluation and refinement of options based on their real world performance, thereby reducing risks and increasing benefits for smallholder farmers adopting innovations.



Co-learning framework for scaling up agroforestry

Keywords: Tree selection, Local knowledge, Farming, Sub-Saharan Africa, Ecosystem services.

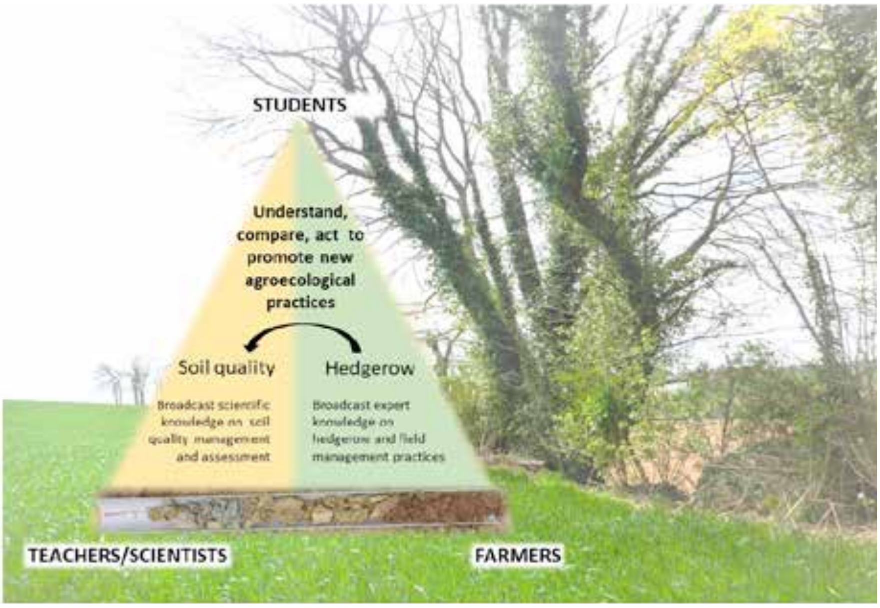
L10.P.67

Intersecting perspectives on the quality of soils amended with wood chips derived from hedge's pruning

Viaud V.[1] (valerie.viaud@inra.fr), Pérès G.[1], Jaffrézic A.[1], Busnot S.[1], Hamelin G.[1], Guéhénneuc T.[2], Menasseri-Aubry S.[1]

[1] *UMR SAS INRA Agrocampus Ouest, Rennes, France*; [2] *Terres et Bocages, Tredaniel, France*

Agroforestry is a pillar of the agroecology program initiated by the French government in 2012. In Western Europe, hedgerow landscapes are one of the most widespread agroforestry systems (Baudry et al., 2000). Initiatives of hedge's restoration have primarily emphasized their value as providers of environmental services. For instance, their local impacts on nutrient leaching and carbon sequestration are widely recognized (Moreno et al., 2018). The « Terres et Bocages » farmers' association promotes a more multifunctional view of hedges as productive resources, contributing to the sustainability of farming systems. Wood chip resulting from tree shaping and early management pruning has a low energy value. While their use as mulching generates shipping costs, the farmers investigate their agronomic interest as an organic amendment in the cultivated field. In this context, the project presented here aims to bring together farmers, teachers/scientists and students in order to challenge different views of soil quality in a hedgerow agroforestry system. It is based on a scholar field experiment involving soil indicator measurements in two livestock farms in Brittany (France).



Keywords: education, experiential learning, soil quality, wood amendment, hedgerow.

References:

1. Baudry J., R.G.H. Bunce, F. Burel. 2000. Journal of environmental Management, 60, 7–22.
2. Moreno G., S. Aviron., S. Berg., et al. 2018. Agroforest Syst, 92, 877–891.

L10.P.68

Agroforestry and Rotational intensive grazing: *Livestock farmers' words*

Vicet J.-C.[1] (jean-charles.vicet@pl.chambagri.fr), Lemarié C.[2]

[1] *Loire-Atlantique, Chambre d'agriculture Pays-de-la-Loire, Nantes, France*; [2] *Sarthe, Chambre d'agriculture Pays-de-la-Loire, Le Mans, France*

In Loire-Atlantique, at the West of France, we can see paddocks surrounded by trees managing by dairy farmers. They choose to create and manage innovative paddocks inspired by the bocage system. Indeed, this agricultural practice is a heritage as rotational intensive grazing was common in the first part of the twentieth century. Yet, these new paddocks are designed for contemporary farming: trees are planted instead of hedges which permits crop rotations.

These new rotational intensive grazing systems have numbers of benefits. Firstly, paddock's size is designed for a 2 or 3 days grazing rotation which contributes to maximise fodder quantity and quality. If there are more paddocks available than needs, they can be cultivated or can be cut for hay. Moreover, small paddocks help avoid grazing refusal as there is less food available. Secondly, trees contribute to animal well-being as they provide shade. Thirdly, farmers and advisors notice that cows don't cross trees lines and are quickly adapted to the new pathway without harming fences. This helps zone management of livestock. Finally, farmers save time as distances are shorter.

To enhance this note, we will come with a farmer to the 4th World Congress on Agroforestry. His story will help to explain how rotational intensive grazing systems are created according to each farmer's situation and needs.

A farmer explaining is rotational grazing systems with trees during the European Commission's field visit

Keywords: Rotational intensive grazing, Agroforestry.

L10.P.69

Multifunctional boundary hedges: making the most of the possibilities

Vityi A.[1] (vityi.andrea@uni-sopron.hu), Kiss-Szigeti N.[2], Szalai Z.[3]

[1] *University of Sopron, Co-operational Re, Sopron, Hungary*; [2] *1University of Sopron, Co-operational Re, Sopron, Hungary*; [3] *Szent István University, Department of, Budapest, Hungary*

Hegdes and shelterbelts have history in some European countries, for their important role in protecting fields, people, poverty and livestock and improving productivity.In Hungary and many other Eastern-European countries hedge and shelterbelt management is a historical agroforestry practice. During the last decades their numbers are reduced and their condition is deteriorating in many places.After their disappearance environmental problems occurred (e.g. soil degradation) and led to economic difficulties. Therefore, the Hungarian Regional Agroforestry Innovation Network (RAIN) focuses its work on promoting the multifunctional benefits of shelterbelts and their innovative use in mixed farming for land owners.In this case study the farmers and researchers share their experiences on silvoarable organic mixed agroforestry farm where boundary hedges are planned and managed in accordance with the principle of making the most of the possibilities.

Keywords: shelterbelt, hedgerow, agroforestry, multifunctional, mixed farm.

L10.P.70

Agroforestry can decentralise production of food and energy and encourage 'commoning'

Wolfe M.[1] (wolfe@wakelyns.co.uk), Smith J.[2], Westaway S.[2], Bell K.[3], Meldrum J.[4]

[1] *CAWR Coventry University, Wakelyns Agroforestry, Nr Eye, Suffolk, United Kingdom*; [2] *Organic Research Centre, Newbury, Berks, United Kingdom*; [3] *Small Food Bakery, Nottingham, Notts, United Kingdom*; [4] *Hodmedods, Halesworth, Suffolk, United Kingdom*

Agroforestry systems designed to *decentralise* both food and energy production, based on *diversity* at all levels, within and among crops, can mitigate climate change and increase sustainability. For example, the organic crop rotation at Wakelyns Agroforestry is widening the range of crops grown both for resilience and for diet in the locality.

For wheat, we have developed a composite cross population which is reliable in widely varying environments including alley cropping, with no external inputs. Small-scale sourdough fermentation of the wholemeal flour produces easily digestible bread with outstanding taste and quality. For apple, dispersal of different varieties among timber trees provides a high level of protection against all common pests and diseases with no external inputs, again with potential for fresh consumption and local processing and marketing.

System maturity (the main tree planting was completed in 1994/5) leads to vegetational climax progression and increasing biodiversity which contributes to productivity both directly and indirectly. For example, muntjac established naturally on the site and has become a livestock enterprise through regular culling for local processing. This aspect of decentralised food production was achieved at almost no cost.

However, we delay climax progression of the trees by coppicing and pollarding so as to maintain tree growth at maximum rates, increasing potential fuel production. For the past 10 years, wood chip (mainly willow and hazel) produced on the farm, has provided central heating and hot water for the farmhouse. We now aim to change the current boiler for a small-scale CHP (combined heat and power) unit which will deliver both heat and electricity so as to further decentralise energy production and reduce transmission losses.

Thus, alley cropping *integrates* decentralisation of both food and energy production, while delivering many other benefits including increased biodiversity, carbon sequestration, water storage and health benefits for the crops, animals and humans involved. The next stage, already in progress, is to encourage wide replication of the principal system to other small-scale, food and energy circles (not chains) in different localities. This will highlight the potential for 'commoning' (Ferrando & Vivero-Pol 2017) to sustain and enrich the natural world from the soil upwards by connecting these replicates.

Keywords: Decentralise, Diversity, Food, Energy, Commons.

References:

1. Ferrando, T, Vivero-Pol, J L (2017) http://www.righttofoodandnutrition.org/files/rtfanw-2017_eng_0.

L10.P.71

Agroforestry management to maximize ecosystem services provided by soils

Mao Z.[1] (maozhun04@126.com), Zuo J.[2], Cardinael R.[3]

[1] *UMR AMAP, INRA, Montpellier Cedex 5, France*; [2] *Division of Forest, Nature and Landscape, KU Leuven, Leuven, Belgium*; [3] *UPR AIDA, CIRAD, Montpellier, France*

Agroforestry systems have shown promising advantages in providing a number of key ecosystem services and many of them are directly linked with the soil compartment, such as fertility maintenance, carbon sequestration, erosion and landslide mitigation, fungi/bacteria-borne pest control, preservation of soil habitats etc. Today, managing a multifunctional agroforestry system has been a key quest for both researchers and practitioners. This is a challenging issue as it covers multiple disciplines stretching from biophysical to socio-economical domains. For this goal, this work will present a framework encompassing and highlighting some key issues on the multifunctionality of agroforestry systems, at both temperate and tropical conditions, with a focus on ecosystem services involving belowground functions.

Bibliographical metrics based evidences will be presented showing the state-of-the-art and knowledge gaps in R & D on multifunctionality of worldwide agroforestry. Roadmap and emerging methodologies for optimisation of our management for promoting such multifunctionality are proposed and discussed.

Keywords: Agroforestry, ecosystem services, multifunctionality, optimisation.

ABSTRACTS

Agroforestry adoption

Adopting the future of land use

- L11 -
Agroforestry in public policies

From pen pusher to tree pusher: agroforestry in public policies

The Sustainable Development Goals, agreed in 2015, encourage all countries to address 17 social, environmental and economic goals that promote prosperity while protecting the planet. Whilst there is clear evidence that agroforestry can support the attainment of these goals (see the other sessions!), farmers continue to cite administrative and policy burdens as one of the most important reasons for not using agroforestry. In this session, we are seeking papers from tropicaland temperate contexts that move beyond stating that there is a mis-match between our aspirations for agroforestry and its administration and implementation in practice. Instead we want to encourage papers that demonstrate and explain how public policies, initiatives,strategies and action plans can successfully promote agroforestry at regional, national, and international levels. We encourage researchers, practicioners and policy makers to submit and to participate to an exciting roundtable about the key policy ingredients to make agroforestry attractive for farmers. Hopefully by learning about agroforestry policies that work, we can frame the key steps towards an agroforestry transition.

L11_O.01

Agroforestry: Linking Local Action, National Policies and Global Frameworks

Schultz M.[1] (maria.schultz@viskogen.se), Elfstrand S.[2], Fogde M.[3], Hansson L.[4], Höök K.[5], Malmer A.[6], Nyberg G.[7], Schaffer C.[8], Öborn I.[9]

[1] *Vi Agroforestry / Agroforestry Network, Stockholm, Sweden*; [2] *SwedBio at Stockholm Resilience Centre, Stockholm, Sweden*; [3] *SIANI at Stockholm Environment Institute, Stockholm, Sweden*; [4] *Focali, Gothenburg, Sweden*; [5] *NIRAS, Stockholm, Sweden*; [6] *Swedish Forest Agency, Jönköping, Sweden*; [7] *Swe University of Agricultural Science, Uppsala, Sweden*; [8] *Agroforestry Sverige, Stockholm, Sweden*; [9] *World Agroforestry (ICRAF), Nairobi, Kenya*

For agroforestry to reach its full global potential, there is a need to overcome barriers and create favourable environments at all levels. This requires horizontal integration across sectors, such as agriculture and forestry, and vertical integration between local, national and regional governance and operations (Coe et al. 2014). Local uptake can be enhanced through for example active farmers' organisations and the availability of sustainable value chains for agroforestry products. There is also a need for conducive national or sub-national guidelines, policies and plans (with an attached budget to facilitate implementation), and a link to regional and global frameworks to create a favorable environment for scaling up agroforestry.
The Agroforestry Network (2018 and 2019) in Sweden has produced a series of reports and briefs to explain how and why agroforestry should be at the top of policy- and decision-makers' minds. The recommendations can be considered at local, national, and global levels:
Local action: this includes increasing knowledge and cooperation among key stakeholders whilst ensuring gender equality and equity; engaging with farmers' organisations and groups; considering longer funding cycles and increased funding for agroforestry projects and research; supporting more demand-driven, participatory and inclusive research which benefits from local knowledge systems; strengthening agroforestry value chains; and promoting multi-functionality in landscapes through a mix of tree species on farmland and mosaics of forests around farm land and in uplands.
National and regional policy: this includes making agroforestry visible in policies, strategies, and budgets and communicate successful implementation; strengthening land tenure and resource rights for smallholder farmers and indigenous peoples; ensuring that policy instruments and investments are appropriate for smallholder farmers, especially women; and using multi-actor dialogues to integrate policy-making particularly across agriculture and forestry.
Global frameworks: this includes connecting agroforestry practices to the Sustainable Development Goals (SDG), the Paris Agreement, and the Convention on Biological Diversity, and report progress. Agroforestry can contribute to at least nine out of the 17 SDGs: 1, 2, 3, 5, 6, 7, 12, 13, and 15.

Keywords: sdg, policy.

References:

1. Coe, R et al. (2014). Current Opinion in Environ. Sustain. 6, 73–77
2. Agroforestry Network (2019). Achieving The Global Goals Through Agroforestry
3. Agroforestry Network (2018). Scaling up agroforestry – Potential, Challenges and Barriers

L11_O.02

How public/private investment in processing facilities could increase biodiversity in large agroforest. systems in LATAM

Montes Londoño I.[1] (irene.montes@12tree.de), MARTINEZ L.[2]

[1] *12Tree Finance Panama, Panama City, Panama*; [2] *12Tree Finance, Berlin, Germany*

Multiple management decisions affect the species composition and the architecture of agroforests and forestry plantations. Mixed-species plantations and agroforestry systems that incorporate a diversity of indigenous tree species have the potential to restore degraded land in a way that is more productive and supportive of biodiversity and other important ecosystem services (Lamb et al. 2005, Perfecto and Vandermeer 2008, Tscharntke et al. 2012, Leakey 2014).

However, mixed-species plantations and diverse agroforests are more complex to manage than monocultures of well-known exotic species. The complexity of working with multiple species, and the lack of information regarding indigenous tree species performance, ecology and silviculture, have been long recognized as important limitations for the widespread adoption of indigenous species in agroforestry systems and mixed-species plantations (Evans 1999). Nevertheless, and in response to this, an important pool of knowledge on indigenous trees' ecology and silviculture has been developed in the last decade (see for example, Rolim & Piotto 2018, Wishnie et al. 2007), providing project managers of agroforestry and forestry operations with a suitable set of species for planting.

Hence, instead on focusing on technical barriers, this presentation discusses key policies, and public and private investments that could address market related barriers currently influencing management decisions about the species composition in agroforest and forestry plantations under 12Tree's management. Specifically, the need for coordinated private and public efforts to build regional-scale processing facilities that provide a market for timber and non-timber forest products (NTFP) grown in diverse agroforests and mixed-species plantations.

Founded in Berlin in 2016, 12Tree Finance is an investment advisory and asset management company working with institutional investors to place capital in sustainable forestry and agroforestry projects in deforested and degraded agricultural lands of Central and South America. 12Tree manages more than 150 million euros in assets covering about 20 000 ha. Current investments include established and new agroforestry projects in the Dominican Republic, Guatemala, Costa Rica, Panama, Colombia, and Ecuador.

Drawing on 12Tree's experience in Central and South America, this presentation describes three case studies that highlight the enabling conditions for constant growth and advancement of the agroforestry industry. In addition, the presentation reveals how localized eco-industries could help get around the problem of low timber prices triggered by the abundant supply of illegal wood from natural forests.

Keywords: Agroforestry Systems, Indigenous Species, Latin America, Investment, Public/Private.

References:

1. Evans J (1999) Planted forests of the wet and dry tropics: their variety, nature, and significance.
2. Lamb D, Erskine PD, Parrotta JA (2005) Restoration of degraded tropical forest landscapes.
3. Leaky RRB (2014) The Role of Trees in Agroecology and Sustainable Agriculture in the Tropics.
4. Perfecto I, Vandermeer J (2008) Biodiversity conservation in tropical agroecosystems: (...) paradigm
5. Rolim SG & Piotto D (Editores) (2018) Silvicultura e tecnologia de espécies da mata Atlântica.

L11_O.03

How to protect French hedges? The power of the local agroforestry associations

Magnin L. (leo.magnin@ens-lyon.fr)

LISIS, ENS de Lyon - UPEM, Lyon, France

In 2017, the European Court of Auditors special report n°21 concludes that "greening, as currently implemented, is unlikely to significantly enhance the CAP's environmental and climate performance". Can we extend this conclusion to agroforestry? To answer this question, I focus on how the CAP's cross-compliance is able or not to protect hedges.
In France, the greening was directed on the first pillar payments, but also extended to the cross-compliance, that is compulsory rules that every farmer has to follow. They are named "Good Agricultural and Environmental Conditions" (GAEC) and, among them, a new one concerns agroforestry: the GAEC7, which protects ponds, copses and hedges. Since 2015, farmers who receive CAP payments cannot uproot hedges without an authorization. If this seems to be a good thing to conserve a traditional form of agroforestry, in the different French departments the GAEC7 implementation is however highly variable: sometimes the GAEC7 is well applied resulting in the diminution of hedges' uprooting ; sometimes the GAEC7 is not applied resulting in the unchanged, or even increasead, number of hedges' uprooting. My communication identifies political, social and environmental factors that explain this phenomenon in different local contexts.
The materials result from a long field work inquiry (2016-2019) led for my PhD in sociology on the CAP greening. The ethnographic method used is based on social immersion which allows the researcher to understand people's practices and representations. The two types of actors encountered are state local administrations and agroforestry associations. I analyze three types of materials: ethnographic observations; in-depth sociological interviews; and gray literature. This study was partly conducted in collaboration with the French Association of Agroforestries (AFAC). The focus on the regions of Britanny (West), Auvergne (center) and Rhône-Alpes (East) provides a wide range of agricultural practices and social contexts.
The main result is that the GAEC7, even if mandatory, is not implemented in the whole country. Its implementation often, but not necessarily, results from the conjunction of two factors. The first one is that the hedge's official definition excludes some types of hedges. It follows that is difficult to protect hedges that are found in the local landscape but are not officially defined as hedges in the law. But the most important factor is political: I observe a correlation between the activity of local agroforestry associations and the application of the GAEC7. I show that the quality of the relation that these local associations maintain with the state administrations is also crucial to the GAEC7 implementation.
With this French case study, this inquiry moves toward the idea that an efficient agroforestry public policy is not only a text, as ambitious it is, but also, and maybe primarily, a network of local administrations and associations.

L11_O.04

Institutional markets as a driver public policy for the adoption of agroforestry systems in the Brazilian Amazon

Lima Resque A. G.[1] (gabrielresque@gmail.com), Coudel E.[2], Piketty M.-G.[2], Le Page C.[2]

[1] *Campus Paragominas, Federal Rural University of Amazon, Paragominas, Para, Brazil*; [2] *UPR-Green, CIRAD, Montpellier, France*

Agroforestry systems (AFS) are recognized as being a land use system that can improve the sustainability of agroecosystems (Wilson et al, 2016). However, low market opportunities for its products is one of the challenges for its adoption, especially the more diversified AFS (Coq-Huelva, 2016). With this perspective, the Brazillian National School Meal Program (Programa Nacional de Alimentação Escolar, PNAE) and Food Procurement Program (Programa de Aquisição de Alimentos, PAA) have emerged in the last decade as public policies aimed at stimulating purchasing of local products (Grisa & Porto, 2015). This research aims at assessing how the programs have encouraged biodiversification and in particular in AFS. We compare two municipalities in the Brazilian Amazon, Paragominas and Irituia. By realizing interviews with local stakeholders and review of documents, we identify the variety of products that have been acquired through programs representing different cropping systems (Table 1). The AFSs are the most significant cropping system purchased by the programs in Irituia, differently from Paragominas. This can be explained by the set of background initiatives improving AFSs carried out in Irituia. Programs, in this case, have emerged as one of the drivers of this expansion process. We conclude that the programs have a great potential to act on the expansion of diversified systems such as the AFSs, as long as they are associated to other actions present at the local level.

Type of culture	Irituia		Paragominas		Most common cropping system
	PAA	PNAE	PAA	PNAE	
Perennial crops	21	10	10	10	AFS in Irituia and monoculture in Paragominas
Annual crops	6	5	5	5	Slash and burn
Vegetables	15	7	15	13	Vegetable garden
Cattle breeding	0	0	2	2	Extensive system (low inputs)

Table 1: Diversity of types of cultures, species of each type of culture and cropping systems associated to the programs. Note: Values from 2017.

Keywords: Agroecology transition, Institutional markets, Biodiverse agroecosystems.

References:

1. Coq-Huelva et al, 2017, Sustainability, 9(10), 1920, https://doi.org/10.3390/su9101920.
2. Grisa, in: Políticas públicas de desenvolvimento rural no Brasil, 2015, Editora da UFRGS, 155–180.
3. WIlson et al, 2016, Sustainability, 8 (6), 574, https://doi.org/10.3390/su8060574.

L11_O.05

Policies at work : key public policy features enhancing agroforestry spreading and adoption in Quebec, Canada.

Laroche G. (genevieve.laroche@fsaa.ulaval.ca), Olivier A.

Phytologie, Université Laval, Québec, Québec, Canada

Agroforestry systems have been promoted in Quebec (Canada) since the early 1980's through a wide range of public strategies and policies implemented at various policy levels. Looking back at 35 years of adoption and development, we conducted a policy analysis at the national, provincial and regional levels, coupled with interviews with key practitioners (both promoters and agroforestry adopters) to identify key policy features and strategies that generated, enhanced or facilitated agroforestry adoption at various scales. Our study reveals that policies enabling the establishment of regional agroforestry initiatives aiming at specific objectives (soil and water conservation or landscape aesthetics) were the most effective to generate agroforestry adoption. Although on-farm support is a necessary facilitating tool, it is not sufficient on its own to drive agroforestry adoption. Public support devoted to activities surrounding the implementation and maintenance of agroforestry systems have proven to be essential for agroforestry spreading and development, especially when coupled with on-farm support. This includes, among others, support for the creation of promotion and education tools. The analysis highlights the importance of using multiple public tools simultaneously to create the buzz needed to put agroforestry on the map and draw attention on its multiple benefits for farmers and communities.

Keywords: Policies, Adoption, Agroforestry systems.

L11_O.06

Agroforestry in REDD+ and NDCs ways to fulfill the Paris Agreement and reduce deforestation

Fortuna S.[1] (serena.fortuna@fao.org), Tjarvar A.[1], Simelton E.[2], Borelli S.[1]

[1] *Forestry, FAO, Rome, Italy*; [2] *World Agroforestry Centre, Hanoi, Viet Nam*

The 2015 Paris Agreement provides a landmark global commitment to tackle one of the biggest challenges of our time: to keep global temperature rise below 2 degrees, or even more to limit to 1.5 degrees. Countries reflect their commitments to critical target in their Nationally Determined Contributions (NDCs); mitigation actions in land use, land-use change and forestry are referenced in 83 percent of the NDCs.
Reducing Emissions from Deforestation and forest Degradation (REDD+) has been a feature of negotiations in the UN Framework Convention on Climate Change since 2007. Through REDD+, countries have made considerable progress in their thinking and national planning of how agriculture, forestry and other land-use (AFOLU) sectors can contribute to mitigate climate change; some have embedded their REDD+ national strategies as part of their NDCs. After years dedicated to the "readiness phase", focused on strengthening technical capacities, constructing national plans, reference levels, safeguards, and national monitoring systems, government and stakeholders are now piloting the implementation of their REDD+ strategies at different levels.
During the readiness phase, the importance of fostering synergies between agriculture and forestry was recognized and agroforestry became a relevant action in several strategies. Agroforestry has the potential to contribute both to climate change mitigation (by enhancing, managing and conserving carbon stock and by contributing to reducing deforestation and forest degradation) and adaptation (for example by increasing the resilience of communities to shocks). The significance of trees on agricultural land for carbon sequestration was estimated globally to 45,3 PgC (45,3 GtC) or 21.4 tC ha-1. Examples of agroforestry contributions to recover and conserve carbon stocks, are found across the world, for example in the Amazonas, in indigenous communities in Panama (reforestation of degraded lands combining native timber and fruit trees) or in Côte d'Ivoire, where cocoa production funded and combined with other solutions effectively prevented deforestation.
Although increasingly recognized, the role of agroforestry in mitigating climate change still did not reach its full potential.
Basing on a review of available literature and on an in-depth analysis of agroforestry approaches in selected NDCs, the paper aims at understanding where the gaps are and at providing a set of suggested considerations for policy-makers. The paper also maps the role of agroforestry as a measure for emissions reductions from the AFOLU sector, through REDD+ and NDCs. We evaluate the opportunity that these national strategies and contributions offer to scale up agroforestry in moving towards concrete and long-term results within the countries, and bring concrete good practices for how agroforestry can contribute to the goals of national policies and Paris Agreement, for wider uptake.

Keywords: redd+, agroforestry, climate change, policies, NDCs.

References:

1. FAO, 2013, Advancing Agroforestry on the Policy Agenda- A guide for decision-makers.
2. IPCC, 2018, Global Warming of 1.5 °C - special report
3. UN-REDD,2018.Economic and Financial challenges to scaling up sustainable cocoa production in Cote d
4. Villa et al, 2015, Bosque 36(3): 347-356
5. Zomer et al, 2016, Scientific Reports | 6:29987 | DOI: 10.1038/srep29987

L11_O.07

European Agroforestry Policy - history and future opportunities

Lawson G.[1] (gerrylawson@gmail.com), Burgess P.[2], Herzog F.[3], Worms P.[4]

[1] *Edinburgh, Centre for Ecology and Hydrology, Edinburgh, United Kingdom*; [2] *Cranfield University, Cranfield, United Kingdom*; [3] *FAL Agroscope, Bern, Switzerland*; [4] *ICRAF, Brussels, Belgium*

Historical Agroforestry Policies

It is estimated that there are 15.4 million ha of agroforestry systems in Europe, comprising 8.8% of the utilized agricultural area [1]. Yet the first mention of "agroforestry" in policy documents of the Common Agricultural Policy (CAP) of the European Union (EU) was in the 1998 EU Forestry Strategy [2].

The CAP comprises Pillar I which includes direct payments and Pillar II which includes rural development programmes (RDPs). The current CAP, which runs from 2014 to 2020, defines agroforestry in Article 23 of Regulation 1305/2013 as "*land use systems in which trees are grown in combination with agriculture on the same land*". There are 23 RDP measures that can support agroforestry on either agricultural on forest land [3]. The most important is submeasure 8.2 which supports new agroforestry on agricultural land, and which has been used in the RDPs of 35 of the 118 RDP states or regions in the EU [4]. If current plans are fully implemented, 74,000 ha of agroforestry will be established through submeasure 8.2. However, little information is available on progress towards this target, and the existence of a budget for agroforestry does not guarantee that funds will be used for this purpose. Only 6.5% of planned spending on agroforestry was achieved by states or regions in the CAP of 2007-2013. Many farmers were reluctant to plant agroforestry because they feared a reduction in future eligibility for Pillar I payments.

Future Agroforestry Policies

There are important opportunities for agroforestry promotion in the CAP for 2021-2027, which is currently being developed. Within Pillar I, there are plans for Member States to develop "Ecoschemes" and to map and set a minimum threshold for "isolated trees" and "lines of trees and groups of trees" [5]. Within Pillar II, there are plans for "Agro-Environment-Climate Schemes" which include higher- and longer-term payments, but with greater conditionality.

Outside of the European Union, in Switzerland traditional agroforestry fruit orchards and wooded pastures are maintained by agri-environmental measures. The regulations are flexible, so that modern agroforestry systems such as alley cropping on arable land can be supported. In the UK, ministers have argued for a new land-use policy focused on public service provision and "Environmental Land Management" plans after Brexit.

Keywords: policy, CAP, Landscape Feature, LPIS, Greening.

References:

1. den Herder M, et al. 2017, Current Extent & Stratification of AF. Agric Ecosyst Envir. 241: 121–132.
2. Lawson G, et al. INRA; 2005. Options for Agroforestry in the CAP. https://goo.gl/Q7Jajx
3. Mosquera-Losada MR et al. 2018, Agroforest Syst (2018) 92:1117–1127
4. Lawson GJ et al. 2016 In: Gosme M. et al, editor. Proc 3rd European Agroforestry Conf, 425–428
5. European Commission. Proposal for a Regulation to established by Member States

L11_O.08

Policy gaps and opportunities for scaling-up agroforestry in Africa: lessons from the *Regreening Africa* project

Bernard F.[1] (f.bernard@cgiar.org), Chomba S.[2], Bourne M.[2], Neely C.[2], Garrity D.[2]

[1] *Landscape governance, World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [2] *World Agroforestry Centre (ICRAF), Nairobi, Kenya*

Agroforestry is a key component of climate smart agriculture, with trees in agricultural lands providing significant contributions to both climate change mitigation and adaptation. Trees also play key roles in strengthening ecological resilience, whereas various tree products provide economic and nutritional benefits to rural households. The EU-funded Reversing Land Degradation in Africa by Scaling-Up Evergreen Agriculture (Regreening Africa, 2017-22) is an active intervention that deploys agroforestry for land restoration across eight African countries. It has an explicit policy objective to accelerate scaling up of land restoration through policy influencing. The target countries are Ethiopia, Kenya, Rwanda, Somalia, Mali, Niger, Ghana and Senegal. Based on mixed-methods research consisting of an intensive desk review, focus group discussions and key informant interviews, the comparative analysis conducted across the eight countries revealed four key findings: (i) agroforestry has not been mainstreamed or supported through policy frameworks. Various aspects of Agroforestry remain scantly spread across mainstream agriculture, forestry or other environmental policies (ii) There are significant gaps in human, technical and financial capacities to implement agroforestry (iii) There is fragmentation and poor coordination of institutions dealing with agroforestry (iv) Complex land tenure aspects and tree permit regimes constrain the wide adoption of AF by smallholder farmers. Some key opportunities to ensure coherence and widespread adoption of AF practices included: a) the establishment of a national cross-sector AF scaling platform (e.g. in Ethiopia) and development of an AF strategy and action plan (e.g. Rwanda); b) the establishment of networks of rural resource centres to multiply and promote diverse quality tree germplasm together with knowledge and skills on its deployment; c) implementation of the devolution process enabling the integration of AF into sub-national level plans, programmes and policies; d) reforms on land and tree tenure regimes that re-align with the interests of landowners and farmers. As a way forward, the SHARED (Stakeholder Approach to Risk Informed and Evidence Based Decision Making) methodology is being applied in the eight countries to bring together multiple actors, across sectors and stakeholder groups to review evidence, discuss key scaling challenges and develop a roadmap for regreening. Through structured stakeholder engagement and clear strategies to shift behaviour practices, the project hopes to support massive scaling up of evergreen practices and benefits.

Keywords: Agroforestry, Scaling-up, Africa, Policy, Stakeholder engagement.

L11_O.09

Mainstreaming India's National Agroforestry Policy: Challenges and Opportunities

Kumar B. M. (bmkumar.kau@gmail.com), Daniel M. I.

Ecology and Environment Studies, Nalanda University, Rajgir, Bihar, India

Although agroforestry (AF) is widely recognized as a promising land use option to stimulate farm productivity, mitigate environmental challenges, alleviate poverty and hunger, and provide livelihood security to the smallholder farmers, its development is impeded by lack of public policy support. To remedy the situation, India formulated the National Agroforestry Policy (NAP) in 2014. Though a total of 16 or so countries have framed policy agendas to promote AF, India is the first country in the world to have a comprehensive policy. NAP aims to promote AF by removing the constraints in its adoption and incentivizing it. A multi-pronged strategy, focusing on industrial models of AF, removing regulatory barriers for farm-grown timber extraction, and providing market support and credit, is the cornerstone of NAP. The policy also aims to create convergence among various programs/agencies involved in AF and helps to meet the increasing demand for AF products, protect environment and natural forests and minimize risks during extreme climatic events. Although four years since the launch of NAP is not long enough to evaluate its impact, we report here some of the progress made so far. Several initiatives have been made to implement the policy, which includes establishment of a Sub-Mission on AF (SMAF; Rs. 9350 million outlay for 2016-2020) to expand tree coverage on farmland in conjunction with arable crops, liberalising timber transit regulations and amending the Corporate Social Responsibility (CSR) guidelines to put AF under its ambit. SMAF aims at nursery development for quality planting material, peripheral and boundary plantations, farm woodlots, capacity building and demonstration of AF Models. Financial assistance up to 50% of the cost will be provided to the farmers. Several states have also taken steps to streamline the regulatory framework that restricts growing trees on farms. For the wood based industries, CSR provides a golden opportunity for developing back end linkages with growers for enhancing wood availability through tree plantations. ITC Limited, one of the leading private companies, with its subsidiary WIMCO Ltd, has established plantations of different species over 300,000 ha of land in over 60 districts of the country. Although India is estimated to have 25.32 million ha under AF or 8.2% of the geographical area (Dhyani 2014), there are many institutional, technological, ecological and socioeconomic factors, which obfuscate the adoption of AF. Major constraints include property rights (land tenure), tree tenure, supply of quality planting materials, subsidies and extension systems. In view of this, adoption and spread of AF has not kept pace with the expectations, despite climate change issues. Tree planting also could not be done at the expense of food production. The solution to this appears to tree planting on farm boundaries. NAP and other sectoral policies make AF the main form of current and future land use in India.

Keywords: Adoption, Constraints, Tree cover, Timber transit, Agroforestry models.

References:

1. Dhyani, S. K., 2014. Curr. Sci., 107, 9–10.

L11_O.10

ASEAN Guidelines for Agroforestry Development in the Food, Agriculture and Forestry Sector

Catacutan D.[1] (d.c.catacutan@cgiar.org), Oborn I.[2], Finlayson R.[1]

[1] *Southeast Asia Regional Program, ICRAF, Bogor, Indonesia*; [2] *Swedish Univ. of Agricultural Science, Uppsala, Sweden*

The Association of Southeast Asian Nations (ASEAN) Economic Community envisages the region to transform into a single market and production base through multi-sectoral cooperation and integration. The *Vision and Strategic Plan for ASEAN Cooperation in Food, Agriculture and Forestry 2016–2025* lays out the sector's strategic thrusts. Agroforestry was identified as an action program for increasing resilience to climate change, natural disasters, and other shocks. The 20th ASEAN Senior Officials of Forestry meeting in July 2017 agreed to develop the *ASEAN Guidelines for Agroforestry Development* in recognition of the contribution of agroforestry to achieving food security, enhancing climate-change adaptation and mitigation,reducing land degradation, strengthening links between forestry and food production through an integrated approach to landscape management, and enhancing sustainable forest management.

Consultations with international and regional experts, academics, practitioners, forestry-, agriculture- and environment sector representatives from national governments, and farmers' associations were facilitated, leading to the drafting and endorsement of the *Guidelines* by the ASEAN Working Group on Social Forestry and the ASEAN Senior Officials of Forestry. Subsequently, the 40th ASEAN Ministers of Agriculture and Forestry meeting in September 2018 adopted the *Guidelines*.

The *Guidelines* provide a framework for facilitating dialogue in the design of agroforestry policies, programs, projects and investments between, and within, ASEAN Member States. They are expected to foster multi-sectoral cooperation and coordination amongst different sectors (land, economic, water, energy, agriculture, forestry, food, livestock, fisheries) within Member States and stimulate the development of focused policies and programs for agroforestry. This is intended to contribute to improve the livelihoods and asset base of millions of farmers, increase the range, quantity and quality of food, restore land and enhance the environment, and build resilience to climate change.

Through the *Guidelines*, the Food, Agriculture and Forestry sector anticipates even greater collaboration between ASEAN Member States in sharing technical and policy development, increased trans-border trade in agroforestry products and enhanced ecosystem services, all of which support closer and quicker integration. ASEAN and Member States are now preparing for implementation of the *Guidelines*, with two 'road maps' for agroforestry development already underway in Cambodia and Myanmar and more to come.

The presentation will highlight the authors' experience in bringing agroforestry into ASEAN's agenda, particularly, with respect to scientific inputs, processes and collaborations required for conducting this type of boundary work, stimulating discussion on linking the science of agroforestry with regional and national policy and implementation.

L11.P.01

Watershed and biodiversity protection due to legislation improvement on Agroforestry areas, São Paulo State, Brazil

Abdo M. T. V. N.[1] (mtvilela@terra.com.br), Barcellos I. F.[2], Amorim D. A. D.[2], Magalhães J. L. A.[3]

[1] *SAA, APTA Polo Centro Norte, Catanduva, Jdim amendola, Brazil*; [2] *SAA, SMA, São Paulo, SP, Brazil*; [3] *CEF, ULISBOA, Lisboa, Portugal*

According to Brazilian new legislation, the New Forestry Code Law No. 12.651(May, 25th, 2012) some areas that provide protection to native vegetation and water resources from watersheds should be protected and are the so called Permanent Preservation Area (PPA). Those protected areas can go up to 30 meters near rivers and 50 meters near springs. They are isolated because if covered or not by vegetation they have environmental function of preserving water resources, landscape, geology and biodiversity, facilitate genetic flow of fauna and flora, protect the soil and ensure the well-being of human populations. Those PPA areas are located continuous to river, pounds, springs or lakes edges or under high declivity areas. Also the Legal Reserve, are protected areas located inside a rural property. With the legislation agroforestry systems are encouraged to be planted with the purpose of ensuring the sustainable economic use of those areas but as it requests the plantation with only 50% of nonnative species and at least 1000 plants/ha in PPA it results in a high biodiversity promotion. In the Legal Reserve the plantation should include at least 600 plants/ha according to the resolution SMA 44 (2008). The agroforestry systems are often considered as a restoring plantation in those Permanent Protection Areas once they could induce the restoring process of vegetation and soil by the inclusion of trees to agricultural production ensuring biodiversity of the ecosystem and optimizing land use when compared to monoculture and also because of income generation and food production. According to São Paulo State Resolution SMA 32(2014) small landowners with less than 4 local rural modules are able to install agroforestry systems in these areas. This permission promoted a high demand of agroforestry system plantation in these areas once the agroforestry system can be explored with agricultural products giving the landowner some extra income and also giving environment gain due to native trees plantations and maintenance. The monitoring of the increase of plantation in those areas have been done by an electronic registration system of national scope established by Law 12.651 / 2012 , the Rural Environmental Registry which gathers the information of the properties and rural possessions composing a database that will help environmental and economic planning and combat to deforestation. More than 259 thousand properties that have 4 rural modules or less were registered. The information given by landowners inserted in the system the location of native vegetation remnants, Permanent Preservation Areas (PPA) and Legal Reserves (LR) and this rregistration of rural properties is essential and is a requirement for joining the Environmental Regulation Program (PRA) where the landowners make a commitment to fulfill the legal requirements within a established period of time to plant the areas deprived of vegetation.

Keywords: Watershed, biodiversity, Tropical trees.

References:

1. Abdo, M.T.V.N.et al.2008.Revista Tecnologia & Inovação-Agropecuária, Campinas,v.1, n.2, p.51-59.
2. Galizia Tundisi et al. 2010.Biota Neotropica 10(4), pp.67-75.
3. Site of São Paulo State legislation: http://www.legislacao.sp.gov.br/legislacao/index.htm
4. http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2012/Lei/L12651compilado.htm

L11.P.03

Payments for ecosystem services (PES) schemes as a driver to agroforestry implementation in Brazil

Albuquerque M. (marcia.fca@gmail.com)

University of Paris 1/Mackenzie Universi, São Paulo, SP, Brazil

Agroforestry can provide a wide variety of ecological services. Supply services, such as the production of food, wood and biomass; regulatory services, such as erosion control, carbon sequestration and fire risk reduction; cultural services, such as increasing recreational, aesthetic and cultural values; and self-maintenance services, such as pollination, nutrient retention and increased soil fertility. Thus this practice could be encouraged through the adoption of PES schemes.

PES schemes consist at the payment of land or other natural resources managers in exchange for the provision of specified ecosystem services that would not be provided in the absence of such a payment. Generally, they can take the form of government subsidies or direct negotiations through contracts between private actors. They are considered by different fields of research as one of the tools of ecological services management through market instruments. The purpose of this paper is to analyse if Brazilian PES schemes could effectively encourage farmers to adopt agroforestry practices.

Amongst the results, this paper shows that despite the lack of federal legislation, there is already a diversity of PES schemes at the regional level, consisted mainly by government subsidies. The multiplication of legislation, court decisions and PES contracts show the growing interest on the subject.

Among the regional PES, it is notable the encouragement of agroforestry practices for the supply of several environmental services. One example is the Reforestation Program established in 2012 by the State of Espirito Santo. Its goal is to compensate certain land use methods (including agroforestry systems) that generate environmental services through a contract between the landowner and the Department of the Environment and Water Resources.The economic rewards for the maintenance/generation of environmental services can be granted by providing financial support for the development of technical projects or through financial compensation made directly to the owner.

In order to reach these results, a study of Brazilian federal and regional legislation regarding PES schemes was made. All the work was supported by a wide literature and jurisprudence review.

This paper concludes that Brazil already counts with several regional PES programs that could encourage the adoption of agroforestry practices. However, the need for post-accession monitoring and control, high transition costs, program discontinuity and change of rules can generate legal uncertainty.

Keywords: agroforestry, PES scheme, public policy, Brazil.

References:

1. TEJEIRO, G. and STANTON, M, 2014, Sistemas Estaduais de Pagamento por Serviços Ambientais, p. 68

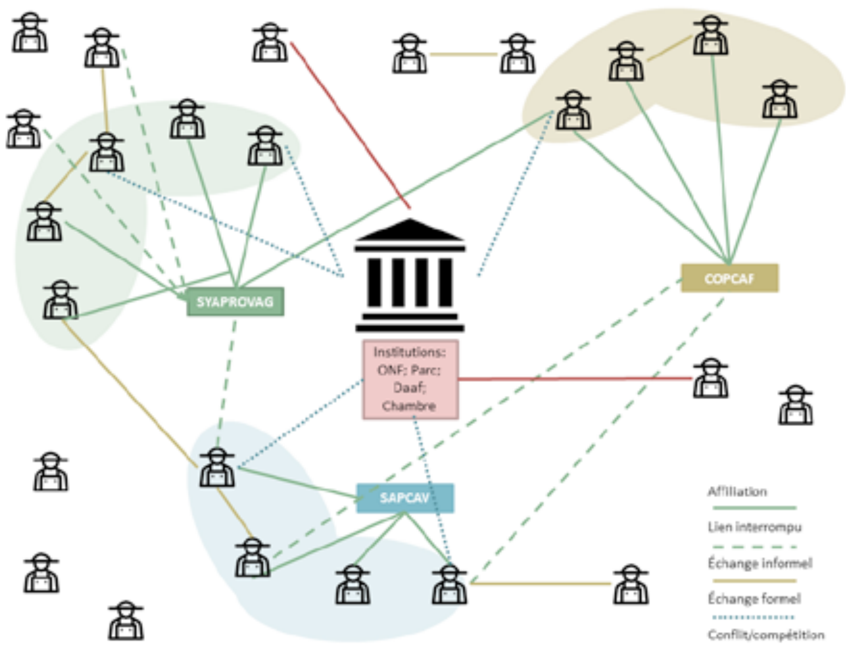
L11.P.04

Between actors visions and institutional framework: Synergies and divergences within the undergrowth of a European UPR

Castro Nunes T.[1] (jean-louis.diman@inra.fr), Cheval A.[1], Barlagne C.[2], Apatout M.[3], Bezard M.[3], Drillet E.[3], Alexandre G.[4], Diman J.-L.[1]

[1] *PEYI - 0805, INRA, Petit-Bourg, Guadeloupe, France*; [2] *James Hutton Institute, Aberdeen, Scotland, United Kingdom*; [3] *Syaprovag, Petit-Bourg, Guadeloupe, France*; [4] *URZ, INRA, Petit-Bourg, Guadeloupe, France*

The complexity of the game of actors mobilized around the issues of valorization of the Guadeloupe forest is a question of research and a major stake for the sustainable development of the territory. Like other ultraperipheral European tropical regions (Jouan, 2017), the study reveals deep antagonisms for the advent of a territorial policy of sustainable agroforestry valorization in a context where the land resource is limited. Between the regional authority, decision-maker of a territorial policy and manager of European funds, the departmental authority, large public forest owner, decentralized State services, guarantors of compliance with national regulations, the Chamber of Agriculture in representation of Guadeloupe farmers, the institutional micro-sheet complicates the emergence of a viable agroproductive sector in the Guadeloupe forest (Demené 2013, Cruse 2014). In corollary, we find among producers (Castro Nunes et al., 2018), a proliferation of divergent strategies sometimes crossed, depending on opportunities, or threats with tensions sometimes curbing the synergies around innovative endogenous collaborative initiatives. In a territory where the forest has played a major socio-economic role, beyond the currently promoted agroforestry models (Vinglassalon et al., 2018), or the ecological sanctuary advocated elsewhere, it seems necessary to strengthen the work of participatory co-construction to achieve an inclusive territorial agroforestry project.



Keywords: sustainable development, Guadeloupe, territory, forest, game of actors.

References:

1. Cruse, 2014. Une géographie populaire de la Caraïbe. Mémoire d'encrier.pp.592
2. Demené, 2013. Entre nature et agriculture. Agricultures patrimoniales et services environnementaux.
3. Jouan, 2017. Diagnostic agraire du Centre-Est de l'ile de la Réunion. Quelle place pour l'agro...
4. Castro Nunes, 2018. Diversity of the socio-economic strategies of valorization of the undergrowth...
5. Vinglassalon, 2018. A paradigm shift for agroforestry on the Guadeloupe archipelago: towards...

L11.P.05

Re-introducing agroforestry in the Czech agriculture through a cooperative project

Chládová A.[1] (chladova@ftz.czu.cz), Lojka B.[1], Houška J.[1], Kotrba R.[1], Weger J.[2], Jobbiková J.[2], Vávrová K.[2], Martiník A.[3], Krčmářová J.[4], Szabó P.[5], Kala L.[5], Doležalová H.[6], Švecová R.[6], Šebek J.[6]

[1] *Faculty of Tropical AgriSciences, Czech University of Life Sciences, Prague, Czech Republic*; [2] *Department of Phytoenergy, Silva Tarouca Research Institute, Průhonice, Czech Republic*; [3] *Faculty of Forestry and Wood Technology, Mendel University in Brno, Brno, Czech Republic*; [4] *Institute of Ethnology, Czech Academy of Sciences, Prague, Czech Republic*; [5] *Institute of Botany, Czech Academy of Sciences, Brno, Czech Republic*; [6] *Association of Private Farming, Prague, Czech Republic*

In the Czech Republic, industrialised agriculture is predominantly practiced. Intensive and industrial agriculture is able to provide sufficient agriculture products to supply high demands; however, it has a number of adverse effects on the environment such as, soil erosion and compacting, decreasing of soil fertility, loss of biodiversity, reducing landscape functionality, breaking local nutrient and energy cycles, etc. Agroforestry systems (AFS) entails an option that can minimize these negative effects and can provide more diverse and sustainable production. Agroforestry is currently not a common land-use system in the Czech Republic. Traditional agroforestry nearly disappeared during the era of collective farming throughout of 20th century, except for small remnants, modern agroforestry systems are not in practice yet. The traditional agroforestry practice did not survive decades of agricultural industrialisation, and hence, it is scarcely practice nowadays. To re-introduce agroforestry as a sustainable agricultural practice among Czech farmers, technical background and research on its implementation is needed. Therefore, the research project "Agroforestry in Czech Republic - potential for regional development and sustainable rural landscape" funded by the Technology Agency of the Czech Republic (ETA programme, TL01000298) started in 2018. It aims at evaluating the benefits and constraints of using AFS in Czech Republic with a focus on the socio-economic, legal and environmental context. The project evaluates planting and adaptability of selected tree species on arable land in areas affected by soil erosion and drought, as well as animal husbandry combined with tree components. The target areas will be large contiguous arable lands with intensive agriculture in the Central Bohemia and South Moravian Region. Based on detailed literary review, socio-ethnological surveys, production and economic data gathered from farmers, the AFS benefits on the agricultural land will be evaluated. Furthermore, legislative constraints and opportunities for trees growing on agricultural land will be analysed. Scientific publications and the development of methodologies for the application and implementation of the AFS in Czech Republic will be the main and final output of the project.

L11.P.07

Building Resilience for Adaptation to Climate Change through Forest and Landscape Restoration

Esteghamat M. (minaesteqamat@gmail.com), Aghakhani S.

PAs and Natural Resource Management, ZIPAK NGO, Tehran, Iran

Land degradation has emerged as a major threat to the development of green economies worldwide. Degraded lands cannot provide the goods and services needed by people living in and around them. They could be restored into sustainable agriculture, agroforestry, pastoral uses, or natural and planted forest cover. International commitments to land restoration have been launched through the Bonn Challenge and the New York Climate Summit on September 2014 that have declared global commitments to restore 350 million hectares out of 2 billion hectares of the global degraded lands. This is as a practical, action-orientated platform to facilitate the implementation of several existing international commitments that require restoration, including the CBD Aichi Target 15, the UNFCCC REDD+ goal, the Rio+20 land degradation target and many of SDGs.

The Restoration Opportunities Assessment Methodology (ROAM), produced by IUCN and the World Resources Institute, is a flexible and affordable framework approach for countries to rapidly identify and analyze forest landscape restoration (FLR) potential and locate specific areas of opportunity at a national or sub-national level.

This study evaluated the most effective models and participatory approaches for restoration through profitable and sustainable land management systems at scale, to develop restoration programs and landscape-level strategies in Iran. For this purpose, the objective, strategy and action plan for landscape restoration have been localized and customized to the specific conditions of the country, including its biophysical conditions and its stakeholders, taking into account their interests, indigenous knowledge and the decisions they make.

Some of the expected outcomes and achievements of this study are: Better information for improved land-use decision-making; High-level political support for FLR; Fundamental inputs to national strategies on FLR, REDD+, adaptation and biodiversity conservation, and for mutually reinforcing convergence between such strategies; A basis for better allocation of resources within restoration programs; Engagement of and collaboration among key policy-makers and decision makers from different sectors, as well as other stakeholders with interests in how landscapes are managed; and Shared understanding of FLR opportunities and the value of multifunctional landscapes.

By implementing ROAM, decision-makers and stakeholders can expect to deliver the multiple functions and different types of outcomes that will be approached through this methodology. Restored landscapes and seascapes can improve resilience including adaptive capacity of ecosystems and societies, and can contribute to climate change adaptation and generate additional benefits for people, in particular indigenous and local communities and the rural poor, using a participatory approach involving all stakeholders.

Keywords: Forest and Landscape Restoration, Restoration Opportunities Assessment Methodology, Bonn Challenge, Climate Change Adaptation.

References:

1. IUCN, 2011, A guide to the Restoration Opportunities Assessment Methodology (ROAM)
2. http://www.bonnchallenge.org/
3. Faham E, S, et al., 2009, Participation in Social Forestry
4. FRWO, 2014, National Forestry Plan, Iran

L11.P.08

Potential of national and international policies and policy instrument in the development of agroforestry in Chad

Foundjem-Tita D. (d.foundjem@cgiar.org), Degrande A.

World Agroforestry Centre (ICRAF), Yaounde, Centre Region, Cameroon

Within the context of climate smart agriculture (CSA) in most dryland countries, agroforestry diversifies and increases food production, improve livelihoods, and increase adaptation and mitigation to climate change. The right enabling environment are prerequisites for technology development and uptake amongst which agroforestry. Yet, many countries often fail to tap into the opportunities provided by national and international policies and the global institutional environment to develop agroforestry with prevailing literature citing national policies and legal context as major impediments to agroforestry uptake. We aim to show with the case study of Chad that most countries can exploit opportunities in national polices and legislation on the environment and forest to enhance agroforestry. To demonstrate the latter, information was collected through (i) literature reviews of important national and international polices and legislation governing access to land and trees, amongst which 'La Loi 14', Chad's 2010 poverty reduction strategy paper; draft zero of the National Environmental Policy; (ii) interviews and focus group discussions with NGOs, Government officials and farmers; (iii) household surveys with 100 farmers. We found that despite the absence of a specific agroforestry policy in Chad, the country has adopted many policies and developed strategies that may be exploited to develop the practice. Most stakeholders interviewed had positive attitudes towards agroforestry, but its uptake is constrained by limited expertise and inadequate extension efforts, limited access to improved planting material, and poor mastery of the forestry law by farmers and forestry officials. This gives room for rent seekers to collect access fees to trees on both forest and farm land thus discouiraging tree planting. The study concludes that more farmers will become involved in tree planting on farm land as awareness increases, and as water and planting materials are made available. We propose that the Government of Chad should unmask elements of agroforestry in its current forest and environment policies and policy instruments and demonstrate the importance of the technology to the country's economic and environmental challenges. It is important for the country to develop clear agroforestry action points in subsequent climate change and environmental policy documents so that tree planting initiatives entrenched in such policy documents could be implemented from an agroforestry perspective.

Keywords: climate change, environmental degradation, forestry policies, tree planting, Chad.

L11.P.10

Farming the Future – Building Rural Networks for Climate-Adaptive Agriculture

Leyequien E.[1] (euridice.leyequienabarca@hvhl.nl), Smits T.[1], Bijl M.[2], Reubens B.[3], Triste L.[3], Pardon P.[3], Debruyne L.[3], Eweg R.[1], Stobbelaar D. J.[1], Nederhof E.[1], Strikwold M.[1], Strijkstra A.[1], Elferink E.[1], Sechi V.[1]

[1] *Van Hall Larenstein U. of Applied Scienc, Velp, Gelderland, Netherlands*; [2] *Forestry Service Group, Garderen, Netherlands*; [3] *ILVO, Merelbeke, East Flanders, Belgium*

Farmers in Europe are facing many challenges in their transition towards a climate-adaptive agriculture, where agroforestry has been recognised as a climate resilient alternative. In the Netherlands and Belgium this transition is hampered by technical, financial, economic and legal issues. The project FARM LIFE, funded by the EU, contribute to the EU climate policy priority of Climate Change Adaptation and aims at developing a suitable and practical transition toolkit that supports farmers in developing adaptive farm plans implementing agroforestry. To develop the transition toolkit we involve stakeholders from the quadruple helix ensuring the project is well embedded in local context. Moreover, we setup a baseline for parameters for measuring project performance to enable monitoring and comparisons, gathering context data and additional studies, which are combined into an integrated design process resulting in contextualized Adaptive Farm Plans, including the development of resilient, self-propagating local and regional business networks. Additionally, to prepare the future agricultural transition managers we develop a master's curriculum. Through this co-creative approach in which the involvement of farmers, government, entrepreneurs in the agri-food sector, agricultural organisations, knowledge institutes and other societal actors come together we build rural networks targeting at replication and upscaling in the Netherlands and Belgium, but also other European countries.

Rural networks for climate adaptation

Keywords: FARM LIFE, Climate adaptation, agricultural transition.

References:

1. Cook, David. 2004. Ed. Schumacher Society, 96 pp.
2. European Comission. Strategy on adaptation to climate change.https://ec.europa.eu/clima/policies
3. Hernandez-Morcillo, Monica. et al. 2018, Environmental Science & Policy, p. 44-52.

L11.P.11

How to take into account the trees in the next common agricultural policy (CAP) ?

Liagre F.[1] (liagre@agroof.net), Hannachi Y.[2], Lemoine L.[2], Sanson B.[3], Pointereau P.[3]

[1] *AGROOF / AFAC-Agroforesteries, Anduze, France*; [2] *APCA, Paris, France*; [3] *AFAC-Agroforesteries, Paris, France*

REUNIR AF is a national project, coordinated by APCA and AFAC and founded by the Agriculture Ministry, to coordinate the Agroforestry Development in France. This program named a referentt in each province to lead the regional adoption of agroforestry. A key action is to make sure of the « Agroforestry » presence in the regulations, in the first and second pillar in the CAP. To this purpose, various actions are led to determine the key parameters for adoption regarding the current regulations and to propose some adaptations or innovations in the proposals for the next CAP.
From November till January, an important survey will be led to all the professional public concerned by the CAP evolution : farmers in first place, but also the technical advisors in association or Agriculture Chamber, the administration (instruction but also the control office). Interviews will be organized in all the province and 700 persons will be interviewed. The main objectives are to realize a state of the current CAP and to formulate new proposals for the next CAP Period, at different scale : European, National, and Regional. The survey will take attention to the articulation between the CAP and administrative or local regulation, to check if it could exist some contradictions between European and national or regional measures.
The project will take part to the European activities from EURAF. A possible European survey could be organized in collaboration with the different national associations.

Keywords: CAP, adoption, subsidy, paiment, regulation.

References:

1. Robert C, Liagre F, Lemoine L, Hannachi Y, 2018, Agroforesterie et statut du fermage, appui à la com
2. Hannachi Y, Angeniol C, Gaudaré J 2015, L’agroforesterie et les arbres ruraux dans les réglementatio

L11.P.13

Agroforestry Policy on the Atlantic area

Mosquera-Losada M. R.[1], Curran E.[2], McAdam J.[3]

[1] *Univ. Santiago Compostela, Lugo, Spain*; [2] *Agriculutre Food and Marine Cornea, Forest Service, Cork, Ireland*; [3] *Univerity of Belfast, Belfast, Northern Ireland*

The Western part of Europe is dominated by Atlantic weather conditions which are associated with high rain fall conditions of over 600 mm to 2500 mm per year. This precipitation provides excellent conditions for high productivity for all types of crops which are mainly associated with forestry and to permanent grasslands in the Western part of Europe. There is also a temperature gradient from the North to the South that creates growth restrictions associated with cold and droughts in areas like Ireland and Galicia. Both areas have enormous potential to increase agroforestry use and promote more sustainable land management. Ireland has a large number of hedgerows that help reduce the negative impact of winds in grassland production but also contributes to improved animal welfare. Galicia has a 70% of its land allocated to forestry and should use livestock to reduce forest fires which results in over 100,000 ha of burned land in only a few days every decade when weather conditions become increasingly negative. The benefits that silvopastoralism could provide are even greater considering the rising temperatures and the appearance of extreme events due to climate change. Increasing forest cover in Ireland and delivering agricultural products (livestock) can be achieved on the same piece of land, while access to the land is prolonged through the presence of trees and the enhanced drainage they provide. The potential for agroforestry to mitigate the negative effects of wildfires in Ireland is also recognised. Increasing forest land used by livestock in Galicia is essential to increase income and rural development as livestock produces a short and medium term income to farmers that otherwise cannot live exclusively from the benefits of forestry. Tree species selection and tree density becomes a key issue in both cases. Broadleaves such as oak ,ash (some species), birch, willow, walnut, poplar or cherry are excellent species because they can provide feed in the autumn or when pruned and shaped to obtain high value timber trees. In addition they can protect water, intercepting silt and nutrient runoff and can increase soil fertility as they incorporate leaves every year into the soil increasing nutrient recycling and carbon storage. When selected the species it is important to take into consideration the time when the leaves appear, the capacity of generating epicornic buds, fruit and nuts, but also its management such as the distribution within the plot or the timing for thinning and final harvests as this will affect the development of both livestock and forest stand. The management of light will be critical too as the trees mature and shade increased it is important that there is enough light for grass to thrive. In spite of the known positive impacts silvopastural agroforestry systems could have in both areas, the number of measures promoting them is still rather small.

L11.P.14

Agroforestry promotion in Europe through forestry measures

Mosquera-Losada M. R. (mrosa.mosquera.losada@usc.es)

Crop production and Project Engineering, Univ. Santiago Compostela, Lugo, Lugo, Spain

Santiago-Freijanes1, A. Pisanelli2, M. Rois-Díaz3. Aldrey-Vázquez A4,
Rigueiro-Rodríguez A1, Pantera A5, Lojka B6, Ferreiro-Domínguez N1,
Mosquera-Losada MR1
1Crop Production and Engineering Projects Department, High Polytechnic School, University of Santiago de Compostela, 27002 Lugo, Spain
2 Institute of Agro-Environmental and Forest Biology, National Research Council, Porano, Italy
3European Forest Institute, Yliopistokatu 6, 80100 Joensuu, Finland
4 Geography Department, Facultad de Geografía e Historia, Praza da Universidade nº 1, 15782 Santiago De Compostela, Spain
5TEI Stereas Elladas, Dpt. of Forestry & Natural Environment, 36100 Karpenissi, Greece
6 Czech University of Life Sciences Prague, Faculty of Tropical AgriSciences, Department of Crop Sciences and Agroforestry, Kamycka 129, Praha, Czech Republic

Agroforestry is considered a sustainable form of land management that optimizes the use of natural resources (nutrients, radiation, water). Agroforestry was a traditional land use system in Europe before modern times. However, before the sixties land intensification and consolidation destroyed millions of trees all over Europe. On the contrary, some good examples of agroforestry promotion are found in Eastern European countries in order to reduce the effect of extreme events such as winds, flooding at the beginning and mid of the last century. In Western European countries, the introduction of trees in the land has been promoted by agroforestry, afforestation and reforestation at the end of the last century. Afforestation of agricultural lands have been the most successful CAP measure (over 1 million hectares) while agroforestry measures were not extensively adopted which may be explained by the funds associated to afforestation measure which compensated the losses of income 15 or 20 years in afforested lands. Agroforestry was poorly adopted in the CAP 2007–2013, having a better success in the CAP 2014–2020 due to the recognition of woody vegetation and the compensation of 5 years given for maintenance once agroforestry is established. However, policy rules ensuring Pillar I payment when agroforestry measure is adopted such as a management plans ensuring that maximum tree density (100 trees per hectare) is not reached, should be pursued.

Keywords: POLICY, CAP, Measures.

References:

1. Santiago-Freijanes JJ, Pisanelli A, Rois-Díaz M, Aldrey-Vázquez JA, Rigueiro-Rodríguez A, Panterae

L11.P.15

Agroforestry policy in Europe: current status and future prospects

Mosquera-Losada M. R.[1] (mrosa.mosquera.losada@usc.es), Santiago-Freijanes J. J.[1], Pantera A.[2], Pisanelli A.[3], Ferreiro-Domínguez N.[1], Silva-Losada P.[4], den Herder M.[5], Rois Diaz M.[5], Rodriguez-Rigueiro J.[1], Arias-Martínez D.[1], Villada A.[1], Rigueiro-Rodríguez A.[1]

[1] *Crop production and Project Engineering, Univ. Santiago Compostela, Lugo, Spain*; [2] *TEI-Lamia, Greece*; [3] *CNR, Italy*; [4] *EURAF, France*; [5] *EFI, Finland*

Agroforestry is one of the most prominent tools to make easy the transition of European agricultural and forestry farms to more sustainable land use systems such as agroforestry. The extent of agroforestry in Europe is 19.5 million of hectares, of which 85% is allocated to silvopastoralism mainly associated to European Southern countries but also present in some Eastern countries. Silvopasture is associated to the improvement of livestock farming systems providing feed in a more sustainable way while increasing the multiple ouputs production from the same unit of land, therefore improving rural development. The current share of silvopastoralism in the EU is the 10% of the permanent grasslands which shows the huge potential that this land use has. The second most important agroforestry systems are the homegardens which represents the 8.3% of agroforestry lands and occupy around 8.65% of the land allocated to homegardens. Forest farming is not inventoried at all, while silvoarable only occupies almost half a million hectares and less than 1% of the arable land. Europe fosters agroforestry mostly through the Rural Development programs with more than 383 and 467 measures fostering agroforestry in one way or another in the previous CAP (2007-2013) and current CAP (2014-2020). Future measures should be fostered through the CAP Strategic plans developed at country level.

Keywords: policy, silvopasture, homegardens, silvoarable, forest farming.

References:

1. Mosquera-Losada MR, Santiago-Freijanes JJ, Rois M, Moreno G, den Herder M, Aldrey JA, Ferreiro-Domí

L11.P.16

What kind of governance to enhance agroforestry? The case of Québec, Canada

Olivier A.[1] (alain.olivier@fsaa.ulaval.ca), Anel B.[2], Cogliastro A.[3], Rivest D.[4]

[1] *Département de phytologie, Université Laval, Québec, Québec, Canada*; [2] *Agroforesterie et paysage, MRC du Rocher-Percé, Chandler, Québec, Canada*; [3] *IRBV, Montréal, Québec, Canada*; [4] *Département des sciences naturelles, Université du Québec en Outaouais, Gatineau, Québec, Canada*

Although the rate of adoption of agroforestry is still low in the province of Québec, Canada, a growing interest toward agroforestry is observable among various stakeholders of the agricultural, forestry, environment and territorial planning sectors. But how to meet their expectations with regards to agroforestry support? One of the means to stimulate networking, technology transfer and policy development in agroforestry was the creation, in 2008, of an Agroforestry Committee supported by the Québec Reference Center for Agriculture and Agri-Food (CRAAQ), a network of experts and organizations aiming at sharing of information and knowledge management and dissemination. The mandate of the Agroforestry Committee, which comprises representatives from farmers' and foresters' unions, agricultural and forestry advisory groups, universities, research centers and ministries of agriculture and forest, is to contribute to the development of agroforestry systems offering solutions to the issues of rural territories by fostering networking, sharing of information and knowledge transfer.
In the last few years, the Agroforestry Committee organized various events, among which a Forum (2010), a Scientific symposium (2013), and a Workshop on research and development in agroforestry (2013). It developed a network of demonstration sites that can also be consulted online (2013). More recently, a video presenting inspiring examples of agroforestry practices among farmers was released (2018). Since the participants of the events organized by the Agroforestry Committee identified the absence of recognition at the political level and the lack of technical and financial support as some of the most important constraints to adoption of agroforestry, a working group stemming from this committee was also set up in order to draw up a document about the strategies to put in place to stimulate such an adoption (2017). An analysis of the current situation in view of the challenges faced by the agroecosystem brought the working group to make six recommendations: the recognition by the public authorities of the potential of agroforestry systems; an increased technology transfer through the setting up of networks of agroforestry advisors and demonstration sites; the provision of financial support to producers through a program specifically dedicated to agroforestry; the creation of new knowledge through research; the development of adapted plant material; and an increased dialogue between the various actors of the agriculture, forestry, environment and rural development sectors. The implementation of these recommendations should help the scaling-up of agroforestry in Québec. However, the ability of the Agroforestry Committee to reach policy makers could be a pre-requisite for that. The advantages and disadvantages of such an organization for stimulating the development of agroforestry will be discussed.

Keywords: governance, networking, policy, stakeholder, technology transfer.

L11.P.17

Plan de développement de l'agroforesterie 2015-2020, en France

Pinard C. (christophe.pinard@agriculture.gouv.fr)

DGPE, Ministère de l›agriculture et de l›alim., Paris, IDF, France

The agroforestry development plan 2015-2020 in France

I - Results after 3 years

"To develop and manage agroforestry sustainably in all its forms and throughout French territory, one of the levers for the agroecology project for France" – this was the goal of the agroforestry development plan launched by the Ministry of Agriculture on 17 December 2015. As part of the agroecology project driven by the Ministry, this plan is reliant on a wide range of key partners: the Ministry of the Environment, research bodies (INRA, CIRAD, technical institutes) and development organisations (chambers of agriculture), representative non-profit associations (Afac-Agroforesteries, AFAF), organisations with regional remits (regional nature parks), public bodies of all kinds (INAO, agricultural teaching establishments), and others. It is organised around 5 core focuses and 23 actions aimed at contributing to the development of agroforestry in all its dimensions.

Method

The plan is coordinated by the Ministry of Agriculture and Food (climate change and biodiversity office). The 23 actions are driven by one or two bodies, and in some cases by the Ministry itself or in others by its partners. A steering committee meets regularly to assess the work done, validate policy choices and suggest additional avenues for consideration. National days are also organised on a regular basis in order to disseminate widely the results of the work in progress (the fourth such day proposed by the Ministry took place in December 2018).

+ Sidebar:

Four types of agroforestry predominate in France:

** 700,000km of hedgerows form typical so-called "bocage" landscapes, livestock farming areas*

** 100,000 hectares of meadow orchards are used for livestock and fruit production*

** 15-20,000 hectares of agricultural parcels contain in-parcel tree rows*

** Silvopastoralism is also used, especially in mountain areas*

II - Some major accomplishments : 5 exemples

III - What now?

After three years' work, the plan launched in December 2015 by the Ministry of Agriculture and Food has implemented a large proportion of its planned activities. This work must continue, in order for example to gain in-depth knowledge of ongoing changes in the various agroforestry systems at national level and to support the development of projects at local level. Regional roll-out of the plan currently involves the launch of consultation processes with volunteering regions, some of which have made great progress on this topic (e.g. Reunion Island, Normandy region, Corsica). This will undoubtedly be an objective to be developed in the next plan for 2020-2025.

Contact: dgpe.agroforesterie@agriculture.gouv.fr

Ministry of Agriculture and Food

Keywords: National policy, Agro-ecology.

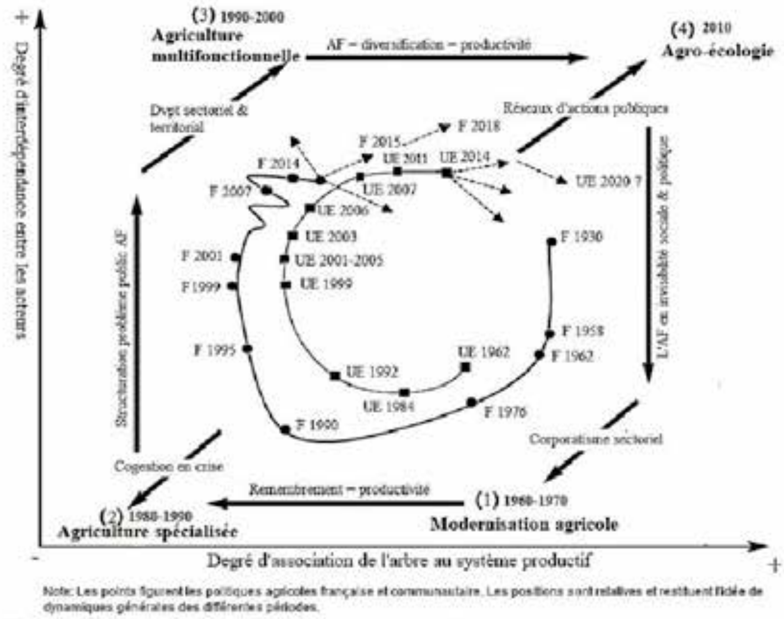
L11.P.18

Agroforestry : a reconfiguration of agricultural policies within the framework of agro-ecological transition ?

Sachet S. (stephane.sachet@hotmail.fr)

33, University of Bordeaux, Port-Saint-Père, France

Using the Norbert Elias' concept of « Social figuration », this paper analyses the implementation of agroforestry into the French national public policy through "the agroecology project for France", and in the European policy through the «greening» of the Common Agricultural Policy. This study shows the slight evolution of the nature of social dialogue in the definition of agricultural policies. Network's expertise seems promoted at the expense of the typical corporatism of the agricultural stakeholders. Now, technical innovation appears and develops through empirical experiences amongst informal groups where farmers, scientists, institutions and civil society stakeholders cooperatively work together. Through close fieldwork observation, this work attempts to range these politics from marginal adaptation or ecological redesign?



Paths of agroforestry policies in France and European Union.

Keywords: Agroforestry, Agroecology, Agricultural policies, Ecological redesign, Greening.

References:

1. Hervieu, B. et al, 2010. Les mondes agricoles en politique., Presses de Sciences Po, pp 450., Paris.
2. Elias, N. (1991 [1970]). Qu'est-ce que la sociologie ?, La Tour d'Aigues, Éditions de l'Aube, Paris.

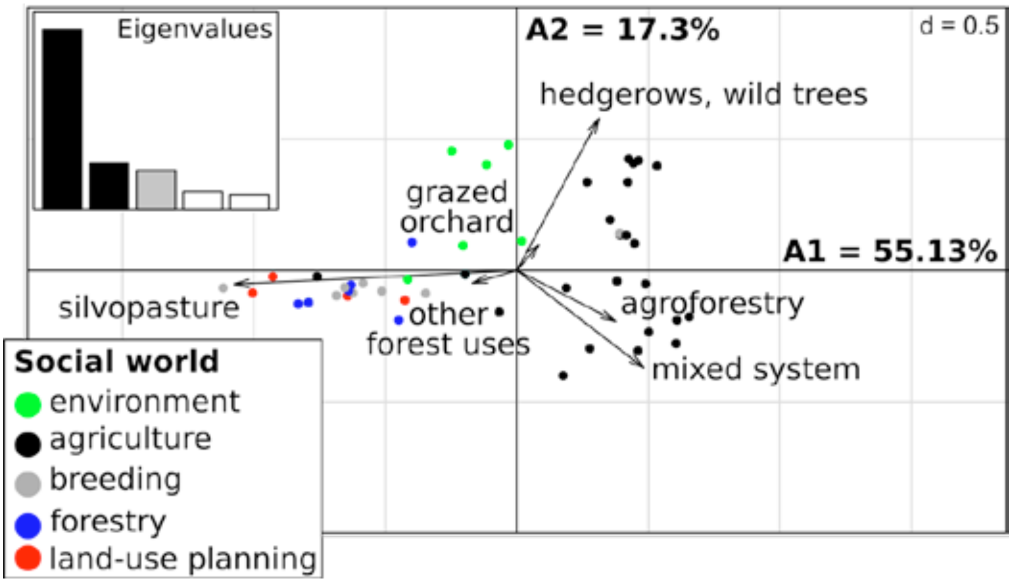
L11.P.19

The policyscape of agroforestry within Mediterranean protected landscapes in France

Therville C.[1] (clara.therville@gmail.com), Antona M.[2], de Foresta H.[3]

[1] *UPR GREEN / UMR AMAP, CIRAD / IRD, Montpellier cedex 5, France*; [2] *UPR GREEN, CIRAD, Montpellier, France*; [3] *UMR AMAP, IRD, Montpellier, France*

Agroforestry systems (AFS), presented by their supporters as systems able to reconcile multiple social and ecological functions, are potentially interesting for a diversity of sectoral policies such as forestry, environment or water policies. They are presently in a process of being institutionalized in Europe through the development of specific policy instruments. In this context, we investigated the policyscape of agroforestry, meaning the articulation between multiple policies impacting a diversity of AFS in two Mediterranean protected landscapes: the Ventoux biosphere reserve and the Verdon regional nature park. We conducted in depth interviews with 50 practitioners and institutional representatives from diverse policies directly concerned by AFS. We found that if some AFS such as silvopastures are highly intersectoral and concerned by a large diversity of instruments, others such as alley-cropping systems are confined in the agricultural sector (Figure 1). Presently, systems such as grazed pastures are largely ignored by policies. Our results indicated that instruments specific to agroforestry represent a minority in relation to the diversity of sectoral instruments impacting AFS at a landscape scale. Regarding this agroforestry policyscape, we discuss opportunities for agroforestry development with issues of policies coordination, lack of instruments or of involvment from environmental or land-use planning policies for certain types of AFS.



Fifure 1: Non-symmetric correspondence analysis on the references made by stakeholders to different types of agroforestry systems.

Keywords: policyscape, policy instrument, Mediteranean landscape, agroforestry, protected area.

L11.P.20

Almost a decade of REDD+: Why has Degradation and Deforestation of forests sustained in Western Uganda?

Uwimbabazi M. (muwimbabazi@gmail.com), Kiyingi I., Agaba H., Kisekka R., Ntakimanye A., Kabonesa B., Musiimenta S., Galabuzi C.

Forestry Resources Research Institute, NARO, Kampala, Uganda

Almost one-fifth of global carbon emissions come from land use changes, largely attributed to deforestation in tropical countries. Deforestation and degradation of tropical forests have gained attention due to increased momentum on global climate change negotiations. A study was conducted in western Uganda to; i) determine the socio-economic attributes of private natural forests owners, ii) assess the status of private natural forests under REDD+ iii) assess the drivers of deforestation and degradation of forests under REDD+ and iv) assess the effect of REDD+ on livelihoods. A participatory approach using semi-structured interviews and focus group discussions was followed to collect data. Quantitative data were analyzed in SPSS 20. Results showed that up to 69% of Private natural forest owners were middle aged men with limited education (86%) and involved farming (62%) as a key source income. About 48% of the forests were slightly logged, 30% slightly degraded and 14% heavily degraded (the canopy was ≤ 30% and void of trees of ≥20 cm DBH). The topmost drivers of deforestation and degradation include agricultural expansion and land grabbing. Although some participants were still protecting their forests, the incentives provided or promised seem to have just encouraged others to stay with the program rather than conserve the forests. To ensure effectiveness of REDD+, a review of the nature of incentives and the approach of delivering them should include assisting the smallholder farmers with mechanisms to address crop raiding and land tenure insecurity. Without these, perpetuity of tropical forests on private land under REDD+ will be in jeopardy.

Keywords: Tropical forests, Forest Degradation, Livelihoods, Carbon Sequestration, Carbon Sequestration.

L11.P.21

Developing a vision on agroforestry for the Nijmegen-area in the Netherlands

van der Meulen S.[1] (suzanne.vandermeulen@hvhl.nl), Verschuur M.[2], Santegoets J.[3]

[1] *Sustainable Foodscapes in Urban Regions, Van Hall Larenstein University, Velp, the Netherlands*; [2] *Sust. Agribusiness in Metropolitan Areas, Van Hall Larenstein University, Velp, the Netherlands*; [3] *Forest and Nature Management, Van Hall Larenstein University, Velp, the Netherlands*

The municipality of Nijmegen is developing a vision on agroforestry in its surrounding areas. To investigate the current state view of stakeholders on agroforestry, a Rapid Appraisal (RA) has been carried out in the region around Nijmegen, completed with in-depth interviews (Verschuur, 2012; Van der Linde, 2014).

A number of the interviewees are actively involved in a form of food forestry production, with a focus on crop production (figure 1). These initiatives are small and are currently not planning to scale up to larger sized farms or processing units, which would be needed to provide food for a city like Nijmegen. People who are at the moment involved in agroforestry are very passionate and very much looking for connections outside their farms, which is key for the establishment and acceptance of a new system. The other side is that at this moment agroforestry in the Netherlands is mainly associated with the small scale food forests. With the aim of providing the city of Nijmegen with food coming from agroforestry, this is might not be enough and many questions remain. Part of these circle around the agroforestry system itself: what types of sustainable systems will fit the area? Others deal with the economics and business models. Also, what will be the effect on the landscape in the Nijmegen-area? And last but not least: a discussion is needed about the role and responsibility of the municipality of Nijmegen, if they want to further develop and implement their vision.

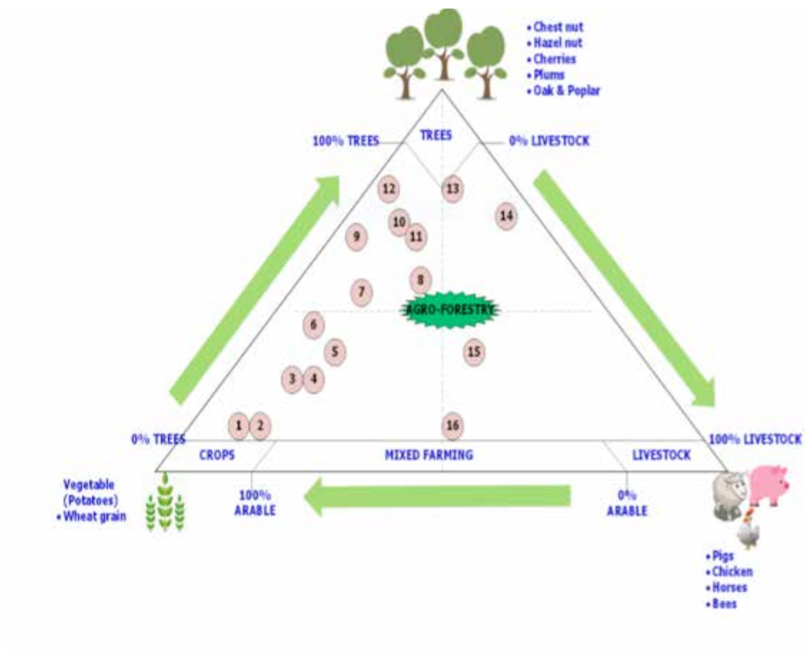


Figure 1: classification of agroforestry farms in the Nijmegen area

Keywords: Rapid Appraisal, system, urban, scale, local food.

References:

1. Burgess P.J., 2016. Presentation at “Designing the path» Brussels
2. Van der Linde, D, 2014; Praktijkgericht onderzoek in de ruimtelijke planvorming. Velp, NL
3. Verschuur, M. (ed), 2012. Sustainable Cereal Business in the Doesburger Eng. Wageningen, NL

ABSTRACTS

Agroforestry adoption

Adopting the future of land use

- L12 -
Economics of agroforestry: the link between nature and society

An agroforestry wedding band between society and the natural world

Agroforestry practices and techniques are relatively well described as well as environmental aspects (biodiversity, impact on soils and fauna...). Impacts on farmer incomes and long-term economic benefits and strategies are still partially lacking in explaining why some farmers move to agroforestry.
Social issues are mainly seen from an ethno-botanic perspective. This session focuses on socio-economic aspects, including income analysis (in particular for vulnerable countries and populations link to food security), social components (farmers' perceptions, organization and policy), payments for ecosystem services and other environmental issues. The objectives of this session are 1) to contribute to knowledge on economic impacts and social nature of agroforestry practices in order to bridge the science-policy gap, 2) to provide a broader view of understanding the basics of agroforestry practices and development using a multi-disciplinary context, and 3) to highlight experiences linking science, local communities and policy. Beyond agroforestry techniques and its positive environmental impact, securing income generation, improving resilience and a social vision of this paradigm explain as well why long term practices is critical. Beyond the local knowledge involved in agroforestry spaces, we will explore the visions and complexities that the different agroforestry situations offer. Papers on both local experiences and larger contexts and analyses are welcome.

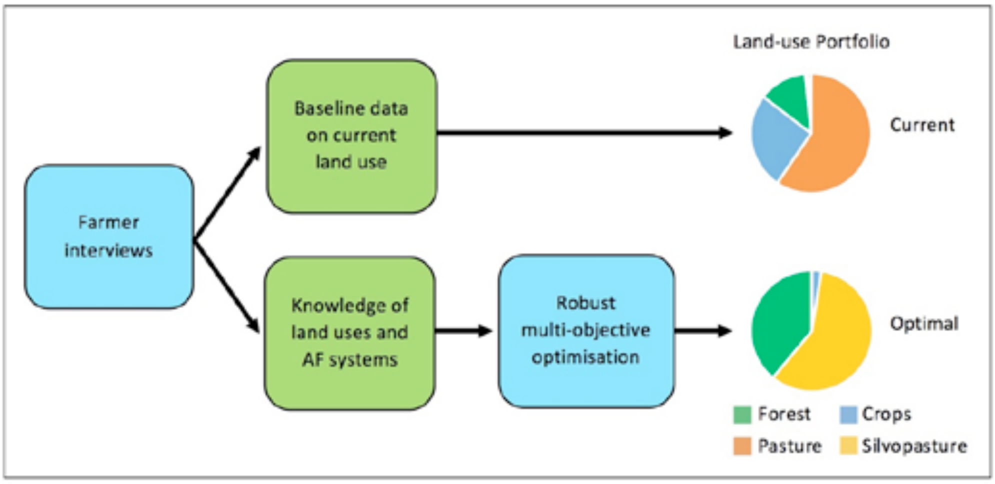
L12.1_O.01

Robust land-use modelling informed by farmer knowledge – assessing the socio-economic potential of agroforestry systems

Gosling E.[1] (elizabeth.gosling@tum.de), Reith E.[1], Knoke T.[1], Paul C.[2]

[1] *Institute of Forest Management, Technische Universität München, Freising, Germany*; [2] *Forest Econ. & Sust. Land-use Planning, University of Göttingen, Göttingen, Germany*

Agroforestry (AF) systems have clear potential to increase ecosystem services in agricultural landscapes, but to what extent do they meet the socio-economic needs of farmers? We present a goal-programming approach that integrates farmer knowledge and future uncertainties in the optimisation of farm portfolios. Using this robust, normative method we investigate the potential of AF to meet multiple objectives at the farm level, focusing on a forest frontier region in eastern Panama. We obtained data from farmer interviews, drawing on participatory research methods to quantify farmers' knowledge and perceptions of six land-uses. Results show farmers viewed silvopasture very favourably, and this AF system dominated the optimised farm portfolios. Maintaining liquidity appears to be a key driver of farmers' land-use decisions in the study area. Differences emerged in the preferences and perceptions of different farm types, highlighting that a one-size-fits-all approach to promoting AF systems may be inappropriate. Overall, results suggest that farmers in the study region would be receptive to silvopastoral systems, which as part of a diversified farm portfolio can contribute to a range of socio-economic objectives. However, important barriers to adoption, such as a complicated tree harvesting permit system, remain. While we tested the modelling approach in Panama, it is easily transferable to guide land-use planning in other tropical and temperate regions.



Overview of research methods and results

Keywords: silvopasture, land allocation, robust optimisation, Panama, farmer interviews.

L12.1_O.02

Beyond economic advantages of agroforestry systems: what role and place of externalities in farmers' strategies?

Penot E.[1] (eric.penot@cirad.fr), Danthu P.[2], Chambon B.[3], Bertrand B.[4]

[1] *UMR innovation, CIRAD, Montpellier, France*; [2] *UR HortSys, CIRAD, Montpellier, France*; [3] *UR 34, CIRAD, Bangkok, Thailand*; [4] *UR IPMF, CIRAD, Montpellier, France*

Most agroforestry systems in the world results from local adaptation to climate, soils, crops and markets conditions for a specific crops combination and generally linked with a crop opportunity for export during colonial era which is mainly true for coffee, cocoa, rubber and clove. The focus is then put on income generation and rapid monetarization of local livelihoods. Some systems are purely resulting from local demands such as coconut tree based systems with focus on food for self-consumption. Some systems are based on a main cash crop (rubber, cocoa, coffee…). In all cases, production diversification is a key element for a better global resilience through production of the main crops and fruits, firewood, timber wood, resins, rattan… and other plants such as medicinal plants. Some products are sold and some self-consumed largely depending on access to markets. The "useful" biodiversity is then largely known and combined to fulfill a better resilience, based on crop diversification in order not to depend only on one product and generate in the short/mid term several sources of income. But the "non useful" biodiversity or more exactly the non-marketable biodiversity is also producing ecologic services in the long run that are highly appreciated and generally well known by local people. What is the role of these externalities in agroforestry development and associated farmers' strategies. If most income analyses have difficulties in providing a value to these externalities, they may have a key role in farmers' choice and preference in agroforestry rather than monoculture when they have the choice.
In other words, if profitability and short term income generation are often a priority for most smallholders, long term stability, positive externalities provided by ecological services of agroforestry systems and the search for a better resilience are key factors in developing agroforestry strategies in the long run. We provide several examples of that trend for rubber agroforestry in Indonesia and Thailand, clove agroforestry in Madagascar and coffee agroforestry in Nicaragua.

Key selected bibliography

Arimalala, Penot, Michels, Rakotoarimanana, Michel, Ravaomanalina, Roger, Jahiel, Leong Pock Tsy, Danthu. 2018. Agroforestry systems. https://doi.org/10.1007/s10457-018-0268-9
Stroesser, Penot, Michel, Tongkaemkaew, Chambon.2018. Revue Internationale du Développement/Editions de la Sorbonne n° 235 (2018-3),
Danthu, Penot, Mahafaka Ranoarison, Rakotondravelo, Michel-Dounias, Tiollier, Michels, Normand, Razafimamonjison, Fawbush, Jahiel. 2014. BFT 2014. N° 320 (2). http://publications.cirad.fr/une_notice.php?dk=574435
Penot. 2016. *Promoting environmental friendly and socially responsible rubber cultivation*. Conference 17-19 October, 2016. XTBG, Menglun, Mengla, Yunnan, China
Penot, Chambon, Benavidez López, Tongkaemkaew, 2018. Congrès RRI, VII forum de l'innovation. RRI NImes.

Keywords: Agroforestry, Externalities, strategies, Asia, Madagascar.

References:

1. Arimalala, Penot, Michels, Rakotoarimanana, Michel, Ravaomanalina, Roger, Jahiel, Leong Pock Tsy, Da
2. Stroesser, Penot, Michel, Tongkaemkaew, Chambon.2018. Revue Internationale du Développement/Editions
3. Danthu, Penot, Mahafaka Ranoarison, Rakotondravelo, Michel-Dounias, Tiollier, Michels, Normand, Raza
4. Penot. 2016. Promoting environmental friendly and socially responsible rubber cultivation. Conferenc
5. Penot, Chambon, Benavidez López, Tongkaemkaew, 2018. Congrès RRI, VII forum de l'innovation. RRI NIm

L12.1_O.03

Rethinking agroforestry - Shifting the income incentives from the agricultural component to the tree component

Gassner A.[1] (a.gassner@cgiar.org), Dobie P.[2], Pinon C.[1], Replan E.[1], Robert R.[3], Pulhin F.[4], M Mohd N. F.[1], Vidal A.[5], Rodel L.[1], Öborn I.[3]

[1] *Worldagroforestry Center (ICRAF), Los Banos, Philippines*; [2] *Worldagroforestry Center (ICRAF), Nairobi, Kenya*; [3] *Worldagroforestry Center (ICRAF), Bogor, Indonesia*; [4] *Forestry Development Center, University of the Philippines, Los Banos, Philippines*; [5] *IUCN, Washington, United States*

More than 150,000,000 ha of tropical forests were converted to farmland between1980 and 2012, with devastating effects on livelihoods, biodiversity and ecosystem services, resulting in a global outcry for restoration supported by a UN Decade. Agroforestry has become one of the key restoration interventions. Using the Philippines as a case study the paper demonstrates the current mismatch between the agroforestry systems promoted and the development objective to be achieved which is restored forest landscapes. Farmers and forest dependent communities, like elsewhere in the world — want trees that provide income, and fairly quickly, in the absence of functional markets and enabling policy frameworks and financial support native timber tree species are not a very high preference. This is leading to the inclusion of exotic fruit, fodder and fast-growing timber trees in the agroforestry models promoted and implemented on forested lands.

We conducted a literature review on a 110 successful agroforestry case studies, documented by the Institute of Agroforestry of the University of the Philippines and reviewed more than 50 commercial forestry investment proposal (CFIP) that were submitted to the Department of Environment and Natural Resources of the Philippines, to be considered under the Natural Resources and Environmental Management Program program. The analysis show that on the one hand current farmer and community driven species selection is strongly following the agricultural with trees understanding of agroforestry, with the main socio-economic benefits coming from the crop component, ensuring food security and from tree products, providing income. The CFIP models analyzed are exclusively designed with financial incentives for planting trees. Long term sustainable aspects looking at access and benefit sharing of slow growing timber species is largely absent. While the Philippines has one of the most progressive forest legislation frameworks with respect to supporting private timber production, it is compounded by a web of policies and laws that regulate the planting, harvesting and sale of trees on farms and of state land, unintentionally restricting farmers and larger private investors who want to plant indigenous forest species and restore degraded land.

Based on the Philippine case studies we argue that successful forest restoration programs need to move beyond the traditional view that land should be classified based on a specific land use: that timber is produced on forest land and food is produced on agricultural land. A unifying agroforestry policy could serve as a bridge between sectors that rarely coordinate their actions, bringing together not only government agencies but also small and large sectoral interests to navigate a clear path through the tangle of policies and regulations to ensure swift and efficient achievement of national commitments through better use of trees on farms and degraded state forest land.

Keywords: Forest Restoration, smallholder, agroforestry, incentives, income.

L12.1_O.04

A holistic approach to analyze agroforestry heterogeneity at the cropping system and landscape scales in Madagascar

Mariel J.[1] (juliette.mariel@cirad.fr), Penot E.[2], Labeyrie V.[1], Herimandimby H.[3], Danthu P.[4]

[1] *Environnement et Société, GREEN, cirad, Montferrier-sur-Lez, France*; [2] *Environnement et Société, INNOVATION, Cirad, Montpellier, France*; [3] *ESS, Université d'Antananarivo, Antananarivo, Madagascar*; [4] *Hortsyst, Cirad, Montpellier, France*

The multi-dimensional diversification of agroecosystems, from the plot to the landscape scale, is known to be a key factor of social-ecological systems resilience. Agroforestry research especially brought considerable insights on this issue by documenting the socio-economic, agronomic and environmental outcomes of this type of practices. However, the drivers of agroforestry practices' heterogeneity and its spatial patterns remain poorly understood. This requires a diachronic perspective as the observed agroforestry systems often result from the gradual implantation of tree in pre-existing plantations, fallows, forests or pastures. This study addresses this issue through an original diachronic approach at the landscape scale, which contrasts from more usual static approaches focusing on cropping systems. We characterized the drivers of the observed heterogeneity of agroforestry practices and its spatial patterns in the landscape of a village located in the Analanjirofo region on eastern coast of Madagascar. In this locality, small farmers cultivated for 50 years varied perennial crops (clove, litchi and fruits, vanilla, coffee…) within different patterns including complex agroforestry systems. Analyses were conducted in 2016 on both qualitative and quantitative data collected through farmers' surveys on the following topics: i) the plant species grown in local agroforestry systems, ii) farms socio-economic characteristics, and iii) economic evaluation at plot level. A land-use map was built in 2016 through photointerpretation of drone and satellite pictures, and was compared with a map from 1966. The survey showed that a wide diversity of agroforestry practices currently exists on the locality regarding their plant species composition. Agroforestry accounted for 20% of the land surface in the study locality, resulting in a highly heterogeneous landscape mosaic. By merging the analysis of farmers' survey and the diachronic analysis of the land-use map between 1966 and 2016, we were able to give insights on the economic, demographic and geographic processes that led to the observed heterogeneity of agroforestry practices and their spatial patterns. These results raise perspectives to understand the processes involved in agroforestry evolution and expansion in Analanjirofo landscape over the past 50 years. Our results are relevant for supporting the orientation of social-ecological systems toward resilient trajectories.

Keywords: agroforestry, Landscape, diversification, farming practices, resilience.

References:

1. Dandoy, 1973, In Atlas des structures agraires à Madagascar, La Haye, 94. Maison des Sciences et de
2. Tiollier & al, 2014, Bois et forêts des tropiques, no 320: 2
3. Scales & al, 2008, Environmental Conservation 35
4. Torquebiau, 2013, Land, 705-725
5. Fischer, 2006, Frontiers in Ecology and the Environment, 8086

L12.1_O.05

Forest or agroforestry systems, farmers value trees for ecosystem services provision in Nicaragua

Feintrenie L.[1] (laurene.feintrenie@cirad.fr), Cifuentes-Espinosa J. A[2], Dos Santos-Moreira N.[2], Bustillo-Vazquez E.[3], Sibelet N.[4], Gutiérrez-Montes I.[5], Vermeulen C.[6]

[1] *UR Forests and Societies, Cirad-Catie-Icraf, Turrialba, 7071 Cartago, Costa-Rica*; [2] *Catie, Turrialba, Cartago, Costa-Rica*; [3] *Gembloux Agrobiotech, ULG, Gembloux, Belgium*; [4] *UMR Innovation, Cirad, Montpellier, France*; [5] *Posgrado, Catie, Turrialba, Cartago, Costa-Rica*; [6] *Terra-Forests for life, ULG-Gembloux AgroBiotech, Gembloux, Belgium*

In Central Nicaragua, in a rural landscape where trees grow everywhere, we studied the relations between land uses and the perception of ecosystem services (ES) provision by farmers. We worked in 3 municipalities and interviewed more than 100 households distributed among 10 communities, from 2016 to 2018. During gender specific focus groups we produced participatory maps of land uses (following Braslow et al. 2016), localized ES with the Pebble Distribution Method (described by Sheil et al. 2002), and analyzed land tenure issues using the analysis grid for land tenure proposed by Le Roy et al. (1996). Participatory observation (as detailed by Jankowski y Sabourin 2012) and semi-structured interviews (Newing 2010; Sibelet *et al.* 2013) were used to analyze livelihoods conditions, households' economies (data later analyzed with the support of Olympe software), and determining factors regarding land uses and tree planting.

Results prove no relation between land tenure security and the plantation of trees. Land occupation by any farming system with or without trees, such as food crop or pasture, is informally recognized as proof of ownership. Farmers plant trees around their house, in pastures or on the borders of paths, for the high value they attached to them. Trees provide goods (timber, fuel wood, fruits, medicine…) and services (preservation of soils and water resources, regulation of pests and diseases, action on the local climate), and are also recognized for their social value. With the same logic, both women and men recognized forest as the main land use regarding ES provision. By contrast, they consider it of less interest than agricultural land uses regarding household's income and livelihoods. Logging is not a well-remunerated activity, and the forestry law imposes strong restrictions to timber sale. Women and men farmers perceived that forests are important for soil, water and biodiversity preservation. They may provide fuel wood and timber for family needs, but these are also provided by trees in agroforestry systems and elsewhere in the farm. Indeed, fuel wood is more often collected in agroforestry systems, including sylvopastoral ones, as are fruits and medicines. Timber trees might be preserved when opening new agricultural lands over forests, for later use, and timber species spontaneous regrowth in agricultural lands might be protected by farmers.

Forests poorly contribute to the household's livelihood, trees within agroforestry systems provide the same ES than forests, and deforestation for agricultural land use conversion is a way to gain access to land. For these three reasons forests are converted into agricultural land uses until only remaining in locations of poor agricultural value. Because farmers value trees, these are preserved and even planted within agricultural lands, leading to a rich variety of agroforestry systems. As a result, agroforestry systems replace forests for their higher economic value to farmers.

Keywords: ecosystem services, family income, coffee agroforestry system, sylvo-pastoralism, home garden.

References:

1. Braslow J, et al. 2016. Ciat, Cali, Colombia.
2. Sheil D, et al. 2002. CIFOR. 93 p. ISBN:979-8764-88-9.
3. Le Roy E., Karsenty A. & Bertrand A., 1996. Karthala editions, 392pp
4. Jankowski F, and Sabourin E. 2012. Cirad.
5. Newing H. 2010. Routledge.

L12.1_O.06

Planting trees to increase food security? The case study of the groundnut basin of Senegal

Faye Mane N. F.[1] (ndeyefaye@gmail.com), Jahel C.[2], Bouquet E.[3], Leroux L.[4]

[1] *BAME, ISRA, Dakar, Senegal*; [2] *TETIS, CIRAD, Dakar, Sénégal*; [3] *MOISA, CIRAD, Montpellier, France*; [4] *AIDA, CIRAD, Dakar, Sénégal*

In Senegal, areas covered with scattered trees, intentionally selected and preserved by the populations, are dominant features of the landscapes. Numerous studies have highlighted the multifunctionality of these parklands, where people use trees as fodder for herds, as natural fertilizers for crops, and food, wood and pharmaceutical providers for households livelihoods (eg. Sène 2004; Baudron et al, 2017). A study conducted in Mali conclude that parklands were responsible for between 26 percent and 73 percent of household revenue (Faye et al. 2010). Regardless of this, the role of the parklands and the importance of their preservation remains little discussed in rural development policies and programs, and the potential of the tree in reducing food insecurity remains poorly explored. As human pressure on lands, increase of herds demography and climate change effects are currently threatening parklands (Bayala 2014), the need to better understand the contribution of trees in household's resilience takes on increasing importance.

How might trees affect livelihoods and food security of farming families? Based on a dense survey, our work aims at improving our understanding on the links between parklands and household food security.

Our study area is the groundnut basin in Senegal where we choose the arrondissements of Niakhar (Fatick region) and Nioro du Rip (Kaolack region), of approximatively 400 km² each. They differ in the parkland composition in terms of tree species and density, and in the social rules of access to the trees. In each of these areas, 200 households were surveyed over the 2018 cropping season. The questions focused on the description of the parkland to which they had access (collective or individual access), their uses of products from trees, their production system and their non-farm activities. For each household, two indicators of food security level, frequently used in the literature; were calculated as well: the Household Food Insecurity Access Scale (HFIAS) and the Coping Strategies Index (CSI).

Our preliminary results show that parklands have an impact on household food security, particularly in sustaining nutritional intake, and highlight the complementary roles through time of different tree species in coping strategies. We then estimated incomes from the sale of tree products to highlight the economic importance of trees. Our results also demonstrate the importance of collective areas for families whose state of food insecurity is the most critical.

By replacing the tree at the heart of the coping strategies of households in times of hunger, this study contributes to providing scientific knowledge that could then be used to advise policies and programs addressing food insecurity.

Keywords: food security, parklands, senegal, coping strategies.

References:

1. Sène A., 2004. Environnement et sociétés rurales en mutation : approches alternatives. 185-199
2. Baudron, F. et al., 2017. Ecology and Society 22(2):28.
3. Faye M. et al., 2011,Forests, Trees and Livelihoods, 20:2-3, 113-136.

L12.1_O.07

Different tree specie and management system economics as buffer zones in Baltic climate conditions

Makovskis K. (kristaps.makovskis@silava.lv), Lazdina D.

Forest regeneration and establishment, LSFRI Silava, Salaspis, Latvia

Buffer zones alongside watercourses on agriculture land sites can reduce potential nitrate pollution and leaching. Aim of the study was to compare different tree specie as buffer zones on agriculture lands and calculate economic return, when different management systems are used. In the study willow, hybrid aspen, poplar and grey alder tree species were used as buffer zones, different management systems were tested and economic calculations were done. Buffer zone establishment, planting, management and harvesting costs were calculated. Different willow and hybrid aspen clones, and different poplar planting materials (0.2m and 1.2.m cuttings) were included in economic calculations. Additional calculations were done, if perennial crops would be mixed with tree species in buffer zones. In calculations reed canary grass, festulolium and galega perennial crops were used in calculations. Highest buffer zone establishment and planting costs were for willows and lowest for poplar with 0.2m cuttings. Perennial crop planting in buffer zones together with tree species will give positive effect on buffer zone economics and revenues, if buffer zones are used in biomass production.

Keywords: buffer zones, agroforestry buffer zones, willow buffer zones, poplar buffer zones., SRC buffer zones.

L12.1_O.08

Making hedgerows pay their way: the economics of harvesting hedges for bioenergy

Smith J.[1] (jo.s@organicresearchcentre.com), Westaway S.[1], Mullender S.[2], Giannitsopoulos M.[3], Graves A.[3]

[1] *Agroforestry, Organic Research Centre, Newbury, United Kingdom*; [2] *Sustainability, Organic Research Centre, Newbury, United Kingdom*; [3] *Cranfield University, Cranfield, United Kingdom*

Across much of Europe, hedgerows are an important part of our joint cultural heritage, covering a total of 1.78 million hectares in the EU (den Herder et al. 2016). Innovative reinterpretation of traditional hedgerow management techniques for modern farming systems represents an opportunity for farmers to both diversify income streams and increase system sustainability. Recent trials in the UK have investigated the potential of using biomass from hedgerow management for local heat production as a way of supporting the rejuvenation of old hedges, restoring not only their economic role but their value to the wider landscape (Westaway et al. 2016). These trials assessed the feasibility of mechanising the process of coppicing hedges and processing the resultant material, and demonstrated that hedges can be managed to produce woodfuel of a quality that meets industry standards. However, to be attractive to farmers, the management of hedges for bioenergy must be profitable. This paper reports on a cost:benefit analysis of these UK trials using the FarmSAFE model (Graves et al. 2011) to test the hypothesis that harvesting hedgerows for woodfuel is financially profitable. Costs associated with standard hedgerow management by flailing every two years are compared with hedgerows managed on a 15 year coppice rotation, under different scenarios (scale of machinery, end use/market for the woodfuel, and the availability of grants).

Figure 1. Harvesting hazel hedgerow with tree shears, Elm Farm, Berkshire, UK 2014

Keywords: coppicing, woodfuel.

References:

1. den Herder et al. 2015, AGFORWARD D1.2 http://agforward.eu/index.php/en/current-extent-and-trends-of
2. Graves et al. 2011, Agroforestry Systems 81: 93-108 doi.org/10.1007/s10457-010-9363-2
3. Westaway et al. 2016, 12th European IFSA Symposium, Harper Adams University, UK,

L12.1_O.09

Dealing with financial constraints in a complex agroforestry system in the Brazilian rainforest

Padovan M. P.[1] (padovan@incaper.es.gov.br), Arco-Verde M.[2], Amaro G.[2], Nogueira F.[3], Ruas F.[4], Braz W.[1], Rodrigues A. C.[4]

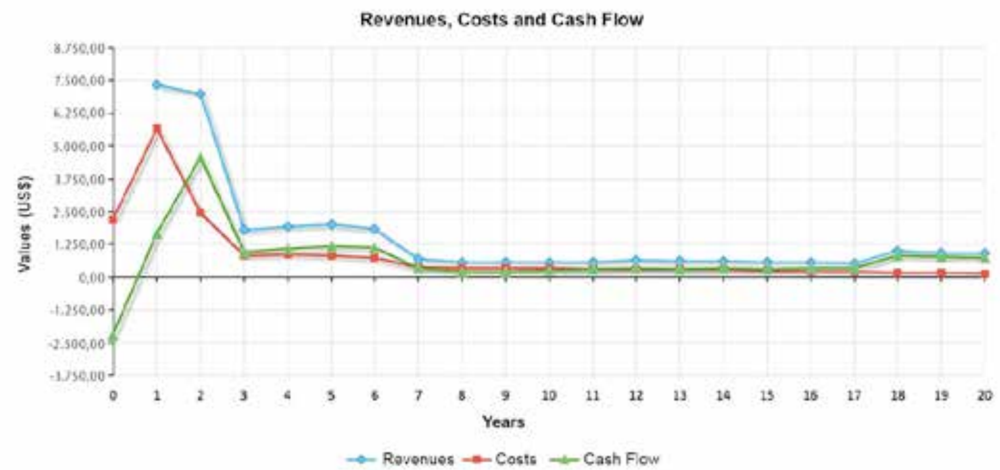
[1] *INCAPER, Vitoria, ES, Brazil*; [2] *EMBRAPA, Colombo, PR, Brazil*; [3] *FUNDAGRES, Vitória, ES, Brazil*; [4] *INCAPER, Vitória, ES, Brazil*

Ecological and socioeconomic advantages have been attributed to agroforestry (Montagnini 2005). Complex systems based on diversity of natural ecosystems are rising in importance since they provide more biodiversity and diversification of products per cultivated area. However, high costs of implementation have been one of the main constraints for widely adoption (Alavalapati *et al*. 2004; Franzel *et al.* 2005). This investigation aimed to test the financial viability of a complex and successional agroforestry system.

The study was carried out in April 2018, in harsh environmental conditions in the state of Espírito Santo, Brazil. The financial analysis was based on Arco-Verde & Amaro (2014) regarding economic and technical coefficients applied over 2 years and simulated for a 20-year period. Twenty-two plant species with different density, function and time in the system were used per hectare.

Most costs were concentrated in the first year. Overall, major costs were related to the labor. Costs and revenues per species over time were obtained. Cash flow was positive by the end of the first year when production of annual species occurred (Figure).

Annual, semi-perennial and perennial species combined in a successional system resulted in a positive environmental impact in a long-lasting production system. Annual species allowed minimizing costs of implementation. Simulations enabled adjustments in terms of species selection and management in order to reach sustainability.



Keywords: financial assessment, successional system, annual species, technical coefficients.

References:

1. Alavalapati et al. 2004. In: Valuing agroforestry systems. Methods and application. 1-8p.
2. Arco-Verde & Amaro. 2014. Documentos 274, Embrapa Florestas. 74p.
3. Franzel et al. 2005. In: Valuing agroforestry systems. Methods and application. 9-37p.
4. Montagnini,F. 2005. Journal of Sustainable Forestry. 51-67p.

L12.1_O.10

The Alliance Approach to Innovation in agroforestry: Agro-ecological innovations, Alliance and Agency

Parrot L. (laurent.parrot@cirad.fr)

CIRAD, Montpellier, France

Agro-ecological innovations aim at promoting sustainable agricultural practices that have long term benefits. However, farmers rarely adopt beneficial innovations in agro-ecology despite expressing an understanding of the benefits and a desire to do so. It has been argued that the farmers lack sufficient knowledge to implement complex innovations. We believe that in many cases such knowledge is necessary, but is ultimately insufficient for complex innovation adoption. We argue that there is a need to understand the economics of agro-forestry as a series of relational acts. All interventions, all innovations are relational acts between people. Effective economics is therefore an effective analysis of the relatonal acts occuring in an agro-forestry system: between the farmer and his or her farm, family, markets, and so on. The goal of such an approach is to select for exemple the pertinent and useful information. In order to assess the effectiveness of a relational act, we will present Alliance Approach to innovation. This approach is modeled after the therapeutic Alliance Approach at work in cognitive and behavioral sciences. We argue that using the Alliance Approach will not only prove effective in helping farmers adopt complex agro-ecological innovations, but also a better fit for the human centered development of capability approach human development, as it is likely to enhance both the well-being and agency of the farmers.

L12.2_O.01

Forest gardens increase the financial viability of farming enterprises

Melvani K. (Kamal.Melvani@cdu.edu.au), Myers B., Crase B.

RIEL, Charles Darwin University, Darwin, NT, Australia

Forest gardens (FGs) are tree-dominant land uses in small, family farming enterprises in Sri Lanka (McConnell et al., 1997). Although the financial performance of FGs has been described, how they compare with other components in farming enterprises and their current and future contributions to farming enterprises as a whole are poorly understood. This information is critical given the global quest for financially viable farming models that increase livelihood security (Pretty et al., 2014) in the face of climate variability (Marambe et al., 2015) and shrinking natural resources (Food and Agriculture Organisation, 2018). We investigated and compared FG financial performance with other components of farming enterprises in short (reference year, 2012-2013) and long-terms (beyond 2013). Farming enterprises include On farm (land uses: FGs, paddy, cash crops, plantations, swidden plots and livestock), Off farm (employment, trading, grants) and household components. Data were collected for 85 farming enterprises in nine locations of the Intermediate zone in Sri Lanka. Floristic, timber and fuelwood inventories were undertaken and area mapped for all land uses. Financial data were collected using household income and expenditure surveys and quantified using accounting procedures. Forest gardens occupied the largest area and had the highest floristic diversity of all land uses. Tree crops were more productive than seasonal crops despite multiple stressors including rainfall variability, animal and insect pests, and labour scarcity. In the short-term, FGs contributed 29% to household food self-sufficiency, generated the highest profit and profitability, and were the most financially efficient land use in the On farm component. Average FG profit (Current assets) was greater than enterprise profit. In the long-term, FGs had the highest number of timber and fuelwood species (Biological assets) with the highest Net Realisable Value (NRV). Forest gardens contributed 90% of total NRV (all land uses) and were repositories for Biological assets in enterprises. Forest gardens occupied 68% of the study area. This land value and FG Biological assets collectively amounted to significant Noncurrent assets in farming enterprises. Current and Noncurrent FG assets contributed 79% to farmers' equities and were their core ownership interest in enterprises. Forest gardens increase the financial viability of Sri Lankan farming enterprises. They offer immense potential to farmers in other tropical countries challenged by declining agricultural livelihoods and similar stressors, and thus warrant consideration in global agricultural planning.

Keywords: Forest gardens, Farming enterprises, Sri Lanka, Financial viability.

References:

1. Food and Agriculture Organisation. (2018).http://www.fao.org/3/I9535EN/i9535en.pdf
2. Marambe, B., et al. (2015). In W. L. Filho (Ed.), Handbook of Climate Change Adaptation
3. McConnell, D. J., et al. (1997). Farm management for Asia: a systems approach, FAO
4. Pretty, J., et al. (2014). Annals of Botany, 114(8), 1571-1596. doi: 10.1093/aob/mcu205

L12.2_O.02

Traditional agroforestry as a sustainable customary land use system in the protected and conserved areas of Iran

Esteghamat M. (minaesteqamat@gmail.com), Aghakhani S.

PAs and Natural Resource Management, ZIPAK NGO, Tehran, Iran

There is increasing recognition that the territories and areas managed by local communities and indigenous people contain significant levels of biodiversity, and that the knowledge and practices of these people have contributed to conservation of ecosystem, species, and genetic diversity. Indeed, a combination of sustainable and biodiversity-friendly use of natural resources, adaptation to climate change and landscape conservation aims characterises many of customary management systems. Besides their contributions to the conservation of biodiversity, these practices secure the needs of millions of people for water, food, energy, medicine, shelter, fodder, income, recreation and spiritual sustenance. Therefore, understanding development of traditional production and conservation practices will provide valuable information to design ecologically sustainable land use systems such as Agroforestry.
In this context, an exploratory study through PAR[1] has been conducted in some determined Protected and Conserved Areas of Iran with the help and supervision of DoE[2] and FRWO[3] to explore the traditional agroforestry systems practiced by the local community and indigenous people. At the next step, conservation impacts, livelihood and cultural significance as well as the threats of those practices have been evaluated in a participatory way with all the key stakeholders. An inventory was also made on the customary conservation approaches of the selected Protected and Conserved Areas elaborated especially by the community elders. The study showed that several traditional agroforestry systems, based on community needs and site-specific characteristics, have developed over thousands of years in Protected and Conserved Areas. Among all cases, home-gardens; NTFPs; traditional river and coastal fisheries; multipurpose trees; pasture restoration; native and compatible trees in pastures and other silvopastoral systems within the tribal territories have the most compatibility with the need of communities and the climatic condition of the target sites. Considering the governance conflicts in the protected and conserved areas in Iran, recognition of customary land use systems would be a big step towards participatory management of protected and conserved areas. Finally, the outcomes of this study used for recommendation of some effective sustainable agroforestry systems modelled after the adopted traditional agroforestry practices in studied protected and conserved areas, with easy acceptance by communities. Accordingly, a guideline has been developed for recognition of traditional conservation and production practices inside the protected and conserved areas at the national level.
[1] Participatory Action Research
[2] Department of Environment
[3] Forest, Rangeland and Watershed Organization

Keywords: Customary Land use Systems, Traditional Agroforestry Practices, Protected and Conserved Areas, Bio-cultural diversity Conservation.

References:

1. Esteghamat M, 2010, Traditional Agroforestry Systems as a Feature of Sustainable Development in Ir
2. IUCN, 2013, Governance of Protected Areas, Guideline Series No.20
3. DoE, 2006, Atlas of Protected Areas of Iran
4. Goshtasb H, et al, 2017, Principles and Management of Biosphere Reserves, Iran

L12.2_O.03

Agroforestry as a source of enhancement of livelihood options in rural areas of Jharkhand state of India

Kumar S. (sanjeevkumar201@gmail.com)

Regional Chief Conservator of Forests, Department of Forests, Environment & CC, Hazaribagh, Jharkhand, India

Jharkhand, an eastern state of India is richly endowed with natural resources, which are vital for development and prosperity. A study to evaluate the benefits of agroforestry tree-products especially Non Timber Forest Products (NTFPs) was conducted in Thirty five villages of East Singhbhum(Jamshedpur), West Singhbhum(Chaibasa), Saraikela-Kharsawan, Ranchi, Gumla, Simdega, Dhanbad, Hazaribagh, Giridih and Chatra districts of Jharkhand . It was found that NTFPs play an important role in rural livelihood in the shape of medicine, food, fruits, fibre, firewood, oil, lac, silk etc. Of these NTFPs, Lac, Silk, Mahua (*Madhuca latifolia* L.), Bamboo occupy an important place in rural economy. Jharkhand has abundance of Lac and Silk host trees. Lac, which is a natural resin secreted by an insect, *Kerria lacca* (Kerr.), cultivated on host trees like Palas [*Butea monosperma* (Lam.) Taub], Kusum [*Schleichera oleosa* (Lour.) Oken] and Ber [*Zizyphus mauritiana* Lam.]. In Jharkhand mostly Tassar Silk is reared which is an important vanya variety produced by a wild silkworm of *Antheraea mylitta* Drury. *Antheraea mylitta* Drury feeds primarily on Asan [*Terminalia tomentosa* (DC) Wt. &Arn], Arjun [*Terminalia Arjuna* (Roxb.exDC.)Wt. &Arn.] and Sal [*Shorea robusta* (Gaertn.f.)] and secondarily on *Lagerstroemia parviflora* Roxb*., Zizyphus mauritiana* Lamk*.* Their production and applicability have been growing in different sectors. Lac is much in demand in the sector of printing ink, furniture polishing, handicrafts, cosmetics, dyeing sector and pharmaceuticals sector. Similarly Silk is much in demand in textile sector which involves many subsidiary operations. Hence livelihood options based on lac and silk cultivation and their subsidiary operation have occupied a sizeable space in rural economy. Similarly products from *Madhuca latifolia, Buchnania lanzan*, Bamboo Sps. have also influences on the economy of rural people. The paper critically examines various facets of these NTFPs and their contribution in improving earnings of rural people.

Keywords: Agroforestry, Jharkhand, Livelihood, NTFP, Rural.

L12.2_O.04

Honduran farmers' perception of cacao agroforestry systems

Van Isterdael J.[1] (codesa@yahoo.es), Diaz J.[2]

[1] *CODESA, Santa Rosa de Copan, Copan, Honduras*; [2] *Colonia Sula, La Lima, Honduras*

With Canadian aid and the assitance of the Honduran Agriculture Research Foundation's (FHIA), small farmers planted in this decade 4,000 hectares of cacao agroforestry systems, an initiative for sustainable economic development. ¿What is the farmers perception of these cacao agroforestry systems on income, food security and adaptation to climate warming? is a question the Andalusian cooperation agency through the ETEA Foundation set to answer with a 2016 survey of 131 farmers', 29.8% women. Focal-group workshops in 12 communities worked on: • Drawing a cacao plantation, • Explaining the components and discussing: a. strengths of the systems (satisfaction), b. difficulties, limitations and challenges (dissatisfaction) and c. changes experienced and, • made a climate time line. The facilitator directed the conversations with open questions, avoiding suggestion of expected answers. The young cacao farms have yield of about 200 kg/ha/year and some older farms have yield of 1,200 kg/ha/year. No group spontaneously mentioned income increase but agreed they are in the investment phase. Five years to mature is a big hurdle and for some, income generation distracts from optimum management. It is not easy for the very poor to participate effectively. All mentioned there is always something to harvest for self-consumption with these systems, including fire wood from temporary shade. These systems help to improve diet and nutrition. Few mention the income opportunities by transforming cacao, agritourism and sale of budwood. They are aware of the challenges of increasing organizations membership to be able to ferment and sell at a better price, but recognize volumes are small. All focal groups believe climate is less predictable, warmer, with longer dry spells and less but torrential rains. The negative impact of Hurricane Mitch and El Niño drought (2014-2015) are remembered by all. The later killed some young cacao trees but not mature plantations. All corn and beans plots were lost. They foresee no threats to sustainability of plantations, they feel well trained and will protect investment done thus far. Groups recognized the systems as a radical departure from traditional agriculture development initiatives. They are diverse, flexible and adapt to family preferences, plot conditions and allow inclusion of women and men. They recognize improvements: higher soil fertility, water retention and less soil erosion. Few groups mentioned the benefits of no-burn, biodiversity protection and landscape enhancement. Families recognize added wealth-heritage with permanent shade of high value certified tropical wood trees. We recognize the need for a follow-up study as cacao matures and to broaden the survey. Findings clearly show Honduran small farmers with new cacao agroforestry systems have a positive perception of the economic and environmental benefits. This development initiative is a winning strategy and should be applied to other developing tropical regions.

L12.2_O.05

Cultivation of willows for economic and ecological purpose: A sustainable livelihood option in Kashmir

Masoodi T. H. (deanforestry@skuastkashmir.ac.in), Sofi P., Bhat G. M., Mughloo J. A., Rashid M.

Forestry, Skuast- Kashmir, Ganderbal, Jammu and Kashmir, India

Willow is one of the most widely grown species and comprises about 13% of the total broad leaf plantations established on government and privately owned lands of Kashmir Valley. The results of our study vis-à-vis viability measures indicated that cultivation of willows in Kashmir has a great economic feasibility with respective NPV of $ 3964 and $4802 and BCR of 1.55 and 1.57 when the plantations are managed and used for making cricket bats and basketry under a production period of 20 and 7 years respectively. The economic feasibility of willows for biomass production in short rotation coppiece forestry managed under a planting design that accommodated 17600 plants ha-1 revealed that the first rotation of this crop harvested after 4 years of plantation yielded 15 tons (fresh weight basis) of biomass ha-1 yr-^{1} which increased to 23 tons ha-1 yr-^{1} after 2nd rotation cycle of 3 years. Thus at the prevailing local rate of Rs. 7.0 /kg for fuel wood a grower is expected to generate an income of Rs 1.00 to 1.60 lakhs from one hectare of SRC willows on lands generally unsuitable for agricultural crops. The analysis of data reveals that the gross and net income realized from this plantation after two rotation cycles amounts to Rs 8,76,750 and 49,625 ha-1 with B: C ratio of Rs 1.73 for every rupee invested at an interest rate of 12%.

The results further revealed that willows can store up to 292.98 t C ha-1 and Sequester around 1075.24 CO2e t ha-1. The analysis of economic feasibility of carbon trading with willows indicates that Net Present Value of future returns derived by discounting both costs and benefits at 12 % rate of interest is Rs 7,49,406 with a benefit cost ratio of 2.93 for a productive rotation of 20 years. The profitability using profit function model indicated that carbon trading with willows is a viable option with net profit of Rs 29,926 and 30,654 ha-1 yr-^{1} at a discounting factor of 12% and 10 % respectively. Thus enhancing carbon sequestration through commercial plantations of willow can prove to be a long term future policy option for sustained carbon sequestration programme in Jammu and Kashmir where willows alone comprise a total population of > 37 million trees.

Keywords: willow, cricket bat, basketry, SRC, carbon sequestration.

References:

1. Anonymous (2007) Report on diagnostic study on cricket bat cluster Anantnag (J & K). Minist
2. Masoodi TH, Masoodi NA, Islam MA, ZafferSN, Chauhan SK. (2008) Basketry from introduced willows of K
3. Puttoo BL (2010) Introduction of commercially important willow species during early 20th century- A
4. Gittinger JP (1976) Economic Analysis of Agricultural Projects, Agricultural Refinance and Developme
5. Puttaswamaiah K. (Ed.) (1989) Project evaluation criteria and cost benefit analysis. Oxford and IBH

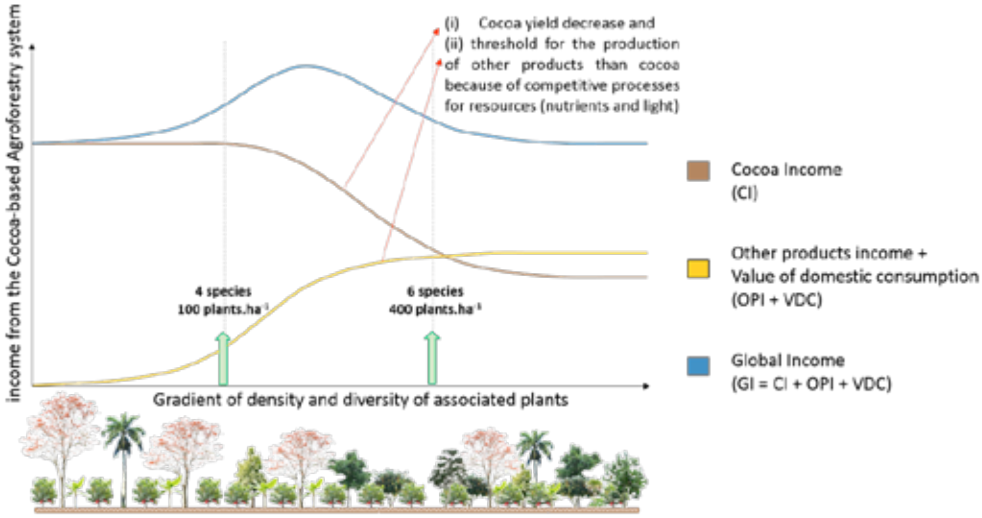
L12.2_O.06

Contribution of plant diversity to farmers' income in cocoa-based agroforestry systems

Notaro M.[1] (martin.notaro@cirad.fr), Gary C.[2], Deheuvels O.[3]

[1] *CIRAD, Villa Altagracia, Dominican Republic*; [2] *INRA, Montpellier, France*; [3] *CIRAD, Lima, Peru*

The diversity of associated crops within cocoa-based agroforestry systems (CAFS) generates different productions that can be either sold or self-consumed. This wide range of plant species and densities directly influence the amounts of products to be sold and/or self-consumed by the producers and their families. Consequently, the impacts on the overall economic performances of these CAFS can be important but have been poorly assessed. We characterized 140 CAFS distributed over 3 production areas in the Dominican Republic in order to (i) build a typology of Dominican CAFS according to their cultivated plant structure, and (ii) compare the agro-economic performances of each type of CAFS. We found that the sum of the different sales, including cocoa, do not differ significantly among the 3 types of CAFS that we characterized. However, a high degree of diversification combined with a significant densification of associated fruit species weakens the economic performance of cocoa sales, but increases fruit sales and the level of self-consumption of the farming household. On the other hand, a low diversification of plants associated with nitrogen-fixing trees increases the economic performance linked to the sales of cocoa but reduces fruit sales and self-consumption. This study evidences different farmer's strategies. It also provides elements for the improvement of agricultural practices towards different economic options between sold and self-consumed products provided by CAFS.



Evolution of incomes according to a gradient of density and diversity of plants associated with cocoa trees in AFS: CI for cocoa income, OPI for other products income, VDC for value of domestic consumption and GI for global income.

Keywords: Cocoa-based Agroforestry system, Diversity of associated plants, Density of associated plants, Economic performances.

L12.2_O.07

Role of Innovation System in Coffee Agroforestry System to Adapt to Climate Change in Kenyan Coffee and Dairy Sectors

Asayehegn K.[1] (kinfe85@gmail.com), Temple L.[2], Iglesias A.[3]

[1] *Dr., Hawassa, SNNPR, Ethiopia*; [2] *UMR Innovation, CIRAD, Montpellier, France*; [3] *UPM Madrid, Madrid, Spain*

Climate change is one of the most widespread anthropogenic challenges affecting agriculture and agricultural production in the coffee agroforestry system, where its impacts on economic growth in general are still issues in debate. An adjustment to the actual or expected changes in the agricultural sector using different innovative adaptation strategies has to be among priorities in policy decisions. Research on sectoral systems of innovation in coffee agroforestry systems, however, has paid little attention to adaptation to climate change, notably in agricultural trade and agri-business. This paper, therefore, explores the role of systems of innovation in coffee agroforestry system in adapting to climate change, which have methodological, conceptual and policy implications. It focuses on two case studies in the Kenyan coffee based agroforestry system, i.e. the coffee and dairy sectors, which differ in terms of stakeholders and institutional setups. In the coffee sector, the actors' system is highly centralized and the system of innovation is oriented towards technology development. In contrast, the dairy sector consists of a diversity of actors, and its system of innovation is based on institutional building and marketing. The capacity to innovate and adapt in the coffee agroforestry system, therefore, depends on institutional arrangements in addition to technology development, suggesting that the dairy sector in Kenya could be an example for the coffee sector.

Keywords: Agroforestry, Climate Change, Coffee and Dairy, Sectoral System of Innovation, Central Kenya.

L12.2_O.08

The Contribution of Agroforestry to Food Security in Nepal Mid-hills

Cedamon E. (edwin.cedamon@adelaide.edu.au), Nuberg I.

School of Agriculture, Food and Wine, University of Adelaide, Adelaide, South Australia, Australia

Farmers in Nepal have practiced some form of agroforestry for centuries, however the contributions of trees and agroforestry to food security is poorly understood. Using a bio-economic model, **EnLiFT**, the food security index across 6 household types of rural Nepal were estimated for selected agroforestry interventions. Market-oriented timber production shows strong potential to increase food security across all household types with greater benefits accruing to land-rich households (Figure 1). For land-poor households, remittances from household members working abroad remains the strongest route to their food security despite the underutilisation of agricultural land due to adult male labour outmigration. A drawback of market-oriented timber production is the long-term nature of timber production. As EnLiFT assumes that timber can only be harvested from year 9, complimentary livelihood strategies are required to address food insecurity in the short term. Complimentary agroforestry interventions with strongest potential to improve food security include combined high-yielding fodder production and commercial goat production, and production of non-timber forest products. While land-poor households are heavy reliant on foreign remittances for food security, it is argued that policies encouraging use of remittances to promote agroforestry businesses is needed.

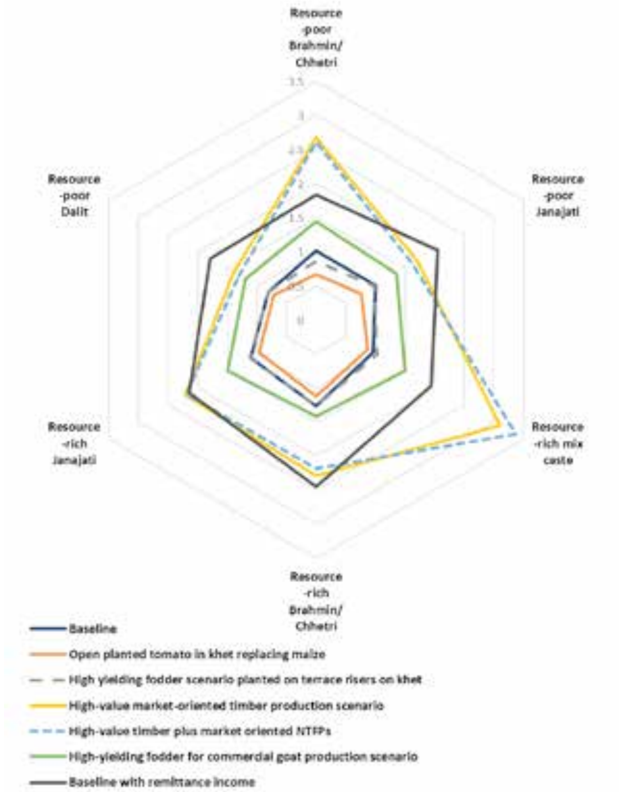


Figure 1. Radar chart of food security indices of household types for seven livelihood scenarios

Keywords: food security index, farm-forest systems, trees on farms, household typology, ENLiFT model.

References:

1. Cedamon et al. (2017) Australian Forestry, DOI: 10.1080/00049158.2017.1339237
2. Cedamon et al. (2016), In J. Meadows, S Harrison and J. Herbohn (eds), Conf. Proc. pg 23-42
3. Pandit et al (2014) Journal of Forest and Livelihood 12: 47-63.

L12.2_O.09

Social innovation for multifunctional cultivated forests in Guadeloupe: Insights from the VALAB and SIMRA projects

Barlagne C.[1] (carla.barlagne@hutton.ac.uk), Nijnik M.[1], Miller D.[2], Diman J.-L.[3], Larade A.[4], Latchman C.[5], Tormin P.[6], Vinglassalon A.[7]

[1] *Social Economic & Geographical Sciences, The James Hutton Institute, Aberdeen, Scotland, United Kingdom*; [2] *Information & Computational Sciences, The James Hutton Institute, Aberdeen, Scotland, United Kingdom*; [3] *UE PEYI, INRA, Petit-Bourg, Guadeloupe, France*; [4] *Parc National de la Guadeloupe, Saint-Claude, Guadeloupe, France*; [5] *GDA EcoBio, Baie-Mahault, Guadeloupe, France*; [6] *EPLEFPA, Baie-Mahault, Guadeloupe, France*; [7] *SYAPROVAG, Petit-Bourg, Guadeloupe, France*

Forests are key components of rural landscapes. While sustainable forestry and agriculture have been identified as vectors of development of rural communities by the United Nations, local communities have a central role to play in the management of related resources (SDGs, 2015). The VALAB project - Integrated Ecosystemic value-enhancement of the Guadeloupean Forest Agrobiodiversity - is a transdisciplinary project that aims to generate innovative modes of value-enhancement of the Guadeloupean Forest. It is coordinated by the Agricultural Union of Vanilla Producers of Guadeloupe (Syaprovag) and is supported by a European Innovation Partnership. The SIMRA project is a Horizon 2020 research and innovation project that aims to understand and to unlock the potential of Social Innovation in Marginalised Rural Areas. Social innovation refers to the reconfiguration of social practices and new institutions such as networks, partnerships, collaborations and governance arrangements - in response to societal challenges and opportunities (Polman et al. 2017; MacCallum et al., 2009). VALAB is studied and supported by SIMRA as a case study and an innovation action. In this research, our hypothesis is that to bring about change, social innovation has to be transformative. We build upon the theoretical framework of transformative social innovation (Avelino et al.; 2017) to analyse and understand i) how problems and opportunities related to linkages between nature and society are tackled within the setting of an operational group and ii) how innovative solutions that meet the end-users needs (including on the economics of agroforestry) are developed. We conducted an in-depth case study of the VALAB social innovation based on a mixed-research methods approach. Our preliminary results reveal that operational groups can be conceptualised as real social innovation laboratories because of both the processes they enable and the knowledge they produce. In particular: i) they lead to new ways of framing sustainability issues in relation to the forest; ii) knowledge is co-produced and shared among participants and new methodologies of work are co-created and implemented; iii) they lead to new governance arrangements; iv) as a result, future actions and projects will be implemented aiming to design viable agricultural farming systems while guaranteeing the protection and preservation of the forest ecosystem. The research contributes to the development of a better understanding of: (i) human-environmental interactions in social-ecological systems; (ii) the perception of pathways to change by relevant stakeholders to suggest on an agroforestry wedding band between society and the natural world; (iii) diverse development trajectories of SES, with identification of management options, policies or institutional arrangements as responses (e.g. social innovations) to assist in overcoming the challenges and achieving sustainability in the Guadeloupean Forest at a local scale.

Keywords: Social Innovation, multifunctional forests, sustainability transition, Horizon 2020, European Innovation Partnership.

References:

1. Avelino, F. et al., 2017. Ecol. Society 22(4), 41. https://doi.org/10.5751/ES-09897-220441
2. MacCallum et al. (2009). Social innovation and territorial development. Ashgate Publishing, Lt pp.76
3. Polman, N. et al. , 2017. Deliverable 2.1, Social Innovation in Marginalised Rural Areas (SIMRA). pp

L12.2_O.10

Fostering knowledge sharing about agroforestry systems through gaming and simulation in Irituia (Northeast Para, Brasil)

Le Page C.[1] (le_page@cirad.fr), Perrier E.[1], Coudel E.[2], Navegantes L.[3], Galvão L.[3], Garcia V.[3], Nunes A. A.[4], Resque G.[5]

[1] *CIRAD, Montpellier, France*; [2] *CIRAD, Brasilia, Brazil*; [3] *UFPA, Belem, Brazil*; [4] *Escola Itabocal, Irituia, Brazil*; [5] *UFRA, Paragominas, Brazil*

In the Eastern Amazon, many small-scale farmers have been spontaneously initiating experiences in forest restoration, mainly through agroforestry systems. To guide more inclusive restoration policies, it is important to assess the socio-economic viability and ecological benefits of the different systems. Following a companion modelling approach, simulation and gaming tools were developed to enable exploring how and why smallholders would engage in farming systems oriented toward agroforestry systems. A stylized model of 4 similar 25-ha family farms was first designed by researchers. This virtual landscape represents a game board. During gaming sessions, participants are requested to select the activities they would like to perform, to locate them in the game board and to indicate the practices related to these activities. These human-made decisions are inputted into a computer simulation model that allows simulating the growth of the plants and calculating a set of indicators to assess the balance between environmental and socioeconomic benefits. This tool has been co-designed with a small group of farmers from the Municipe of Irituia (North-eastern Para, Brazil) who were selected because of the experience in agroforestry systems. The game was then tested by students from Itabocal, a rural school of Irituia Municipe. We present how it enabled fostering knowledge sharing among students, farmers and researchers.

A gaming session in Irituia

Keywords: Gaming, Agent-based simulation, social learning, Brasil.

L12.P.02

Livelihood strategies, and baobab (*Adansonia digitata* L.) fruit use of rural household in Kordofan region, Sudan

Adam I.[1] (somaasomaa40@yahoo.com), Yahia A.[1], Dagmar M.[2]

[1] *Faculty of Forestry, Forest Management, University of Khartoum, Khartoum, Khartoum North, Sudan*;
[2] *Faculty of Life Sciences, Rhein-Waal University of Applied Science, Kleve, Germany*

Baobab (*Adansonia digitata* L.) fruits are integral component of the daily diet and a source of cash income for rural households selling the fruits to urban consumers. The aim of the present study is twofold: (1) assess the contribution of baobab fruits to annual income and poverty alleviation, and, (2) analyse factors that are associated with the commercialization of baobab fruits. Analysis bases on the sustainable livelihoods framework and primary data collected in 2017 from a random sample of 179 rural households from 16 villages in North and West Kordofan states, Sudan. The survey was complemented by key informant interviews and direct observations. Headcount Index and multiple regression were used. Cluster analysis identify three livelihood strategies at each site. Results show that net income from baobab fruits sale contributed up to 11% and 5% of household annual total income in North and West Kordofan, respectively. Without baobab income the poverty headcount index was estimated to be 16.5% instead of 23.2% in North Kordofan, and 20.3% instead of 16.5% in West Kordofan. Results from the clustering indicated that 46% of the households belonged into livestock, agriculture, and baobab mixed strategies in West Kordofan. while The majority 59% of the household belong to Baobab strategy in North Kordofan. this results suggest that poor households turn to baobab fruit and non-farm activities to complement inadequate income. Commercialization of baobab was significantly and positively associated with household size, land size, product price, and transport costs. While the education level of the household head was significantly and negatively associated with commercialization of baobab fruit. The study concluded that baobab fruit commercialization in Kordofan region play a potential poverty alleviation role as a source of income, a safety net, and a means of helping producers left of poverty.

Keywords: Livelihood strategies, Poverty alleviation, Cluster analysis, Sudan.

L12.P.03

Profitability of different cocoa agroforestry systems in the forest-savannah transition zone of Central Cote d'Ivoire

Adou Yao C. Y.[1] (adouyaocy@gmail.com), Kouadio V.-P. G.[2], Diby N'G. L.[3]

[1] *Equipe BioValSE / UFR Biosciences, Université Félix Houphouët-Boigny / CSRS, Abidjan, Côte d'Ivoire*; [2] *Equipe BioValSE / UFR Biosciences, Université Félix Houphouët-Boigny, Abidjan, Côte d'Ivoire*; [3] *World Agroforestry Centre (ICRAF), Abidjan, Côte d'Ivoire*

Cacao (*Theobroma cacao* L.) is known as a shade tolerant tree growing well in the understory of tropical ecosystems. However, to maximize yields (Malézieux et al., 2009: Agron. Sustain. Dev. 29 (1): 43–62), shade trees have gradually been eliminated from many cocoa farms, thus transforming the cocoa landscapes into a full-sun monocropping systems. Such systems are common in West Africa and particularly in Cote d'Ivoire, a country which accounts for 40% of the global production. Nonetheless, few traditional shaded cocoa cropping systems known as 'complex Agroforestry Systems (SAFc)' are still existing mainly in the forest-savanna transition zone in the central part of the country (Kpangui et al*.*, 2015*:* IJAAR 6(3): 36–47). Little is known on the sustainability of these SAFc particularly in terms of profitability. This work aims at analyzing the productivity and the financial profitability of selected SAFc in Central Cote d'Ivoire. We visited cocoa farms to characterize the cropping system and conducted socio-economic surveys with farmers to collect data on the land acquisition costs, farms age, farms maintenance costs, yield of cocoa and associated fruit tree species between 3 cropping seasons (2015 – 2018). We identified three SAFc differing by their level of complexity in term of shade tree density and associated species, namely simple SAFc, mixed SAFc and complex SAFc. The average cocoa yield and the income generated from cocoa over the three years was positively correlated with the complexity of the SAFc. On the contrary, the income generated from the associated fruit species was negatively correlated with the complexity of the SAFc. Overall, the incomes generated from the complex, mixed and simple SAFc were 171,288 ± 67,502, 181,041 ± 47,453 and 166,937 ± 37,760 F CFA/ha respectively, suggesting that mixed SAFc can be recommended as the best profitable cocoa agroforestry option in the study area. However, a trade-off between the financial profitability and the other benefits of agroforestry i.e. ecosystems services, social benefits…need to be considered.

Keywords: Financial profitability, cocoa agroforestry systems, operating account, forest-savannah transition zone, Cote d'Ivoire.

References:

1. Malézieux E, Crozat Y, Dupraz C et al. 2009 Agron. Sustain. Dev. 29 (1): 43–62
2. Kpangui KB, Kouamé D, Gone Bi ZB, Vroh BTA, Koffi BJC, Adou Yao CY. 2015. IJAAR 6 (3): 36-47

L12.P.04

Is agricultural profitability affected by forestry? The case of Hungarian farms

Bareith T. (bareith.tibor@ke.hu), Sipiczki Z., Parádi-Dolgos A., Kövér G., Varga J.

Department of Economics and Finance, Kaposvár University, Kaposvár, Hungary

Agroforestry and agricultural diversification impacts on farmer incomes and long-term economic benefits are still less explored. The essence of our article is that, when examining the profitability of Hungarian agricultural sector, it is worth focus on specific factors determining the profitability like agroforestry and diversification. On the other hand, we used hierarchical clustering with other main variables (agricultural subsidies, plant size, leverage) of agriculture profitability to find out which kind of the agricultural companies belongs to the profitable category. The clustering process was performed using the Ward method. The study analyzes agricultural enterprises based on the farm database of the Hungarian Farming Information System operated by the Agricultural Research Institute. The analysis was performed statistically closed 2013-2015 data. Based on our resarch, the farmers should invest in agroforestry and agricultural diversification because it is a perspective to secure the income generation and to improve resilience.

Keywords: agricultural profitability, forestry potential, agricultural economics.

L12.P.05

Agroforestry as an economic, social and environmental alternative after 50 years of war in Colombia

Benavides J. (infoecosaf@gmail.com)

Bogota, ECOSAF LTDA, Bogota D.C., Distrito Capital, Colombia

Colombia is occupying the second place among the countries with the greatest biodiversity in the world, unfortunately by more of 50 years we had to live the scourge of armed conflict that left thousands of victims and deforested areas caused by the establishment of illicit crops. This project originated in 2006 in the region of Meta, We seeking that the displaced families have a source of decent income, through of agroforestry with non-timber forest products, Amazonian fruits, condiments, spices, colorings and essences. We were based on research from the Institute of Amazonian Studies SINCHI, this in order to establish the nurseries, have the seedlings and to be able to cultivate in an optimal way according to the ecological and topographic conditions and then transform it for to give an added value . As a result we have a Network of 144 families producers and agroforestry units developed, where they are guaranteed better living conditions, food security and decent income. Currently and with the signing of the peace process (Nobel Peace Prize 2016), this agroforestry model and experience is the bet for try to reintegrate more than 6,000 former guerrillas to civil and productive life, , with a potential of more 400,000 ha to recover , the commitment to a new country in peace with opportunities for all where agroforestry combined with the biodiversity of the country is the key to these regions that for so many years lived with fear and state abandonment.

Training, establishment and use of Amazonian fruits within agroforestry systems

Keywords: amazonian fruits, non-timber forest products, armed conflict, illicit crop substitution, agroforestry alternatives.

L12.P.06

Agroforestry systems with cocoa and banana plantation in rubber tree areas to increase income, São Paulo State, Brazil

Borges A. V.[1] (andrey.vetorelli@cati.sp.gov.br), Stucchi Neto F.[1], Miqueletti F.[1], Abdo M. T. V. N.[2], Martins A. L. M.[2], Fabri E. G.[3]

[1] *CATI, SAA, São José do Rio Preto, SP, Brazil*; [2] *APTA, SAA, Pindorama, SP, Brazil*; [3] *IAC, APTA SAA, Campinas, SP, Brazil*

Cacao (*Theobroma cacao* L.) a plant from Central America that was cultivated long before the arrival of the European settlers. Cacao has great importance in the national agricultural scenario since Brazil is the fifth largest producer in the world and 90% of this production is directed to foreign market. After the decline of the crop in the 1980s with the witch-broom problem, there was a restructuring of the production chain leading to a resumption of production in recent years, which resulted in a considerable increase in Brazilian production from 170 thousand tons in 2003 to 279 thousand tons in 2014. This culture has gained attention in the northwest part of São Paulo state where has been increasing planted area in consortium with the culture of the rubber tree (*Hevea brasiliensis*) and banana in agroforestry systems. The dissatisfaction with the price of latex and the possibility of an extra income in the same area of cultivation of rubber tree stimulated large-scale planting in old and new rubber tree plantations. The state of São Paulo produced 56% of the national rubber in 110 thousand hectares and produced 98 thousand tons of dry rubber in 2017. An agreement between CATI (Coordination of Integral Technical Assistance) and CEPLAC (Executive Committee of the Cocoa culture planning) has already directed plantations in the region of São José do Rio Preto. At the same time, some farmers have planted the crop in full sun, as they understand that this is a great opportunity for expansion in the region, which has attracted the interest of industries that process and commercialize cocoa and its products. The experimental areas with cocoa clones from CEPLAC, were planted in rubber plantations, with different spacing (2.5m x 8m and 14m x 3m) located in the northwest region of São Paulo State and also planted in full sun in a consortium with banana and windbreaker of rubber in two spacing. The cost of rubber tree plantation (476 plants / ha) is US$ 5.250 and it takes from 7 to 8 years for exploration and the cost of the irrigated agroforestry system with rubber tree, cacao and banana (397 rubber plants in the first year, 855 second year banana plants and 855 cocoa plants in the third year) is approximately US$ 7,950. At the current juncture the planting of rubber trees monoculture, inspite taking 7 to 8 years to be explored, could make the project unfeasible and would yield approximately 1.6 tons of latex or US$ 340/ ha/year. The agroforestry system model with the three crops would generate US$ 1860/ ha/year and begin to generate income already in the third year.In the regional scenario and within the demand of the cocoa production chain it is understood that this work is the beginning of a long work and, that does not exhaust all the possibilities and questions that the culture will require in the near future, since its large-scale commercial planting is recent in this region and tends to expand rapidly, requiring further studies and further study.

Keywords: Chocolat, Theobroma cacao L., Hevea brasiliensis.

References:

1. BORGES, A.V. et al.2018. CATI, EDR São José do Rio Preto. Boletim técnico n.1,2018
2. http://www.esalq.usp.br/cprural/noticias/mostra/3342/novo-cenario-da-producao-de-cacau-no-brasil.htm
3. https://www.agrolink.com.br/noticias/brasil-e-o-5--maior-produtor-de-cacau-com-90--de-exportacao_217
4. OLIVEIRA,M.D.M.; CARVALHO,Y.M.K. 2017. Análises e Indicadores do Agronegócio v. 12, n. 12
5. SILVA,A.F. et al. Revista de Economia e Agricultura, Vol. 15,n. 3, 2017

L12.P.07

Improving the financial rationale of agroforestry for farmers

Burgess P.[1] (P.Burgess@cranfield.ac.uk), Graves A.[1], García de Jalón S.[2], Palma J.[3]

[1] *Cranfield University, Cranfield, Bedfordshire, United Kingdom*; [2] *Basque Centre for Climate Change, 48940, Leioa, Basque Country, Spain*; [3] *Forest Research Centre, School of Agriculture, Tapada da Ajuda, 1349-017 Lisboa, Portugal*

The integration of trees in livestock and arable production can improve animal welfare, increase biomass production, and provide environmental benefits. Hence, economic analyses from a broad societal perspective have shown that agroforestry can be preferable to separate monoculture livestock and arable systems (García de Jalón et al. 2018b). However the question remains: how can we make agroforestry more financially attractive to farmers? This paper highlights three areas.

Using trees to support existing farm enterprises
Graves et al. (2007) concluded that for agroforestry to be more profitable than both monoculture forestry and agriculture, the profitability of the monoculture systems needed to be similar or the farmer would focus on the more profitable farm or forest enterprise. However, experience with the EU AGFORWARD project suggests that most farmers using agroforestry do not attempt to balance the two enterprises, but rather to make an existing enterprise more sustainable. Hence, for example, trees in a free-range egg system can be used to promote hen welfare, and arable farmers can use trees to reduce soil erosion to enable long-term crop production. Focussing on how trees support an existing farm enterprise is therefore important in agroforestry adoption and practice.
Availability of tree product prices
Early modelling of silvoarable systems indicated higher revenues from agroforestry, compared to separate arable and forest production, due to continued cropping and the benefits of concentrating timber growth on fewer large trees rather than many smaller trees (Graves et al. 2007). There is readily available data on the sale price of agricultural crops. By contrast, there are few details on the interaction between volume and quality on timber and fuelwood prices in many parts of Europe. In practice, valuable timber like walnut can even be sold for firewood, as shown in the case of the commonly-cited walnut-arable system at Les Eduts in Western France (AGFORWARD 2016). More information on timber and fuelwood values is needed.
Simplified government support for agroforestry that provides public benefits
In recent analyses in Europe, increased complexity and management costs are identified as key negative effects of agroforestry (García de Jalón et al. 2018a) but these effects are typically ignored in financial analyses (Graves et al. 2007). In fact within the EU, a complex land use like agroforestry can be penalised within Pillar I of the Common Agricultural Policy and there can be low financial benefits and high administrative hurdles associated with support in Pillar II (Mosquera-Losada et al. 2018). In addition, farmers can perceive that tree planting results in more restrictive environmental legislation on their farm. In view of the societal benefits, we argue that farmers practising agroforestry should receive enhanced public payments, with low administrative hurdles, and this would help to address some of the higher management costs.

Keywords: Profit, Motive, Prices, Regulation, Complexity.

References:

1. AGFORWARD (2016) www.agforward.eu/index.php/en/news-reader/id-30-november-1-december-2016.html
2. García de Jalón S et al. (2018a). Agroforestry Systems 92:829–848.
3. García de Jalón S et al. (2018b). Agroforestry Systems 92:1059–1073
4. Graves AR et al. (2007). Ecological Engineering 29: 434-449
5. Mosquera-Losada MR et al. (2018) Agroforestry Systems 92: 1117–1127

L12.P.09

Diversity of the socio-economic strategies of valorization of the undergrowth of Guadeloupe: a typology

Castro Nunes T.[1] (jean-louis.diman@inra.fr), Chaigneau R.[1], Vinglassalon A.[2], Barlagne C.[3], Hammouya D.[1], Diman J.-L.[1], Bezard M.[2]

[1] *PEYI - 0805, INRA, Petit-Bourg, Guadeloupe, France*; [2] *SYAPROVAG, Petit-Bourg, Guadeloupe, France*; [3] *Social, Economic & Geographical Sciences, James Hutton Institute, Aberdeen, Scotland, United Kingdom*

While agroforestry systems have been described internationally (Nair et al., 1993, Parrotta, 2012), this study sponsored by the VALAB program provides typological insights into the reality of Guadeloupe by deciphering the extreme diversity of farming situations (Perrot et al. 1993). A combination of agronomic, techno-economic and socio-cultural criteria distinguished 5 farms types for a study sample of 40 farmers:
- Organizations with a productive and / touristic vocation are large-scale farms, with business status and a commercial or touristic vocation contrasting with the other stakeholders of the undergrowth of Guadeloupe. Their weight is undeniable in the whole actors of the three traditional sectors of the undergrowth of Guadeloupe (coffee, cocoa, vanilla).
- The traditional crops parcels out of the undergrowth are developed by farmers who have chosen to get out of the constraints that the undergrowth could have in particular in terms of regularity and profitability of the production for the supply of structured trade channels. However, this model appears vulnerable in terms of phytosanitary and socio-cultural values.
- The ONF concession farms are in vanilla monoculture. These multi-skilled farmers cannot live only on this climate-dependent productive activity. They have little leeway to change their agrosystem towards a viable activity in the undergrowth in relation to the rather coercive specifications proposed by the departmental land manager.
- Undersized private understory plantations result from the structural sharing of the activity of the farmers concerned between their farm and other sectors of labor, valuing their labor force in an immediate and less risky way. These farms reflect the current rather general situation of degraded valuation of the Guadeloupean private undergrowth. Fragilized for the most part by sectorized support exacerbating their sensitivity to climatic and economic hazards, they gather potential candidates concerning the initiative that some farmers wish to promote with agroecological integrative diversification projects in the undergrowth.
- The forest gardens are still a model of valorization by old knowledge of the agrobiodiversity of the undergrowth in an integrated and diversified way, fruit of a concomitant transmission of the land heritage and the associated intangible heritage. This mode of development is becoming rarer with the retirement of the old farmers and the structural difficulties of a transmission based on orality and proximity, for these particularly complex agroecosystems.
This typology, essential for understanding the reality of undergrowth agrosystems, is also used as a tool to study their viability. Finally, it makes it possible to envisage development actions adapted to each type of farming.

Keywords: Guadeloupe, undergrowth, socio-economy, typology, diversity.

References:

1. Nair et al. (1993). An introduction to Agroforestry – Classification of Agroforestry Systems.
2. Perrot, C. et al. (1993). Comment modéliser la diversité des exploitations agricoles? Les Cahiers

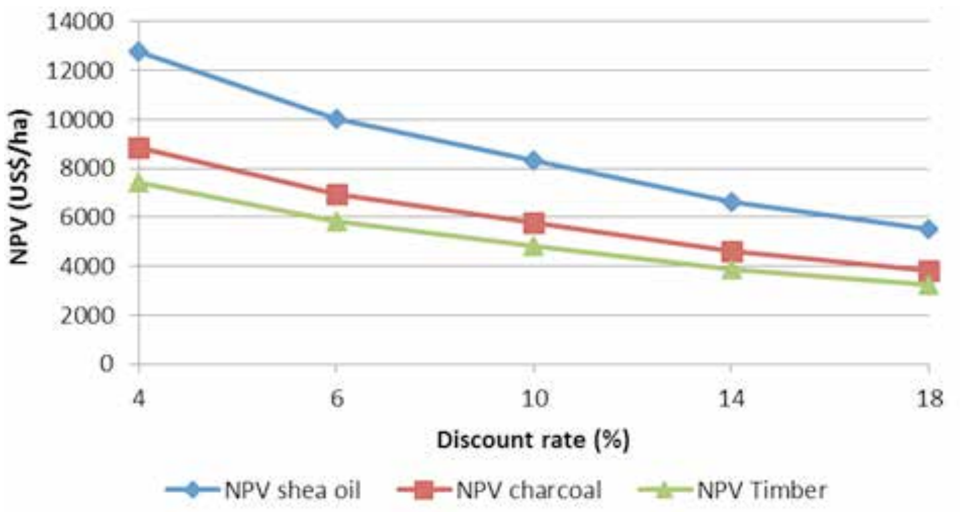
L12.P.10

Shea tree (*Vitellaria paradoxa*) use options in Uganda's agroforestry parklands: A Cost Benefit Analysis

Gwali S.[1] (gwalis@yahoo.co.uk), Sekatuba J.[2], Kiyingi I.[3]

[1] *Tree Improvement and Germplasm Research, National Forestry Resources Research Ins, Kampala, Uganda*; [2] *Agroforestry Research Programme, National Forestry Resources Research Ins, Kampala, Uganda*; [3] *Forest Conservation and Management, National Forestry Resources Research Ins, Kampala, Uganda*

Shea trees (*Vitellaria paradoxa*; Karité in French) are a major presence in the agroforestry parklands of Uganda and a source of livelihoods for the local people in these areas[1]. Shea trees produce nuts that contain abundant oil which is extracted and used in cooking, in cosmetic formulations and medicinal ointments. Shea tree populations in Uganda have been decimated by various anthropogenic practices[2]. This study sought to identify the most suitable shea tree use option that has least social and environmental cost. A consultative mixed-methods approach[3] involving 124 household interviews, 10 focus group discussions and field observations was employed to perform a cost benefit analysis of various use options. Farm gate prices and average quantities harvested per hectare were used to value the shea tree products[4]. The value of environmental services from shea parklands per acre was obtained from secondary sources[5]. Labour costs in charcoal production were US$ 220 ha^{-1}, US$ 132 ha^{-1} in oil production and US$ 44 ha^{-1} in timber production. Environmental services were estimated at US$ 23.9 ha-1yr^{-1}. The Net Present Value (NPV) of she oil production was US$ 8,309 ha^{-1}, charcoal production was US$ 5,766 ha^{-1} and timber production US$ 4,822 ha^{-1}. Since charcoal and timber production are a one-time harvest in 20 years, oil production is therefore the best-bet use option since it continues throughout the lifetime of a tree.



Sensitivity of shea tree use options' NPV to various discount rates. Note the base-case discount rate was 10% during the study period.

Keywords: Shea tree, Vitellaria paradoxa, Cost Benefit Analysis, Agroforestry parklands, Use options.

References:

1. Byakagaba et al. (2011). Agricultural Journal, 6(1), 14 – 22.
2. Gwali et al. (2012). Environment, Development and Sustainability 14, 347-363
3. Boardman et al. (2001). Upper Saddle River, NJ: Prentice Hall.
4. UBOS (2010). Ministry of Finance and Economic Planning, Kampala, Uganda.
5. Rodriguez et al. (2006). Ecological Economics 57(1): 30-44.

L12.P.11

supply response of baobab fruit and pulp on seed to price and non-price incentives in Kenya

Kaimba G.[1] (kinyuakaimba@jkuat.ac.ke), Muendo K.[1], Dagmar M.[2]

[1] *Agricultural and Resource Economics, JKUAT, Nairobi, Kenya*; [2] *Faculty of Life Sciences, Rhine-Waal University of Applied Science, Kleve, Germany*

In Kenya the agricultural sector provides employment and contributes to food security. However, micronutrient deficiencies are prevalent and require interventions from a range of interconnected strategies. Wild plants such as Baobab are often rich in micronutrients and are increasingly being recognized globally for its high nutrients. In spite of the nutritional and economic benefits potentially accruing from the opportunities for trade created by the international markets, the potential of Baobab to uplift local communities from nutritional deficiencies and poverty in Kenya has not been assessed. The present study aims to fill this gap by characterising baobab collector/producers and analyse the structure of market supply of baobab fruit and pulp on seed with respect to non-price incentives in Kenya. A total of 274 respondents were selected using linear systematic random sampling method from a list of commercial baobab collectors in three different counties of Kitui, Makueni and Kiifi. Preliminary results indicate that baobab supply by harvesters/collectors is predominantly done by women and children mainly with basic primary education. Price of the baobab fruit/pulp on seed positively influences the quantity supplied. However, the price is not the main reason why a household sold through a particular marketing channel but rather availability and accessibility of the buyer, timeliness and buyers' ability to pay in cash, and the proximity/nearness to the market also play a role. Household with more number of baobab trees in their farm supplied more baobab to the market than those with fewer trees. Households with unemployed heads and spouses and those with lower on-farm income tended to supply most of the baobab. Moreover, households with children aged between three years and 13 years participated more in the harvesting and hence selling of baobab than those with older children. The results thus imply that government policies targeted at improving commercialization of baobab fruit and pulp would greatly enhance incomes for the vulnerable groups participating in baobab trade as well as raise the nutritional status for everyone in the society.

Keywords: Agroforestry, baobab supply, Incomes, Nutrition.

References:

1. Frison et al., 2011, Sustainability, 3, 238–253.
2. Dawson, et al., 2013, FAO
3. Kehlenbeck, et al., 2013, Bioversity International, 257-269.
4. Olwande, et al., 2008, IJAAS, Volume 1 Number 2: 56-67
5. Wijetunga, 2016 Asian Journal of Agriculture and Rural Development 6 (2), 21-35

L12.P.12

Income of cocoa agroforest-associated species in the forest-savanna transition zone, Côte d'Ivoire

Kouadio V.-P. G. (kvenance@gmail.com), Kossonou A. S. F., Vroh B. T. A., Adou Yao C. Y.

Biosciences, Université félix Houphouët-Boigny, Abidjan, Côte d'Ivoire

The adoption of agroforestry practices depends on several factors, including the possibility of diversifying income sources. In an ecological zone that is apparently not suitable for cocoa cultivation (Camara et al., 2009), three traditional agroforestry systems (SAF) with cocoa have been identified (Kpangui et al., 2015). Their management involves the maintenance, preservation or introduction of local or exotic species. Although the choice of species has been documented, the financial income from the sale of the products of these associated species remains one of the important questions. To address this issue, a botanical inventory coupled with socioeconomic surveys were conducted in 52 plantations of the three identified SAFs. The investigations allowed to count 37 introduced and 35 local plants maintained. The study showed that food products from introduced species such as banana, avocado, orange and cassava provided more benefits. The simple SAF yielded more income than the others. The wood products of the saved local species brought in the most, after the felling of trees and cutting into planks. The logging of local saved timbers (Figure 1) could yield to a farmer between 3,000 and 30,000 FCFA per tree (an average of 15,500 FCFA) according to the diameter and the quality of the tree. The exploitation of wood products tends, however, to favor the expansion of the simple agroforestry system.

View of a framire (Terminalia ivorensis A. Chev.) shot and slaughtered in a cocoa plantation

Keywords: : Economic value, cocoa companion species, agroforestry system, Côte d'Ivoire.

References:

1. Camara et al., 2009. Cahiers agricultures, 18 (5) : 425 – 432.
2. Kpangui et al., International Journal of Agronomy and Agricultural Research (IJAAR). 6 (3): 36-47.

L12.P.13

Apple based Agroforestry in Dendi Woreda, Oromiya Region: Income contribution and determinants for adoption

Lejissas L. T.[1] (lemlemtajebe@gmail.com), Tanga A. A.[2], Ayele Z. E.[3]

[1] *Socio-Economics and Policy, Ethiopian Environment and Forest Researc, Addis Ababa, Addis Ababa, Ethiopia*; [2] *Agroforestry, 1. Ethiopian Environment and Forest Rese, Addis Ababa, Addis Ababa, Ethiopia*; [3] *3. Addis Ababa Science and Technology Un, Addis Ababa, Addis Ababa, Ethiopia*

Despite the long history of agroforestry in Ethiopia, the level of its adoption by farmers and its significance for household income improvement has not been matched by the generated technology and knowledge system. This is due to the system's more attractiveness to relatively wealthy families or those with larger land holdings since they have financial capability and mental readiness to allocate more resources to commercial tree growing (Bellow *et al*., 2008). Poorer farm households often concentrate on producing subsistence crops rather than growing trees as cash crops, the benefits of which can be accrued after years (Negussie Achalu, 2004). A key lesson is that promoting technology is far more complex than simply generating information.

Promotions of on-farm tree/shrub plantings could also greatly relieve the pressure on the remnant natural forest by providing variety of forest products. Beside climatic and biophysical suitability for temperate fruit production, central highlands have a great opportunity for marketing of the produced fruits due to their proximity to the capital city market. Accordingly, this research was intended to find out the contribution of apple-based agroforestry system to improve the household income along with the critical factors that limit the adoption process in the central highlands of Ethiopia.

For this study, a rule-of-thumb that $\mathbf{N \geq 50 + 8m}$, where $\mathbf{N}$ is minimum number of households and $\mathbf{m}$ is explanatory variables, was used (Green, 1991). The market price method was used to estimate the value of goods that are bought and sold in the local market. To answer the question of factors influencing the adoption of apple-based agroforestry system, a binary logistic regression model was used.

Adopters mean annual gross income from vegetable + apple fruit was 344,602.27ETB ($12,763) ha-1yr-1 and mean annual gross income of non-adopters from vegetables was 187,925.43ETB ($6960)ha-1yr-1. Non-adopters annual net income from vegetables was 165,478.34ETB ($6128) ha-1yr-1 and adopters' annual net income from vegetable + apple was 312,378.79ETB ($11570) ha-1yr-1. The mean annual apple fruit production from 928.3trees ha-1 was 3639.68kg ha-1 yr-1 and the gross income was 58,234.85ETB ($2157)ha-1 yr-1. Income obtained from apple contributes 17 per cent of the total income from agri-horticultural system. The mean gross income of adopters from vegetables + apple was 1.8 times higher than the income of non-adopters from vegetables. The mean gross annual revenue of adopters from solely apple fruit production constituted about 17 per cent of the total income obtained from vegetable + apple. The mean net annual income of adopters from vegetables + apple fruit was 2 fold higher than the income of non-adopters from vegetables. However, adoption of the system was significantly influenced by Age (+), formal educational levels (+), livestock holding (+), distance from market to home (+), sex (-) and total land holding (-).

Keywords: Agri-horticulture system, Apple tree adoption, Household income.

References:

1. Bellow, G., Hudson, R. and Nair, P. 2008. Adoption Potential of Fruit-Tree-Based Agroforestry on Sma
2. Negussie Achalu, 2004. Farm Forestry Decision-Making Strategies of the Guraghe Households, Southern-

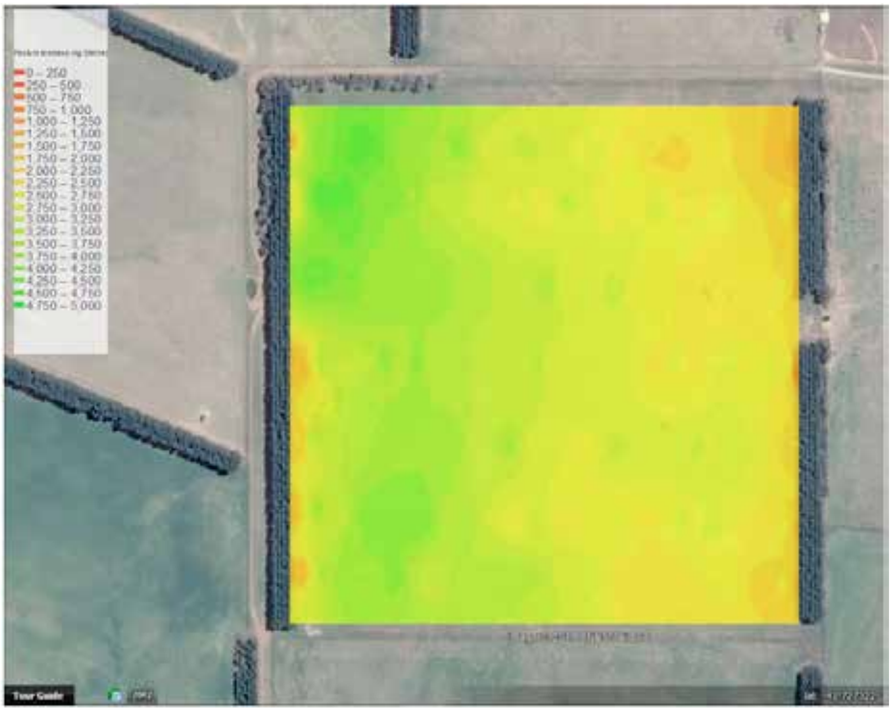
L12.P.14

Quantifying the multiple benefits of trees in agricultural systems to improve the business case for agroforestry

Mendham D.[1] (Daniel.Mendham@csiro.au), Worledge D.[2], Moroni M.[3]

[1] *Land and Water, CSIRO, Hobart, Tas, Australia*; [2] *Land, CSIRO, Hobart, Tas, Australia*; [3] *Private Forests Tasmania, Hobart, Tas, Australia*

Agroforestry offers an opportunity to increase agricultural enterprise profitability. The benefits of agroforestry are multiple, but too often the decision by farmers to adopt an agroforestry system is dependent on only a single benefit, such as the forestry economics being profitable. However, the forestry benefits per se may only be a relatively small component of the overall financial benefits that trees provide to the agricultural system. We established a project in Tasmania to quantify the benefits that agroforestry, in a shelterbelt configuration, conveys to the adjacent agricultural enterprise. The project is also developing a modelling framework to integrate the benefits into a form that allows farmers to understand the scale of the financial returns and the relative contributions of each of the benefit streams. Key results from the study will be presented, including the impacts of shelter on the windspeed, evaporation and pasture productivity. Other values such as carbon and amenity are included in the tool that allows land managers to account for the financial returns from the broader suite of benefits. The benefits of shelter on agricultural productivity tended to outweigh all other returns from the system. The assumption that land for agroforestry needs to have low opportunity cost is challenged by the study, as higher benefits are likely to accrue from the use of agroforestry systems in protection of higher value cropping enterprises.



30% higher pasture production in the sheltered half of a paddock compared to the unsheltered half leads to increased profitability

Keywords: Bioeconomic modelling, Imagine, Shelter benefit, economics, adoption.

L12.P.15

Acrocomia in agroforestry systems – an improved investment decision for family-based smallholder farms in Paraguay ?

Mössinger J.[1] (moessing@uni-hohenheim.de), Carauta M.[1], Hilger T.[2], Berger T.[1]

[1] *Land Use Economics in the (Sub-)Tropics, University Hohenheim, Stuttgart, Germany*; [2] *Agronomy in the (Sub-) Tropics, University Hohenheim, Stuttgart, Germany*

In Paraguay, around 20% of the population runs a family-based farm, where they mainly produce for their own consumption, plant cash crops, as soy and sesame, and maintain a low amount of livestock (Garcia and Chavez 2007; Riquelme 2016). The main challenges of these farm systems are on the one-hand increasing variable climatic conditions and compact and degraded soils, with low yields as a consequence. On the other hand, they face weak access to markets and low integration into the agroindustrial sector. Living on the edge of poverty, the younger generation migrates to cities or leaves the country. Therefore, policy makers and smallholders are interested in alternative production system that are not only economically feasible but also help to overcome the environmental burdens and reduce risk. Acrocomia, also known as macaúba, coyol, or mbocaya, is a native palm-tree in the neotropcis of Latin America. The oil-bearing fruits can be processed to fuel, food and fodder (Hilger et al. 2015). In Paraguay, smallholders collect the fruits from wild growing palms before they are further processed in small factories since almost a century. The diverse product portfolio of Acrocomia has a high potential on the international markets and targeted cultivation would help in managing the palm and oil-quality. The main objective of this research is to find economically viable and locally adaptable cultivation systems including Acrocomia. Attention is turned to agroforestry systems with Acrocomia to especially bridge the gap of a four-year investment until the first harvest.

The district of San Pedro del Paraná in the province of Itapúa was selected as a representative case study for family-based smallholder farms. A literature review was conducted and local experts and farmers were interviewed in order to identify new agroforestry systems related to Acrocomia. In a second step we built a mathematical micro-simulation farm-model with the software package MP-MAS (Schreinemachers and Berger 2011). The model is based on typical crops and livestock production patterns as well as own-consumption, derived from census data and discussed with the smallholders in the area. The model is used to analyze data related to farm-labor, costs and revenues over a 20 years investment horizon. The results are a comparison of land-use-decision options of Acrocomia, the agroforestry systems with Acrocomia and with actual production schemes. The results give further insights into farm-labor distribution, cash-balances and farm-income. Preliminary results show a potential for Acrocomia-Agroforestry systems focusing on consumption-crops. Land and labor is used more effectively and smaller farms among the smallholders can overcome liquidity problems.

Keywords: Acrocomia, mathematical programming, agroforestry, smallholder, Paraguay.

References:

1. Garcia, B. et al., 2007, La agricultura familiar en los países del cono sur. ISBN: 9789290398653
2. Hilger, T. et al., 2015, Agroecology. DOI: 10.1016/j.jpeds.2011.01.029
3. Riquelme, Q., 2016, Agricultura familiar campesina en el Paraguay. ISBN:9789996781933
4. Schreinemachers, P. et al, 2011, Environmental Modelling&Software DOI: 10.1016/j.envsoft.2011.02.004

L12.P.16

Efficiency differentials of agroforestry practices among arable crop farmers in north central, Nigeria

Oloyede A. (oloyedeadeola@gmail.com), Ayinde O.

Dept of Agricultural Economics & Farm Mg, University of Ilorin, Ilorin, Kwara, Nigeria

Measuring efficiency is important because it is an indication of resource saving potential and it is useful for better informed policy formulation and for improved farm management (Idumah, et al, 2015).This study presents the analysis of technical efficiency differential of farmers that adopt agroforestry technologies and the non-adopting farmers in North central, Nigeria. A multi stage sampling techniques was used to select 295 farmers in the study area. Data on input-output and socioeconomic variables were collected and analyzed using descriptive statistical methods and by applying a stochastic frontier production function to the data. Results show that the average farm size of adopters was 2.4 hectares while the non-adopters had an average farm size of 3hectares. The adopters had a significantly higher average gross margin of ₦73,795.57per hectare than the non-adopters ₦56,171.62 per hectare. Result of the technical efficiency showed that the adopters had a mean of 0.84 while that of the non-adopters was 0.79 which was significantly different. Factors affecting the technical efficiency of adopters includes: seed, labourand farm size. The variables that significantly influenced the output of the non-adopters were the seed, farm size and labour. In addition, there are increasing returns to scale for adopters and non-adopters. The study concludes that adoption of agroforestry practices play a significant role in determining the levels of technical efficiency of the farmers.

Table 3: Result of the Maximum Likelihood Estimates of the Stochastic Production Frontier Function of the Farming Households

Variable	Parameters	Adopters	Non-Adopters	Pooled
Constant	β_0	6.268 (8.938)***	8.575(10.023)***	6.734(24.236)***
Seed	β_1	0.365 (8.023)***	0.127 (1.800)*	0.305(8.671)***
Herbicide	β_2	0.054 (1.658)*	-0.002 (-0.078)	0.034(1.481)
Fertilizer	β_3	0.034 (1.835)*	0.009 (0.365)	0.037(2.636)**
Total Labour	β_4	0.209 (3.653)***	0.225(4.823)***	0.222(5.123)***
Other cost	β_5	-0.051(-2.00)**	-0.012(-0.294)	-0.0407(-2.038)***
Farm size	β_6	0.503(3.497)***	0.818(3.921)***	0.476(3.892)
Inefficiency model				
Age	z_1	-0.012(-1.712)*	0.019(1.305)	-0.003 (-0.464)
Gender	z_2	0.244(1.652)*	-0.106(-0.241)	0.074(0.387)
Household size	z_3	0.0583 (2.558)**	0.016(0.268)	0.032(1.136)
Experience	z_4	-0.017 (-2.023)**	-0.059(-1.595)	-0.034(4.147)***
Extension contact	z_5	-0.016(-0.755)	-0.140(-1.604)*	-0.051(-4.203)***
Membership	z_6	-0.137(-0.740)	0.306(0.535)	0.148(0.641)
Land tenure	z_7	0.610(3.253)***	0.131(0.209)	0.736(3.434)***
Number of trees	z_8	0.002(2.240)**	0.030(0.738)	0.001(0.357)
Sigma-squared	σ^2	0.573(10.345)***	1.196(2.265)**	0.615(3.981)***
Gamma	Γ	0.53 (1.892)*	0.878(10.175)***	0.108(0.309)
Log likelihood function		-212.37757	106.99334	-334.28686

Note: Figures in parenthesis are t-values; *, ** and *** represent significance at 10%, 5% and 1% respectively.

Keywords: Technical efficiency, stochastic frontier, agroforestry, arable crop farmers, Nigeria.

References:

1. Idumah, et al. (2015). World Journal of Agricultural Sciences, 11 (1), 01-07, DOI:10.5829/idosi.wjas

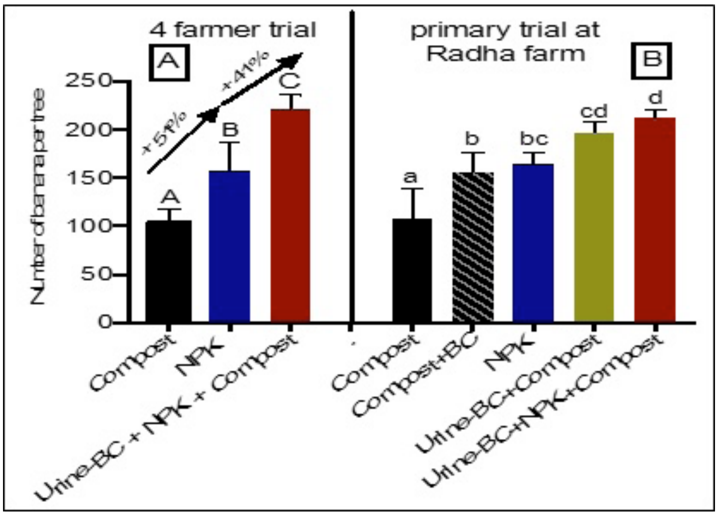
L12.P.17

Revitalizing agrarian economies: The use of biochar on banana-based agroforestry system in Nepal's hills

Pandit B.[1] (bhpandit29@gmail.com), Nuberg I.[2], Shrestha K.[3], Cedamon E.[2], Amatya S. M.[1], Dhakal B.[1], Schmidt H.-P.[4]

[1] *Agroforestry, Nepal Agroforestry Foundation, Kathmandu, Province No 3, Nepal*; [2] *Agriculture, University of Adelaide, Glen Osmo, Glen Osmo, Australia*; [3] *Social Science, University of New South Wales, New South Wales, Sydney, Australia*; [4] *Carbon Farming, Ithaka Institute for Carbon Strategies, Ancienne Eglise 9, 1974 Arbaz, Switzerland*

The use of biochar in agroforestry practices is a new concept in Nepal. The soil application of biochar is considered to be a promising alternative to increase productivity and reduce chemical fertilizers. To test this concept an action research project was implemented in two villages of Lamjung district in the middle hills of Nepal. This study aimed at assessing the productivity and livelihood impacts of a banana-based Agroforestry (AF) system with and without biochar-based fertilization. Biochar was used in one village while another village served as control (with NPK application but no biochar). The information obtained from 111 household survey was verified and tested through five farmers' field trials. The present paper investigates the effect of different fertilizers on banana yields and its contribution to poverty reduction. The result of the study shows that the banana yield increased by 41% in the plots treated with urine-biochar plus compost compared to the control with conventional NPK fertilization; and more than doubled (102%) compared to the fertilization with compost only. Findings also revealed that the poverty level of respondent households using biochar dropped by 30%, at Dhamilikuwa (biochar village) and it is only 19% at JitaTaxar (control village). The study implies that the use of biochar in banana-based agroforestry system has potential for increasing soil productivity and reducing poverty, thereby revitalizing agrarian economy of many Nepali villages.



Keywords: biochar, banana based agroforestry, productivity, agrarian livelihood, poverty alleviation.

References:

1. Schmidt et al. 2015 Agriculture pp 723-741
2. Pandit et al 2017, PLOS ONE 12:e0176378. DOI: 10.1371/journal.pone.0176378
3. Schmidt et al, 2017, Land Degradation & Development. DOI: 10.1002/ldr.2761
4. Shrestha et al. 2017, American Journal of Agriculture and Forestry, doi: 10.11648/j.ajaf.20170504.12
5. Kammann et al. 2015, Scientific Reports 5. DOI: 10.1038/srep11080

L12.P.18

Optimal plant densities for cacao agroforestry systems in the Colombian Pacific region

Perez Zuñiga J. I.[1] (jiperez@agrosavia.co), Rojas Molina J.[2], Zabala Perilla A. F.[3]

[1] *Corporacion Colombiana de Investigacion, Agrosavia, Tumaco, Nariño, Colombia*; [2] *Corporacion Colombiana de Investigacion, Agrosavia, Bucaramanga, Santander, Colombia*; [3] *Purdue University, West Lafayette, Indiana, United States*

Cacao production in Colombia has socioeconomic relevance. Its production implies an estimated annual demand of 7 million daily-labor and supports the monetary incomes of 35000 families, mostly in rural areas (Agronet, 2013). According to Agricultural National Census, 2014, cacao area (recently planted area + harvested area) was 165.000 hectares, located in 27 out of 32 national departments in 327 Colombian municipalities. Given the current socioeconomic scenario, which combines attractive market forecasts for farmers and a post-conflict period, which promotes the developing of new profitable agricultural activities, cacao area has increased in recent years (Cely, 2017). Among the different cacao productive regions, Tumaco – Nariño, has been placed as one of the most important municipalities. It is located in the Pacific region, which is a Colombian post-conflict zone and according to some national "fine and flavor" experts, the cacao harvested in this region has special characteristics, which are attractive for the market[1] (Casa Luker, 2014; Rodriguez et al., 2011). This study was conducted in Tumaco during 2016 and 2017. it was divided into two stages. During the first stage a socio-economic characterization for cacao agroforestry systems was conducted; cacao production costs, plant densities, yields, financial sources, and planted forest materials were analyzed. it was identified that there are 3 plant densities in the region (3mx3m, 3.5mx3.5m and 4mx4m), which affect only the production costs, but also the yields for the farmers. Based on this fact and in order to determine the optimal plant density, a linear programming was conducted, in the second stage. The algebraic model used workforce, financial payments minimum required incomes as constraints, in addition, profitability was used as the objective function. This model was optimized with GAMS software, using CPlex solver and the plant density 3mx3m (1100 plants/Ha), was identified as the optimal solution for it. The minimum required price for this solution was $4.700/Kg and the ICR (Rural Capitalization Index subvention) had to be greater or equal to 20%.

[1] A cacao sample collected in Tumaco-Colombia won the "Excelencia Extranjera' prize in "Salon du Chocolat" at París 2016 .

Keywords: Costs, Utility, Linear Programming, Incentives, Cacao.

References:

1. Agronet. (2013). Red de Información y Comunicación Estratégica del Sector Agropecuario. En: http://w
2. Casa Luker. (2014). Casa Luker. Food Ingredients. Cacao Fino de Aroma. En: http://www.lukeringredie
3. Cely Torres, L. A. (2017). Oferta productiva del cacao colombiano en el posconflicto. Estrategias pa
4. MADR. (2016). Sistema de Información de Gestión y Desempeño de Organizaciones de Cadenas-SIOC. Obte
5. Rodriguez-Campos, J., Escalona-Buendía, H. B., Orozco-Avila, I., Lugo-Cervantes, E., & JaramilloFlor

L12.P.19

Agroforestry as a green economy pathway: Case of West and Central Africa

Piabuo S. M. (p.mandiefe@cgiar.org), Foundjem-Tita D.

Markets, Policies and Institutions, World Agroforestry Centre, Yaounde, Centre, Cameroon

Globally, governments are devising ways to define and integrate “green economy” in their policies to promote economic growth while enhancing environmental sustainability and social progress. The integration of trees into diverse farming systems have emerged as a pathway to ensuring economic growth and environmental sustainability. Agroforestry provides improved and diverse income sources to farmers, enhances soil fertility, reduces deforestation and climate resilience. This system of landscape management enables economic prosperity and environmental sustainability. However, empirical literature on the role of agroforestry as a green economy pathway is sketchy, not clear and vary across the Sahel and humid tropics. This paper develops a framework which underscores agroforestry as a green economy pathway, content analysis of literature on agroforestry practices and impacts over the past 20 years. Sample case studies from the Sahel and humid tropics from 4 countries are used to support evidence from literature review. The results show significant economic, social and environmental benefits from agroforestry practices globally, however environmental benefits are higher in the Sahel region. livelihoods and benefits from environmental services have improved. Adoption and incorporation of agroforestry within national and regional development strategies to enhance green growth is imperative for the development of West and Central Africa and the global development agenda.

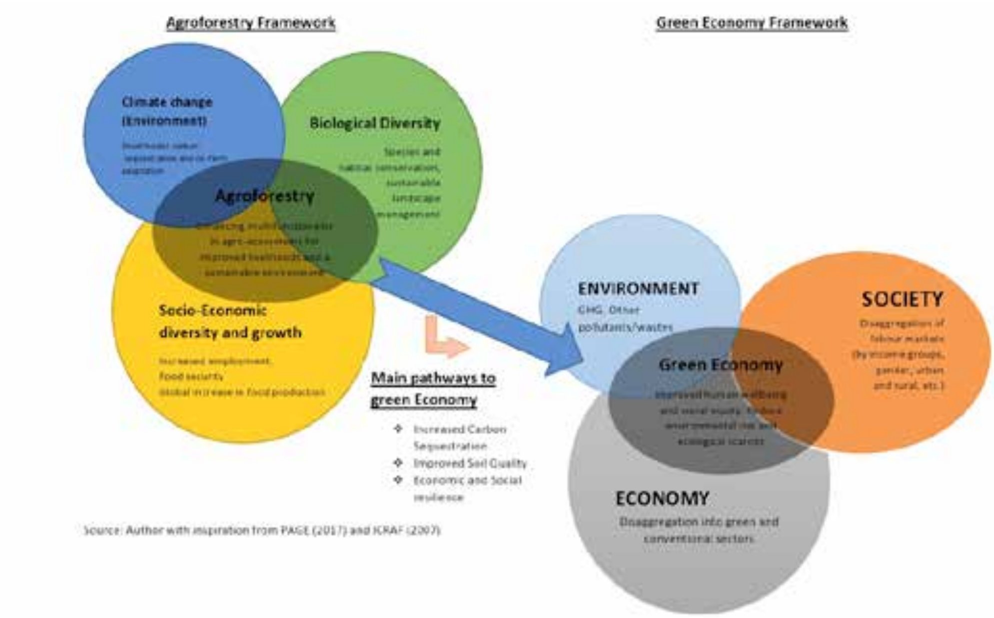


Figure: Agroforestry as green economy pathway

Keywords: Green growth, Landscape management, Agroforestry, Green economy.

References:

1. PAGE (2017), The Integrated Green Economy Modelling Framework – Technical Document.
2. ICRAF (World Agroforestry Centre). 2007. Tackling Global Challenges through Agroforestry Annual Repo

L12.P.20

Holistic risk-return analysis for improving planning and performance measurement of agroforestry interventions

Shepherd K.[1] (k.shepherd@cgiar.org), Luedeling E.[2], Whitney C.[2], Muchiri C.[1], Tamba Y.[1]

[1] *Land Health Decisions, World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [2] *Department of Horticultural Sciences, University of Bonn, Bonn, Germany*

A quantitative risk-based framework is presented for improving planning and performance management of agroforestry interventions at farm and project levels. The framework first identifies the goals of the various stakeholders involved and the intervention options being considered. Then the various on-site and off-site costs, benefits and risks associated with the intervention options are identified, including biophysical, social and economic factors. A combination of available data and expert knowledge is used to estimate probability distributions on all variables. Stakeholder's risk preferences are also quantified. Outcomes are presented in monetised form (e.g. distribution of net present value) providing insights into trade-offs among objectives and stakeholder groups. Partial Least Squares regression is used to identify which variables contribute to positive and negative outcomes, providing opportunities for improvements in intervention design. Value-of-information analysis points to areas where gathering further information would help clarify the decision, and provides a guide on how much it is worth spending to collect it. The analysis also points to which variables should be closely monitored during implementation. The framework is implemented using either Monte Carlo (MC) simulation or Bayesian Networks. An MC package in R software that generates the above analyses is already available. The framework is illustrated with examples at farm, project and policy level.

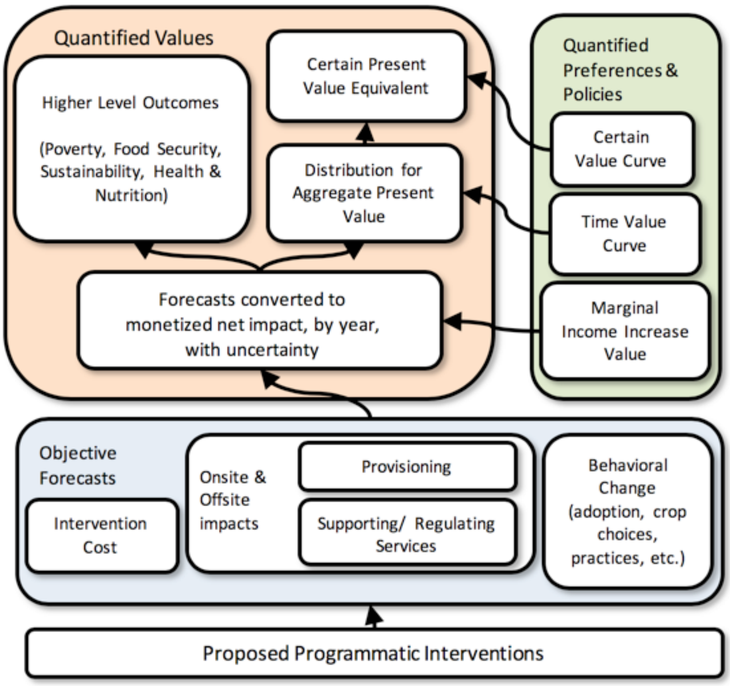


Diagram of framework for evaluating agroforestry interventions

Keywords: Decision analysis, Multiple objectives, Risk analysis, Participatory, Assessment.

L12.P.21

Agro-forestry parkland for the ecological, economic, food and social sovereignty in the Sahel

Valet S.[1] (valet.serge2@wanadoo.fr), Heino-Motelica M.[2]

[1] *Association PASSERELLES, Lyon, France*; [2] *ISTO UMR 7327 CNRS-, University Orléans, Orléans, France*

The agroforestry parkland has been conceptualized empirically in the Sahelian zones, to cope with the constraints pedoclimatic the weak soil fertility, food demand and economic conditions. And now, it is promising to ensure the resilience of agro-systems destroyed by the intensified monoculture promoted since the 1950s. There results showed that under tree a pure culture or mixed / intercropping systems with fewer inputs produced more under the crown than intensified monoculture because of free Eco-Systemic Services.
Provisioning services: food and feed yields are higher than pure crops (LER de 1.20 to 4);
Regulating services: (micro)-climate regulation; protection against wind and rain erosion; weeds, water economy, (micro-biodiversity = 2 to 3 times higher under crown.
Supporting services: OM equivalent Ratio=2.70; Norg. fixation (N-ER = 2.31); stopping leaching of nutrients, trapping nutrients (P-ER = 1.78 & KCaMg-ER = 2; P-ER = 1.78 & KCaMg-ER = 2); sequestration of C and GHG limitation.
Economic and Social services :
Benefit Equivalent Ratio>1; curbing the exodus to limit social disruption.
The influence of agroforestry parkland because of several free ESS, preserve agro-écology and limits the greenhouse effect. Peasants use now the Assisted Natural Regeneration but also the « forest zaï » ensures resilience agroecosystems. Then only the peasants will get their ecological, food, economic, and social sovereignty.

Agroforestry park in Sudan zone with millet (rainy season)

Keywords: Agro-forestry parkland, free Eco-System Services, tree+millet, ecological, food, economic, and social sovereignty, Sahel.

References:

1. Valet S., H. Ozier-Lafontaine, 2013. Sustainable Agriculture Reviews 14. Pp: 185-268.
2. Valet S., H. Ozier-Lafontaine, 2013. Abstract book. 17-18 june, Ghent, Belgium. 127p. p. 65.
3. Valet S., 2017. IRD Edit. Edit scientifique E. Roose. Pp 285-295.
4. Franchome E., J-L Diman, G. Alexandrre, S. VALET, and H. Ozier-Lafontaine, 2015.Tome 2. W. G. Ganpat
5. Valet S., H. Ozier-Lafontaine, 2013. Sustainable Agriculture Reviews 14. Pp: 185-268.

ABSTRACTS

Agroforestry adoption

Adopting the future of land use

- L13 -
Socio-economic and cultural constraints on technology adoption in agroforestry systems

You want me to do WHAT? the many constraints on adopting agroforestry tech

Technology adoption has often been a key constraint on improving productivity, income and yields in farming, particularly in developing countries where market-based systems of production are not well developed, the subsistence economy remains strong, land is held under communal tenure and family labour is the backbone of production. This session welcomes papers that explore socio-cultural and economic factors that constrain or limit the adoption of new technologies in agroforestry systems. We interpret technology in its broad sense to include non-material technologies such as new farm management techniques, labour arrangements, changing gender relations, new regimes of land tenure, etc., as well as material technologies like new processing machinery, inorganic fertiliser and so on. We anticipate that together the presentations will provide an overview of the key constraints on technology adoption and smallholder productivity in much of the developing world and point to potential solutions and strategies to address such constraints.

L13.1_O.01

Breaking open the black box: the socioeconomic factors explaining adoption or rejection of innovations in agroforestry

Curry G.[1] (G.Curry@exchange.curtin.edu.au), Nake S.[2], Rafflegeau S.[3], Lummani J.[4], Germis E.[5], Nailina R.[4], Peter E.[4]

[1] *Sustainable Livelihoods Research Program, Curtin University, Perth, WA 6845, Australia*; [2] *PNG Oil Palm Research Association, Dami Research Stat, West New Britain Province, Papua New Guinea*; [3] *CIRAD, UMR System, Montpellier, France*; [4] *Cocoa Board of PNG, Kokopo, East New Britain Province, Papua New Guinea*; [5] *PNG Oil Palm Research Association, Dami Research Station, West New Britain Province, Papua New Guinea*

The low rate of technology adoption has long been a key constraint on improving productivity, income and yields in farming, particularly in developing countries where market-based systems of production are not well developed, the subsistence economy remains strong, land is under communal tenure and family labour is the backbone of production. We examine four case studies of innovation to explore key socio-economic factors facilitating or constraining adoption: 1. new replanting program for oil palm smallholders in PNG, 2. new selected oil palm planting materials in Cameroon smallholdings, 3. Cocoa Pod Borer control methods in PNG, and 4. high yielding planting materials amongst cocoa growers in PNG. We assess the propensity to adopt along a number of socioeconomic dimensions including intra-household relations, particularly gender relations; tensions between modern and traditional farming practices in terms of labour mobilisation, land tenure and the indigenous values underpinning production, consumption and distribution. The barriers to technology adoption and innovation are not simply technical and nor are they because smallholders lack the relevant knowledge and information to facilitate adoption. Rather, proposed technologies and innovations are often incompatible with indigenous values, habits, and socio-cultural institutions that can make adoption difficult for farmers. Improving adoption rates requires a closer alignment with indigenous social institutions and values.

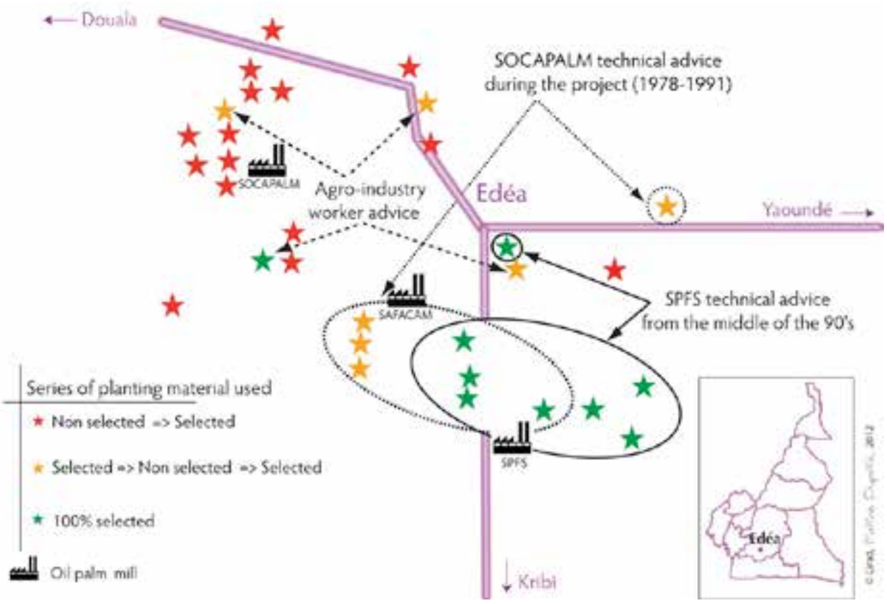


Fig 1: Only those smallholders receiving permanent technical assistance and support from project or agro-industries succeeded in adopting selected oil palm tenera types. Before plantation oil palm development, family farms used their own planting material from local dura type oil palms. Many smallholders were not aware that to participate fully in the new oil palm developments they had to purchase selected seeds from selected seeds suppliers.

Keywords: innovation, agroforestry, adoption, rejection, socioeconomic factors.

L13.1_O.02

Integrated farm planning and its potential to motivate the adoption of agroforestry practices in Ecuador

Proaño R.[1] (rproanoa@gmail.com), Vaca M.[1], Yaguache R.[1], Dávalos C.[2], Terán-Valdez A.[1], Suárez C.[1], Arcos I.[1]

[1] *CONDESAN, Quito, Ecuador*; [2] *Secretaría de Ambiente DMQ, Quito, Ecuador*

Agroforestry systems are an intervention priority in the Andean montane landscapes of Ecuador, as they contribute to the restoration and sustainability of a highly fragmented landscape. However, smallholders are often reluctant to adopt new practices, preferring to maintain conventional monocultures and pastures. Within the framework of the projects EcoAndes and Programa Bosques Andinos, a tool that proved effective in generating acceptance of change was farm planning. This comprehensive, simple and participatory planning tool, based on mapping and analysis of land use options, was used with 38 smallholders who later chose to implement different agroforestry practices; which, in addition to protecting forest remnants, also restored priority areas. Through the farm planning tool, it was possible to: a) generate trust with landowners, by providing them with a tangible and useful product to support their decision-making regarding land use; b) recognize advantages and vulnerabilities of the different farm areas, and jointly reflect on more sustainable use options. The farm plan was a first step towards a more pro-active and informed decision-making by landowners, and has potential to be a key element for external support programs that act in a coordinated manner and contribute to a previously established plan. This tool, which can be updated over time, also contributes to documenting land use change and facilitates the monitoring of impacts of agroforestry practices over time.

Figure 1. Maps showing the current land use (A) and the planned land use (B) in a farm in Carchi, Ecuador. The maps are part of an integrated farm planning exercise, developed to promote sustainable land management options. The farm plan changed from currently having two land use types (forest and pastures), to a more complex arrangement, including silvopastures, agroforestry plantations and restoration of riparian vegetation, in addition to forest conservation.

Keywords: agroforestry adoption, farm planning, landscape restoration, agroforestry systems, silvopastures.

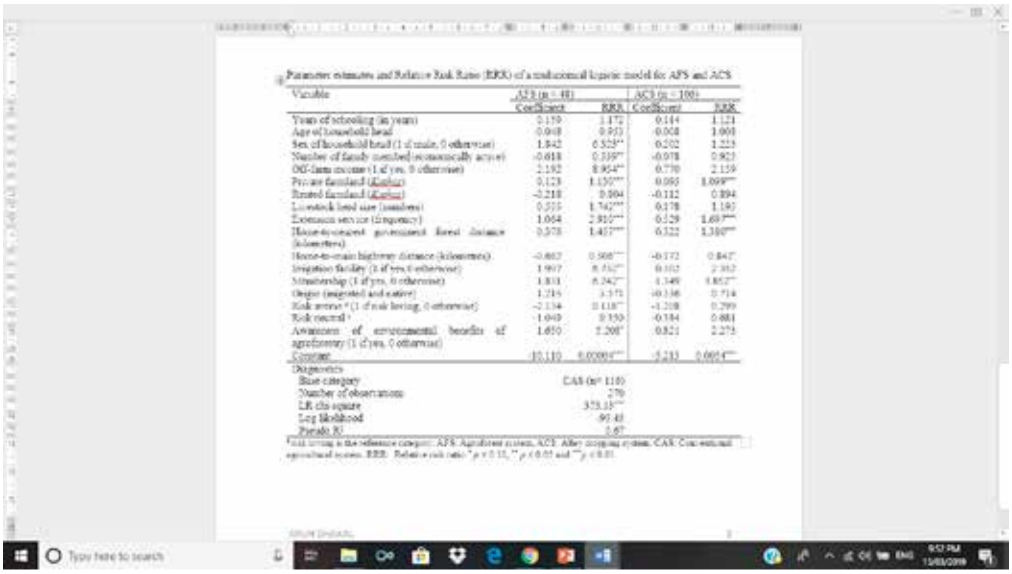
L13.1_O.03

Examining the likelihood of agroforestry adoption with respect to conventional agriculture in Dhanusha district of Nepal

Dhakal A.[1] (arun_dhakal2004@yahoo.com), Rai R. K.[2]

[1] *Nepal Agroforestry Foundation, Kathmandu, Bagmati, Nepal*; [2] *SANDEE, Kathmandu, Bagmati, Nepal*

Land degradation has reduced agricultural productivity in Nepal's terai. This has raised concern over the viability of conventional agriculture of the terai farming system. Agroforestry can be a potential solution to the above problem. This paper aims at identifying socio-economic constraints affecting adoption of agroforestry with respect to conventional agriculture. Data were collected from a survey of 288 households through a face-to-face interview. A multinomial logistic regression (MNL) was run with conventional agriculture as a base category. It was found male-headed households are more likely to adopt agroforestry. Having a source of off-farm income also has a positive effect on adoption because off-farm income acts as a safety net in case of crop failure. Landholding size was found as a major constraint to adoption. Sparing a part of farmland for tree planting means reducing field crop production and thus failing to meet annual food needs of smallholder farmers. Some other variables affecting positively include livestock herd size, provision of extension service, home-to-nearest government forest distance, membership and awareness of farmers about environmental benefits of agroforestry. Irrigation is another constraint that has stopped farmers from promoting a tree-based farming system. Home-to-highway distance, family size (economically active family members) and risk-averse have significantly negative effects on adoption of a tree-based farming system.



Parameter estimates and Relative Risk Ratio (RRR) of a multinomial logistic model for AFS and ACS

Variable	AFS (n = 48)		ACS (n = 100)	
	Coefficient	RRR	Coefficient	RRR
Years of schooling (in years)	0.159	1.172	0.114	1.121
Age of household head	-0.048	0.953	0.008	1.008
Sex of household head (1 if male, 0 otherwise)	1.842	6.323**	0.202	1.223
Number of family member (economically active)	-0.618	0.539**	-0.078	0.925
Off-farm income (1 if yes, 0 otherwise)	2.192	8.954**	0.770	2.159
Private farmland (Kattha)	0.123	1.130***	0.095	1.099***
Rented farmland (Kattha)	-0.218	0.804	-0.112	0.894
Livestock herd size (numbers)	0.555	1.742***	0.178	1.195
Extension service (frequency)	1.064	2.910***	0.529	1.697***
Home-to-nearest government forest distance (kilometers)	0.378	1.457***	0.322	1.380***
Home-to-main highway distance (kilometers)	-0.682	0.506***	-0.172	0.842*
Irrigation facility (1 if yes, 0 otherwise)	1.907	6.732**	[illegible]	2.302
Membership (1 if yes, 0 otherwise)	1.831	6.242**	[illegible]	1.852**
Origin (migrated and native)	1.215	3.371	-0.336	0.714
Risk averse a (1 if risk loving, 0 otherwise)	-2.134	0.118**	-1.208	0.299
Risk neutral a	-1.049	0.350	-0.384	0.681
Awareness of environmental benefits of agroforestry (1 if yes, 0 otherwise)	1.650	5.208*	0.821	2.273
Constant	-10.110	0.00004***	-5.233	0.0054***
Diagnostics				
Base category	CAS (n= 110)			
Number of observations	270			
LR chi square	373.15***			
Log likelihood	-97.43			
Pseudo R²	0.67			

a Risk loving is the reference category. AFS: Agroforest system, ACS: Alley cropping system, CAS: Conventional agricultural system. RRR: Relative risk ratio. * p < 0.10, ** p < 0.05 and *** p < 0.01.

Keywords: Agroforestry, Adoption, terai farming system, multinomial logistic regression, Nepal.

References:

1. Deressa et al., 2009, Environmental Change, 248-255.
2. Dhakal et al., 2012, Agroforedtry Systems, 17-33.
3. Dhakal et al., 2015, Agroforestry Systems, 645-661.
4. Chinanu, 2002, Agroforestry Systems, 99-112.
5. Mercer, 2014, Agroforestry Systems, 311-328.

L13.1_O.04

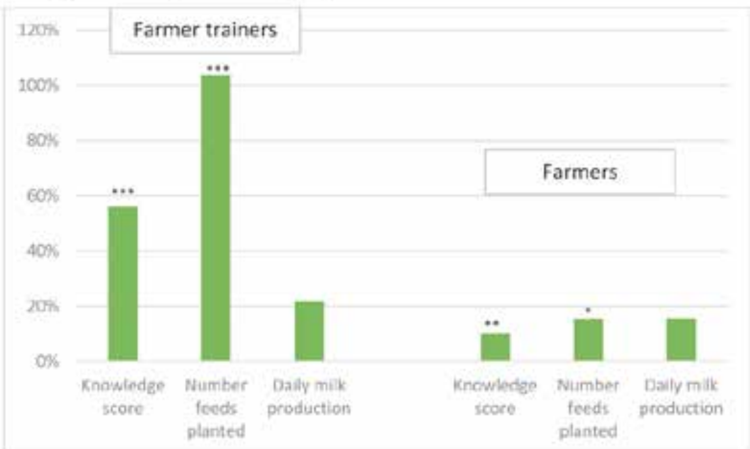
Making extension work: a field experiment on community-based training to agroforestry dairy feeds in Uganda

Gignoux J. (jeremie.gignoux@psemail.eu), Behaghel L., Macours K.

Paris-Jourdan Sciences Economiques, INRA, Paris, France

Cost-effective approaches are needed to provide extension services to smallholders in Sub-Saharan Africa and other developing regions. Waterfall models, with voluntary community-based farmer trainers (VFTs) training their fellow farmers, are promising, but rigorous quantitative evidence is lacking. We consider a VFT extension intervention implemented by the World Agroforestry Center (ICRAF) in Near-East Uganda and diffusing agroforestry techniques, such as fodder shrubs and associated cattle management practices, for improving dairy feeds. Using randomized controlled trials, in co-experimentation with ICRAF, we evaluate the impacts of the program, and three variations of it increasing the access to information, publicity, and non-monetary incentives of VFTs. We collect data on a sample of 600 VFTs (in as many villages) and 2400 fellow farmers, before the start of the intervention and 1.5 and 2.5 years after. We also use monitoring and qualitative data. VFTs are active. The program increases considerably the knowledge of VFTs but also of their fellow farmers (not all of whom have attended trainings) (Figure 1). This translates into the adoption of promoted practices and higher milk yields. This relatively low-cost extension scheme thus leads to information on agro-forestry techniques diffusing along the targeted transmission chain. Variations linking VFTs to professional extension agents and advertising their trainings increase impacts on fellow farmers.

Figure 1: Impact of the program on farmer trainers and farmers



Note: Being trained as a farmer trainer increased one's knowledge score by 56% in a knowledge test on feeds and beneficial feeding practices; living in a village with such a farmer trainer increased knowledge scores by 10%. ***: significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Keywords: Extension, Community-based, Adoption, Dairy feeds, Impact assessment.

L13.1_O.05

The (un)broken promise of agroforestry: case study of adoption of improved fallows in Zambia

Jacobson M.[1] (mgj2@psu.edu), Ham C.[2]

[1] *Ecosystem Science and Management, Penn State, University Park, PA, United States*; [2] *Forest and Wood Science, Stellenbosch University, Stellenbosch, South Africa*

Soil fertility replenishment, through improved fallows, was a key achievement showing the "promise of agroforestry" (Sanchez 1999). The World Agroforestry Centre (ICRAF) was extremely active in eastern Zambia, carrying out extensive research and promotion of fertilizer trees for soil replenishment from 1986 until it ceased operations in 2006 (Ajayi et al. 2006). With partners, ICRAF established a scaling-up team to promote adoption of improved fallows (Kabwe 2010). By 2006, it was estimated that over 61,000 Zambian farmers were "reached" with improved fallow technologies. Today, improved fallows are virtually nonexistent in Zambia. To understand what happened, a "process tracing" approach was used to examine the causal relations of fertilizer tree uptake in Zambia (Collier 2011). According to data from a 2015 national Rural Agricultural Livelihoods Survey, "agroforestry" is practiced by about 5% of households in Zambia and very few use fertilizer trees (Table 1). ICRAF left a "vacuum" and "gap" in agroforestry in Zambia. There has not been a "sense of ownership" by the government, r other entities to agroforestry. This paper discusses institutional and policy factors influencing adoption, including fertilizer subsidies, seed supply, land availability, extension capacity, top-down project approaches, donor demands, as well as a failure to understand farmer/household characteristics, and their knowledge, attitudes toward both the technology and its perceived returns and risks.

Table 1. Percentage of households (HHs) growing fertilizer trees (by province)
Source: IAPRI 2016

Province	Farm HHs (%)	HHs having a fertilizer tree (%)	% of HHs growing trees				
			Faidherbia albida	*Gliricidia sepium*	*Sesbania sesban*	*Cajanus*	*Leucaena*
Central	8.19	25.35	25.35	0.00	0.00	0.00	0.00
Copperbelt	6.92	3.13	2.08	0.00	1.04	0.00	0.00
Eastern	8.72	25.97	21.89	2.95	0.81	0.92	0.20
Luapula	9.97	21.43	0.00	0.00	7.14	14.29	0.00
Lusaka	6.50	21.26	21.26	0.00	0.00	0.57	0.00
Muchinga	11.26	59.38	59.38	0.00	0.00	0.00	0.00
Northern	7.78	3.28	0.55	0.00	1.64	1.09	0.00
Northwestern	26.00	4.80	0.00	0.00	4.00	0.80	0.00
Southern	9.04	22.95	22.55	0.20	0.00	0.20	0.00
Western	5.62	20.00	20.00	0.00	0.00	0.00	0.00
Total	100	21.76	19.19	1.35	0.81	0.72	0.09

Keywords: adoption, improved fallows, fertilizer trees, impact evaluation, Zambia.

References:

1. Sanchez, P. (1999). Environment, Development and Sustainability 1:275-284.
2. Ajayi, O., Place, F., Kwesiga, F. & Mafongoya, P. (2006). World Agroforestry Centre (Paper #5)
3. Collier, D. (2011). Political Science and Politics, 44(4), 823-830.
4. Kabwe, G. (2010). Ph.D. Thesis, Lincoln University.
5. IAPRI. (2016). Indaba Agricultural Policy Research Institute. Lusaka, Zambia.

L13.1_O.06

Factors influencing the adaption of agroforestry systems in mitigating climate change in Ghana: Case of Bongo District

Nunoo I. (nunooisaac85@yahoo.com)

Agric Economics, Agribusiness & Ext, Kwame Nkrumah University of Sci. & Tech, Kumasi, Ghana

Growing public awareness on the impact of global climate change has necssitated the need to embrace agricultural alternatives that move away from fossil fuels and promote a more responsible, sustainable and resilient relationship with the land. The response of farmers' to climate change is very crucial because the success of agriculture especially rain-fed agriculture depends on climatic conditions. The use of trees and shrubs in agricultural systems help to tackle the triple challenge of securing food security, mitigation and reducing the vulnerability and increasing the adaptability of agricultural systems to climate change. Nair (2009) also indicated that agroforestry has received international attention as an effective strategy for carbon sequestration and greenhouse mitigation.The decisions to adopt new technologies are influenced by the range of factors from government policies, technological change, market forces, environmental concerns, demographic factors, institutional factors and delivery mechanism. The objectives of this study are therefore to empirically assess factors that directly affect farmers' decision to adopt agroforestry systems, determine how farmers perceive agroforestry as an adaptation strategy to climate change and access how farmers cope with challenges encountered in agroforestry. The study was carried out in the Upper West Region of Ghana. A multi stage sampling technique was employed to selected 300 households in the study area. To examine the factors that influence a household's decision to participate in agroforestry a logistic regression model was employed. Results showed that, within the last 30 years, farmers observed some impacts of climate change in the study communities. With regards to drought, overwhelming 98% of farmers reported the occurrence of drought in the study area and linked it to climate change. They realized that rainfall is becoming poor in terms of its amounts and distribution. 95 percent of farmers were in support of this claim loss of soil fertility really affected farming activities.Despite the naturally retained trees, farmers have intentional planted and tend trees as well. Farmers' adaption decisions were found to be influenced by several varying factors. The factors of adoption decision included farming experience, agricultural land size, belonging to farmer association, access to extension services, awareness of climate change, and experience in farming. It therefore recommended that Agricultural Extension Officers should make use of farmers' indigenous knowledge on climate change but not just view them as users of knowledge. There is the need for effective provision of extension services to increase tree and food crop interaction on farmers' yield through farmer field school programs. Farmer based organizations should be established to facilitate farmers' access to information about technical issues of agroforestry systems and its role in combating climate change.

Keywords: Agroforestry, Adaption, Climate Change, Ghana, Food security.

References:

1. Nair, P. K. (2009). J. Plant Nutr. Soil Sci., 172, 10–23.

L13.1_O.07

Agroforestry at the crossroads of fields

Labant P. (pierre.labant@gmail.com)

Quercy Forêt, Les Quatre Routes du Lot, France

Although the value of agroforestry has been repeatedly demonstrated by the scientific community and many policies are being implemented for its development, adoption rates remain relatively low in intensive agricultural areas. How can we explain this contrast between the enthusiasm of scientists and politicians for agroforestry and the lack of interest in it among conventional farmers and foresters ?
This contribution is based on Pierre Labant's doctoral thesis and his experience as an agroforestry contractor working with farmers and landowners. The aim is to show that the hybrid status of agroforestry, both agricultural and forestry, without being truly agricultural or forestry, works against the adoption of agroforestry.
Pierre Bourdieu's theory of social fields serves as a support for the demonstration. Agroforestry is indeed located outside the social agricultural and forest fields and, as a result, it is difficult to impose itself on the conventional actors in these fields.
As long as the «dispositif», in the Foucauldian sense, aimed at the development of agroforestry does not take into account the influence of social agricultural and forest «social fields» (the socio-cultural values and practices in agriculture and forestry), the development of this practice will not be able to integrate the hybrid nature of agroforestry into the practice of agricultural and forest occupations.

Keywords: Agroforestery, Adoption, Social Fields, Habitus, Dispositif.

References:

1. Labant P., 2017, Le dispositif spatial agroforestier à la croisée des champs, Thèse, UTJJ, 341 p.
2. Bourdieu P., 1992, Les règles de l'art, Seuil, 480 p.
3. Foucault M., 1977, Dits et Ecrits, Gallimard, pp. 62-93

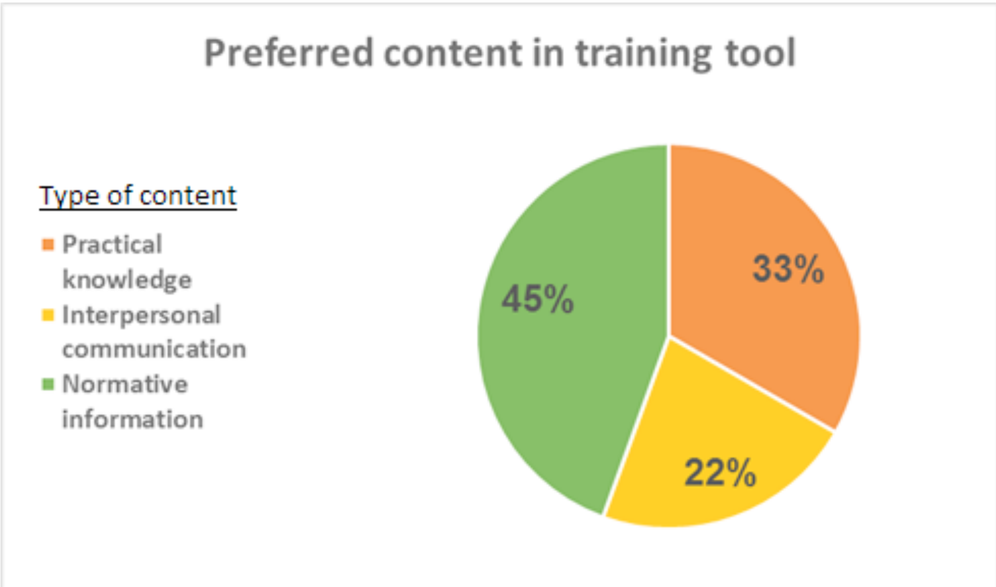
L13.1_O.08

Social marketing of agricultural practices supporting biodiversity conservation

Israely L.[1] (lironisraely@mail.tau.ac.il), Amdur L.[2], Dayan T.[3]

[1] *Zoology, Tel Aviv University, Tel Aviv, Israel*; [2] *The Steinhardt Museum of Natural History, The Open Landscape Institute (OLI), Tel Aviv, Israel*; [3] *The Steinhardt Museum of Natural History, Tel Aviv University, Tel Aviv, Israel*

Encouraging farmers to adopt new practices is social challenge, as agricultural practices such as agroforestry brings multiple environmental & social benefits (Torralba, 2016). Social marketing is a strategic marketing scheme set for promoting social values using commercial marketing tools (Verissimo, 2013). The aim of the study at hand was to develop and evaluate framer's training tool set to encourage the use of agricultural practices supporting biodiversity conservation in Israel. We used mixed model of qualitative and quantitative methods, in 3 stages: (1) Content analysis for mapping the social marketing environment: The farmers, The agricultural practices, and the training tool itself. (2) Development of an online training tool. (3) A field research to evaluate the training tool, together with a farmer association. Stage 1 identified that farmers lack practical knowledge on biodiversity in agriculture, they lack normative information and interpersonal communication on the subject. Stage 2 was able to create an online training tool. Stage 3 identified that farmers consume training content on diverse characteristics (82%) and not only scientific knowledge. They are much more attracted to normative information (45%), and value interpersonal communication (33%) when choosing new practices. Therefore, we concluded that when perusing the assimilation of new agricultural practices, we should work on multiple communication channels, such as social marketing can develop.



Keywords: Agricultural practices, Biodiversity conservation, Social marketing, Social norms.

References:

1. Torralba et al., 2016, Agriculture Ecosystems & Environment 230:150-161, DOI: 10.1016/j.agee.2016.06
2. Verissimo, 2013, Conservation Evidence (2013) 29-31

L13.1_O.09

Agroforestry Extension and Gender Impacts on Self Rated Knowledge

Duffy C.[1] (colm.duffy@nuigalway.ie), Toth G.[2], Murray U.[1], Spillane C.[1]

[1] *Plant & AgriBiosciences Department, National University of Ireland, Galway, Galway, Galway, Ireland*;
[2] *Forest Resources & Conservation, University of Florida, Gainsville, Florida, United States*

Numerous extension efforts attempt to promote climate smart agriculture (CSA) practices in Sub-Saharan Africa. The need to address any gender disparities within such CSA dissemination efforts is widely recognised (Bernier et al. 2015; Chanana-Nag and Aggarwal 2018; Duffy et al. 2017; Twyman et al. 2014). Given the high numbers of female farmers in Malawi, gender-sensitive CSA dissemination and adoption has the potential contribute to sustainable rural development. Here, we quantify approaches for maximizing such potential through comparison of different extension approaches, including lead farmers, non-governmental organization (NGO) trainers, and farmer clubs. We applied ordered logistic regression to data regarding post-extension increases in self-assessed CSA knowledge levels. Male farmers achieved the greatest perceived increases in knowledge through traditional extension means, such as NGO trainers and farmer clubs. While female farmers also achieved perceived increases in knowledge through traditional sources, the knowledge gains were less than those of male farmers. In addition, the interaction of female farmers with lead farmers (i.e. community members trained to train others) made increases in knowledge much more likely. However, the overall impact of lead farmers is constrained by their limited range and availability. While women who received lead farmer visits were more likely to report high levels of agroforestry knowledge retention post-extension, the majority of female participants received no such visits. These findings correspond with the literaure in several ways, including the efficacy and limitations of lead farmers (Toth et al. 2017). Our results can inform more effective approaches for improving CSA extension effectiveness, such as: training more female extension agents, including improving the extent of sensitivity to the needs of female farmers in extension agent training, and coordination of specialized women's groups for the purposes of serving as their own farmer clubs and centralizing receipt of formal extension (thereby increasing confidence and reducing nominal and passive participation).

Keywords: Gender, Climate Smart Agriculture, Agroforestry, Extension, Logistic Regression.

References:

1. Bernier Q et al. (2015) Gender and Institutional Aspects of Climate-Smart Agricultural Practices: Ev
2. Chanana-Nag N, Aggarwal PK (2018) Woman in agriculture, and climate risks: hotspots for development
3. Duffy C et al. (2017) National level indicators for gender, poverty, food security, nutrition and he
4. Toth GG, Nair PR, Duffy CP, Franzel SC (2017) Constraints to the adoption of fodder tree technology
5. Twyman J et al. (2014) Gender and Climate Change Perceptions, Adaptation Strategies, and information

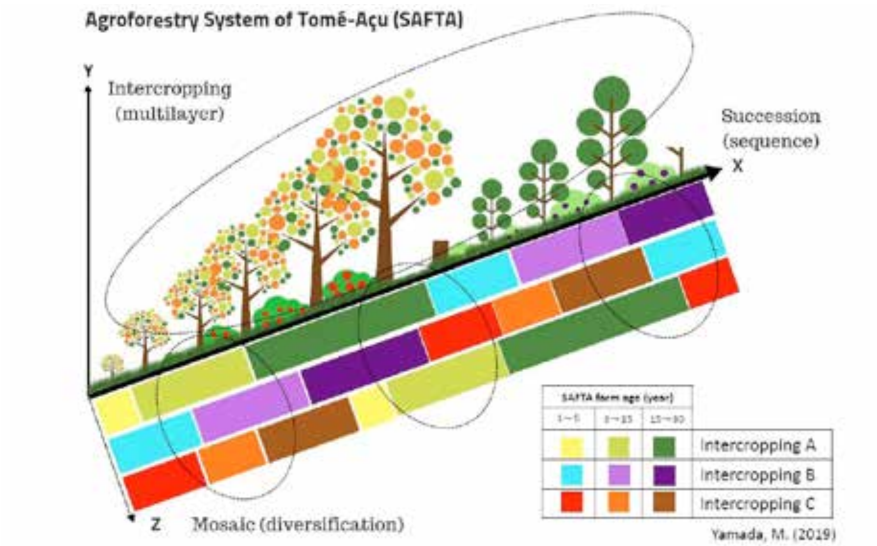
L13.1_O.10

How can we accelerate shade tree planting on West African cocoa family farms for mitigating the rapid climate change?

Yamada M.[1] (masaakiy@cc.tuat.ac.jp), Nkansah G. O.[2], Tamura Y.[3], Owusu E. O.[2], Taguchi M.[4], Kagami S.[1], Fujiwara K.[5], Hoshikawa A.[1], Umemura H. M.[1], Mihara K.[6], Boliko M. C.[6], Bert B.[4], Chitose A.[1]

[1] *Institute of Agriculture, Tokyo Univ of Agriculture and Technology, Fuchu, Tokyo, Japan*; [2] *University of Ghana, Accra, Ghana*; [3] *Ohayo Ghana Foundation, Accra, Ghana*; [4] *Plant Production and Protection Division, Food and Agriculture Organization, Rome, Italy*; [5] *Regional Office for Africa, Food and Agriculture Organization, Accra, Ghana*; [6] *Liaison Office in Japan, Food and Agriculture Organization, Yokohama, Japan*

Planting tall 'economic trees' in cocoa plantations has been recommended for the West African family farms to mitigate climate changes. The trees cast moderate shade over cocoa plantations and cool down air temperature by 4˚C (Schroth G et al 2016), while 2˚C rise of average air temperature is anticipated from 2010 to 2050, with the extended dry spells that may diminish conventional unshaded cocoa farms to 1/5 of the area productive as of 2010 (CIAT 2011). However, under the traditional land tenure arrangements farmers will not plant 'economic trees' for shading cocoa. The tall trees may not only compete with cocoa trees for light, water and nutrients, but also attract chiefs holding free timber harvest rights in his territory by felling farmers' cocoa trees beneath. While the registration and protection system of farmer-planted timber trees (O'Sullivan R et al 2018) may take long before prevailing nationwide, we have started testing non-timber fruit trees to shade cocoa plantations that may contribute to increased income of both farmers and chiefs, do not weaken cocoa trees in dry periods, and do not attract timber sales. We have planted a total one ha in two locations of Ghanaian Eastern Region, demonstration farms of successional agroforestry developed by Japanese immigrants in the Brazilian Amazon (SAFTA). This paper discusses our interdisciplinary and integrated research-education-extension efforts trying to modify SAFTA to be fitted to West African cocoa family farms.



Successional agroforestry system of Japanese-Brazilians in the Amazon (SAFTA)

Keywords: small farm, climate adaptation, land rights, Theobroma cacao, Spondias mombin.

References:

1. CIAT, 2011. Predicting the Impact of Climate Change on Cocoa Growing Regions..29pp.
2. O'Sullivan R et al, 2018. Annual World Bank Conference on Land and Poverty.. 27pp.
3. Schroth G et al, 2016. Total Environment 556: 231–241.

L13.2_O.01

Transdisciplinary approaches to commercialising indigenous agroforestry trees: *Canarium indicum* in the Pacific

Wallace H.[1] (hwallace@usc.edu.au), Hannet G.[2], Hannet D.[2], Kapi S.[2], Waai C.[2], Kill E.[3], Hodges B.[3], Jones K.[4], Simos T.[5], Johns C.[6], Hosseini Bai S.[7], Nevenimo T.[2]

[1] *Genecology Research Centre, University of the Sunshine Coast, Maroochydore DC, Qld, Australia*; [2] *Islands Regional Centre – Keravat, National Agricultural Research Institute, Kerevat, East New Britain Province, Papua New Guinea*; [3] *University of the Sunshine Coast, Maroochydore DC, Qld, Australia*; [4] *Cropwatch Independent Laboratories, Wardell, NSW, Australia*; [5] *Centre for Global Food and Resources, University of Adelaide, Adelaide, SA, Australia*; [6] *Centre for Global Food and Resources, University of Adelaide, Adelaide, NSW, Australia*; [7] *School of Medical and Applied Sciences, Central Queensland University, Bundaberg, Qld, Australia*

Nut trees in agroforestry systems have huge potential to enhance food security and improve livelihoods in developing countries. Indigenous nut trees provide food, shade and timber and provide environmental benefits. Nuts have excellent nutritional value, and can be processed and packed for distant markets. Many indigenous nut species have great potential to be sold commercially. However, only five species of nuts make up 90% of world trade, even though global demand for and consumption of nuts has doubled in the last decade. We report on a series of Australian Centre for International Agricultural Research projects focused on creating new nut industries from Canarium indicum (galip), an indigenous agroforestry tree in the Pacific. We adopted a transdisciplinary research approach with scientists, social researchers, markets specialist, and macadamia nut industry experts to address the barriers to adoption. The most critical barrier to adoption was the need to demonstrate market demand for the canarium products. Other major barriers were the need for processing technology, and lack of investment by smallholders and processors. We conducted research on processing technology, set up a pilot factory and tested the market demand for canarium nuts in Papua New Guinea. Over 2000 smallholders are now participating in the emerging canarium industry in Papua New Guinea. This new industry has already improved livelihoods of smallholder farmers in both Vanuatu and PNG.

Smallholders delivering Canarium indicum nuts to the pilot factory

Keywords: Value-adding, smallholders, processing, nuts, market.

L13.2_O.02

Connecting the Dots: Understanding Factors Influencing Smallholders' Participation in Microcredit for Agroforestry

Fauzi D.[1] (Dimas.Fauzi@wri.org), Wicaksono S. A.[2]

[1] *Social Forestry, World Resources Institute Indonesia, Jakarta Selatan, DKI Jakarta, Indonesia*; [2] *Forests and Oceans, World Resources Institute Indonesia, Jakarta Selatan, DKI, Indonesia*

Community forest (HKm) Beringin Jaya in Lampung, Indonesia has been known as one of the most successful social forestry groups in the country. Our previous study, for instance, showed that HKm Beringin Jaya has been experiencing a decreased tree cover loss rate and welfare contribution from coffee-based plantations within the forest after the permit was granted to smallholders for coffee cultivation. With a high dependency on coffee-based agricultural production, smallholders were incentivized with microcredit access from the Ministry's general service bureau (BLU) to plant nutmeg trees and enhance agroforestry practice. We conducted a random survey of 149 households registered as HKm Beringin Jaya's members to gather various data on social forestry implementation, including income, savings, credit and perception. In addition to a quantitative household survey, in-depth interviews and FGD were also conducted to complement the quantitative data. Although our qualitative analysis suggests that nutmeg price and low interest rates could drive smallholders to access credit, logistical regression analysis shows that education level, land size, water quality perception and BLU credit awareness also influence one's decision to take BLU credit. These findings indicate that incentives to promote agroforestry through microcredit should not only consider potential economic gains, but awareness-raising on agroforestry practice and credit access should also be taken into account.

Logistic regression — Number of obs = 149; Wald chi2(10) = 48.43; Prob > chi2 = 0.0000; Log pseudolikelihood = -65.672727; Pseudo R2 = 0.3509

CreditAccess	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Education	.4759946	.2511731	1.90	0.058	-.0162955	.9682848
HouseholdSize	.3225789	.2136253	1.51	0.131	-.096119	.7412768
landsize	.7956126	.3677962	2.16	0.031	.0747453	1.51648
Income	1.50e-08	1.96e-08	0.77	0.444	-2.34e-08	5.34e-08
SavingRatio	.0444808	.0743162	0.60	0.549	-.1011763	.190138
DebtRatio	-5.20e-07	8.54e-07	-0.61	0.543	-2.19e-06	1.15e-06
EconomicHardship	.206983	.3386949	0.61	0.541	-.4568468	.8708128
WaterQuality	-.9676514	.3667629	-2.64	0.008	-1.686494	-.2488093
CreditAwareness	3.694888	.73683	5.01	0.000	2.250728	5.139048
TenurialSecurity	1.067478	.8772315	1.22	0.224	-.6518642	2.78682
_cons	-6.365752	3.477898	-1.83	0.067	-13.18231	.4508027

Logistic Regression Results

Keywords: Smallholder, agriculture, community forestry, microcredit, agroforestry.

References:

1. Anang et al, 2015, African Journal of Agricultural Research, 2460-2469.
2. Anyiro & Oriaku, 2011, The Journal of Agricultural Sciences, 69-76.
3. Temesgen et al, 2018, Journal of Agricultural Economics and Development, 007-012.
4. Lemessa & Gemechu, 2016, International Journal of Africal and Asian Studies, 43-53.
5. Muba et al, 2018, International Journal of Agricultural Extension and Rural Development, 622-627.

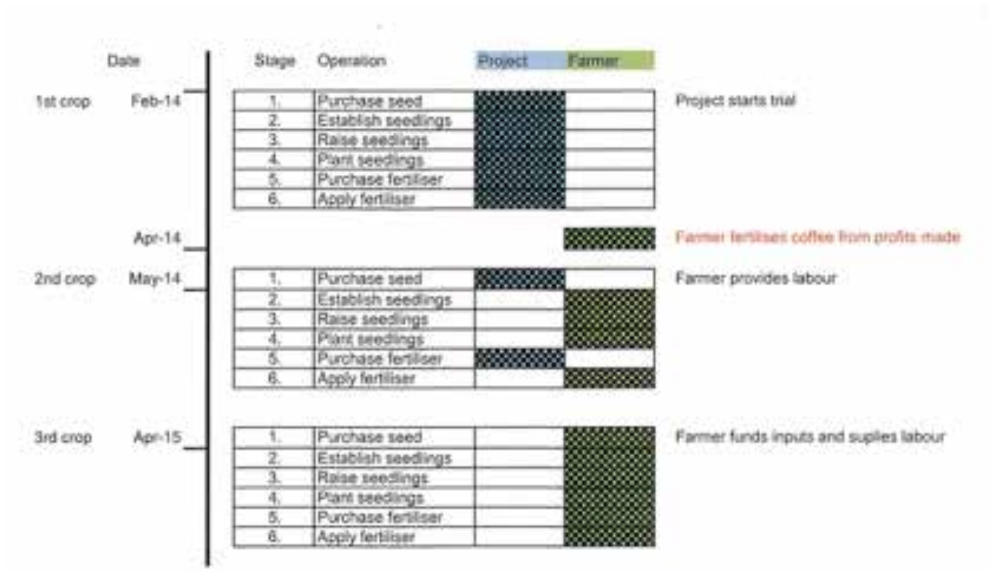
L13.2_O.03

Adoption of coffee-vegetable intercropping intervention by farmers in the highlands of Papua New Guinea

Kiup E.[1] (emma.kiup@my.jcu.edu.au), Webb M.[2], Apis B.[1], Togonave P.[1], Pakatul J.[3]

[1] *Research and Grower Services, PNG Coffee Industry Corporation, Kainantu, Eastern Highlands Province, Papua New Guinea*; [2] *Agriculture & Food, CSIRO, Townsville, Queensland, Australia*; [3] *National Agricultural Research Institute, Aiyura, Eastern Highlands Province, Papua New Guinea*

Intercropping annual food crops in coffee gardens is sometimes done in an *ad hoc* manner (usually without added fertilizer) in order to provide additional food for the household. The objective of this research was to study the adoption of formalised intercropping of coffee with vegetables in a way that improves the nutrition and yield of coffee through its juxtaposition and thus access to nutrients applied to those vegetables. The trials were conducted on-farm to maximise farmer participation and to test the research concepts under real conditions.
The uptake of formalised intercropping was successful in Asaro because farmers were already familiar with this concept as they were already practising *ad hoc* intercropping because of land shortage issues. However, in Bena it was less successful as it was a new concept and was adopted by only one farmer (who had secured a market for his vegetable produce) (Fig 1). One reason for the initial lack of adoption is clear; namely, limited funds to support the technology even though it can have financial benefits in the future.
Increased production leads to increased incomes thus providing resources to further increase vegetable production and improve nutrient management strategies for both coffee and vegetables. However, the adoption of such technologies is minimal and needs more research to identify the gaps for better intervention. This paper explores the various reasons for adoption or non-adoption of intercropping technologies.



Adoption of intercropping by a farmer in Bena. Coloured bars indicate the operations performed by the project staff and the farmer.

Keywords: intercropping, coffee, vegetables, nutrition.

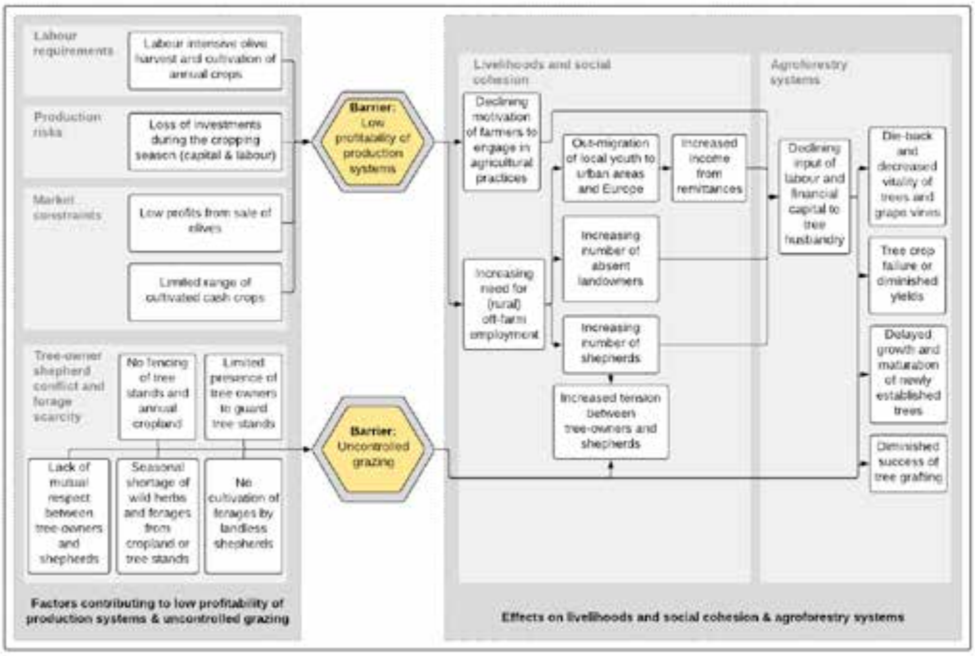
L13.2_O.04

Local agroecological knowledge reveals adoption barriers and options for tree-based diversification in northern Morocco

Kmoch L.[1] (kmoch@chalmers.se), Pagella T.[2], Palm M.[1], Sinclair F.[3]

[1] *Chalmers University of Technology, Gothenburg, Sweden*; [2] *Bangor University, Bangor, United Kingdom*; [3] *World Agroforestry Centre, Nairobi, Kenya*

Moroccan communities are vulnerable to increasing water scarcity and food insecurity. Context specific adaptation options thus need to be identified to sustain livelihoods and agroecosystems in this region, and increase the resilience of vulnerable smallholders and their farming systems, to undesired effects of social-ecological change. This study took a knowledge-based systems approach to explore whether and how agroforestry options could contribute to meeting these adaptation needs. We analysed local agroecological knowledge of smallholders from the Mèknes–Tafilalet region, to (i) characterise existing farming systems at local landscape scale; (ii) identify possible niches for farm-trees within these systems; and (iii) explore locally perceived barriers to tree-based diversification. An iterative cycle of qualitative interviews with 32 farmers, revealed that socio-economic constraints and agroecological conditions in the area differed markedly along a relatively short altitudinal gradient. Agroforestry practices were already integral to all farming systems. Yet, many were at risk of degradation, as water scarcity, low profitability of production systems and uncontrolled grazing constituted critical barriers to the maintenance and diversification of farm-trees. We demonstrate the discriminatory power of local knowledge, to characterise farming conditions at the local landscape scale; and unveil adoption barriers and options for tree-based diversification in northern Morocco.



Causal diagram illustrating local knowledge about low profitability of production systems and uncontrolled grazing as barriers to agroforestry

Keywords: local agroecological knowledge, agroforestry, adoption, climate adaptation, Morocco.

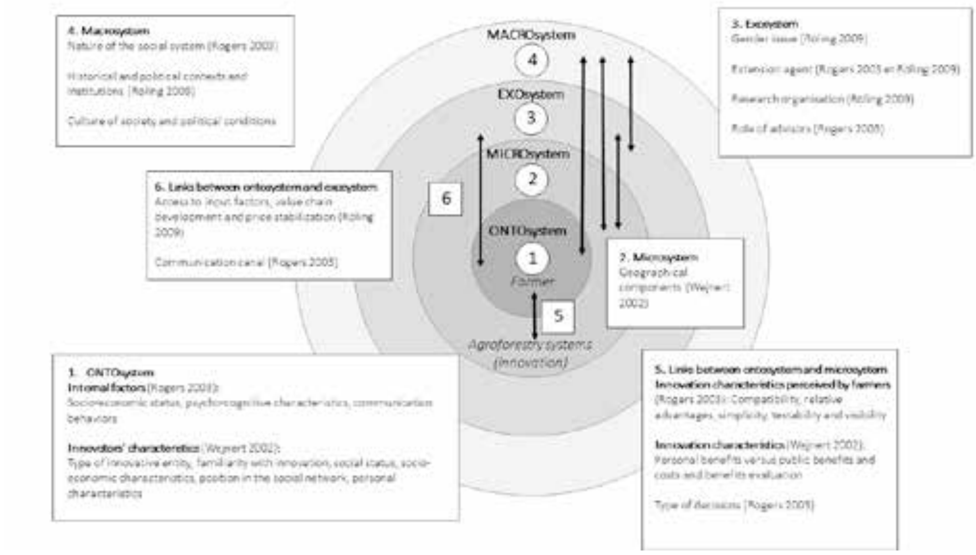
L13.2_O.05

Adoption factors of agroforestry systems: a new conceptual framework

Gelinas N.[1] (nancy.gelinas@sbf.ulaval.ca), Houde-Tremblay É.[2], Olivier A.[3]

[1] *Sciences du bois et de la forêt, Université Laval, Québec, Québec, Canada*; [2] *École supérieure ATDR, Université Laval, Québec, Québec, Canada*; [3] *Phytologie, Université Laval, Québec, Québec, Canada*

Agroforestry systems generate economic, environmental, social and cultural benefits. These benefits are relatively well documented. But before farmers can gain from such benefits, they must adopt agroforestry. Agroforestry projects often face social and economic complexities that animate rural communities, but which can hinder their adoption. At Université Laval, student researchers have shed light, through case studies, on the relationship between agroforestry systems and socio-economic realities. Our study aims to analyze the results obtained by these student research studies and to develop a new conceptual framework for the adoption of agroforestry systems. Through a review of student essays, dissertations and theses on various agroforestry systems carried out at Université Laval and the exploration of trends according to predetermined geographical areas (Central America, South America, West Africa, Central Africa and East Africa), we propose a new conceptual framework based on Johns (2017), and inspired by Rogers (2003), Wejnert (2002) and Röling (1985, 2009). This new conceptual framework, centered on the farmer, makes it possible to understand the transition in farmers' practices, and this, linked to the relations that they maintain with the different systems (macro, exo, micro and onto). Our results show that broad categories of adoption factors may vary by geographic region. However, our conceptual framework will guide future agroforestry interventions and extension.



Conceptual framework to analyse adoption of agroforestry interventions (Johns, 2017)

Keywords: Agroforestry, Adoption, Conceptual framework, Case studies.

References:

1. Johns, K, 2016, Master thesis, Université Laval, 195 p.
2. Rogers, E. M., 2003, Diffusion of innovations. 5e édition. Free Press, New York. 551 p.
3. Röling, N., 1985, Sociologia Ruralis 25 (3-4): 269-290.
4. Röling, N., 2009, International Journal of Agricultural Sustainability 7 (2): 83-94.
5. Wejnert, B., 2002, Annual Review of Sociology 28: 297–326.

L13.2_O.06

Why Farmers Adopt Agroforestry in the Philippines? Implications for Developing Agroforestry Policies

Landicho L. (ldlandicho@gmail.com)

Institute Of Agroforestry, University of the Philippines Los Banos, College, Laguna, Philippines

The need to address socioeconomic and environmental conditions in the upland area in the Philippines, necessitate the introduction of agroforestry technologies. Agroforestry is the main production technology that is integrated in the country's sustainable forest management programs. In spite of these, however, the sustained adoption of agroforestry remains a challenge. This article argues that socioeconomic characteristics of the farmers, particularly age and income, as well as policies are the main determinants in the farmers' choice of adopting agroforestry and conservation farming practices. This argument is based on a study conducted in three upland farming communities in the Philippines, involving a survey of 230 farmer-respondents, nine sessions of focus group discussion, key informant interviews and farm visits. Results revealed five dominant development pathways that exist in the upland farming communities, namely: monocropping + conservation practice (Pathway 1); multiple cropping + conservation practice (Pathway 2); agroforestry (Pathway 3); agroforestry+non-farm activities (Pathway 4); and, multiple cropping without conservation practices (Pathway 5). From monocropping in the 1990s to early 2000, the upland farmers have shifted to crop diversification from the mid 2000 to 2016 at the time of the study. The shift was driven by internal stimuli such as the need for households' source of food and income, as well as external stimuli such as development programs, and climatic variability. Results of the multinomial logistics regression revealed that age (p=0.020), income (p= 0.001) and policies (p=0.011) are the main determinants in the farmers' choice of adopting agroforestry and conservation practices. Specifically, as the income of the farmers engaged in Pathways 1, 2 and 4 increases, they would prefer these pathways rather than Pathway 3. Agroforestry requires the integration of two or more crops, with woody perennials, which imply the need for additional capital to invest on planting materials, farm inputs and labor costs. Similarly, older farmers engaged in Pathways 2 would choose these pathways over Pathway 3. The woody perennial components of the agroforestry systems take about at least seven years before they bear fruit. This may not be favorable among the older farmers because of the perception that they would not have immediate economic benefits from these species. The mean predicted probabilities suggest that there is 13% probability that farmers would choose Pathway 1; 5% would choose Pathway 2; 29% would choose Pathway 3; 52% would prefer Pathway 4 and 1% would choose Pathway 5. These results imply the need to emphasize the ecological services of agroforestry besides its economic contributions, and review the mechanisms of incentivizing and providing support system to farmers engaged in agroforestry, among others. Thus, there is a need to revisit and formulate sound national and local agroforestry policies.

Keywords: climate change, adoption, upland farming, pathways, policies.

L13.2_O.08

Drivers of farmers' decisions to adopt agroforestry: Evidence from the Sudanian savanna zone, Burkina Faso , West Africa

Sanou L.[1] (lassina.sanoulassina@gmail.com), Savadogo P.[2], Ezebilo E. E.[3], Thiombiano A.[4]

[1] *Département Environnement et Forêts, CNRST, Koudougou, Burkina Faso, Burkina Faso*; [2] *World Agroforestry Centre (ICRAF), Bamako, Mali, Mali*; [3] *Property Development Program, National R, Boroko, Port Moresby, Papua New Guinea, Papua New Guinea*; [4] *Biologie et Ecologie Végétales, Université Ouaga I Pr Joseph Ki-Zerbo, Ouagadougou, Burkina Faso, Burkina Faso*

In most developing countries, there has been a long-standing conflict of interest between using land for agriculture and the conservation of biodiversity. This paper reports on a study of factors influencing farmers' decisions to incorporate trees into their agricultural practice. We also discuss the possibility of protecting and managing trees on farmland in order to restore degraded land and improve biodiversity. The data were collected from personal interviews conducted with farmers in the Center-West region of Burkina Faso and analyzed using Principal Component Analysis, multiple linear regression and binary logistic regression. The results showed that farmers' decisions to incorporate trees into their farmland were mainly influenced by silvicultural knowledge and skills, participation in farmers' groups or other social organizations with an interest in tree conservation, the social value of biodiversity in the rural landscape and the perceived economic benefits of trees on farmland. The most important factors associated with variation in levels of motivation to conserve trees on farms included household wealth, gender, age, education level, marital status, residence status, farmland size, household size and technical support. We conclude that an agroforestry project will be more successful if the diversity of smallholder socio-economic characteristics and their perceptions are considered in its design.

Pictorial representation of typical agroforestry system: Vittelaria paradoxa parkland associated with sesame

Keywords: Climate smart agriculture, Agroforestry parkland, Factor and regression analysis, Rural households, Farmers' perception.

References:

1. Acharya, K.P., 2006. Linking trees on farms with biodiversity conservation in subsistence farming sy
2. Bayala, J., Sanou, J., Teklehaimanot, Z., Ouedraogo, S.J., Kalinganire, A., Coe, R. and Van Noordwij
3. Franzel, S., 1999. Socioeconomic factors affecting the adoption potential of improved tree fallows i
4. Kiptot, E. and Franzel, S., 2012. Gender and agroforestry in Africa: a review of women's participati
5. Sanou, L., Savadogo, P., Ezebilo, E. E. and Thiombiano, A. 2017. Drivers of farmer's decisions to ad

L13.2_O.09

The importance of farmers' attitudes for the adoption of agroforestry: a case study in India

Brockington J. (j.brockington@bangor.ac.uk), Hockley N., Brook R.

School of Natural Sciences, Bangor University, Bangor, Gwynedd, United Kingdom

The vast majority of agroforestry adoption studies only consider demographic and socio-economic variables in their analyses. While valuable, the focus on 'extrinsic' factors has neglected underlying psychological and motivational factors that are likely to influence farmer decision-making (Meijer et al. 2015). 'Intrinsic' factors – i.e. farmers' attitudes and beliefs – can be important in constraining or enabling adoption. This study sought to integrate conventional extrinsic factors with intrinsic factors in the analysis of farmers' intentions to adopt (or expand) fruit-based agroforestry systems on their land in the near future. The research took place in a hilly, impoverished, tribal-dominated area of western India. An NGO – BAIF Development Research Foundation – has been promoting agroforestry orchards ('wadi') in the region since 2000 as a means to sustainable intensification and diversification of land-use and livelihood systems.

A formal survey was conducted in nine villages; three villages were sites of BAIF's earliest project in the area, three were sites of an ongoing project, and three were sites where no project had been implemented. Of 143 households surveyed, 57 had participated in a BAIF project and 86 had not. The survey comprised two elements: (1) household socio-demographics and farm/livelihood characteristics, and (2) socio-psychological factors relating to intentions, attitudes, subjective norms and perceived behavioural controls regarding future orchard establishment/expansion. The research had two specific objectives: (1) to assess whether, and to what extent, inclusion of socio-psychological variables improved the capacity of regression models to predict future intentions towards orchard adoption; (2) to assess whether, and to what extent, differential exposure to an agroforestry intervention affected farmers' beliefs and intentions towards future adoption.

The first key finding from this study is that inclusion of socio-psychological variables in regression models significantly improved predictive capacity. Attitudes and perceived behavioural controls were strong predictors of future intentions towards orchard adoption. The second key finding is that farmers' beliefs and intentions towards future adoption varied markedly according to exposure to BAIF's interventions. Farmers who had participated in a BAIF project tended to have more positive beliefs and stronger intentions towards future orchard adoption than non-participant farmers. However, in the villages where BAIF had implemented a project long ago (>10 years), the beliefs and intentions of non-participants towards orchard adoption were notably stronger than those of non-participants in recent project villages and in villages where no intervention had occurred. This indicates that longer-term exposure to a new technology contributes to positive attitudes/beliefs concerning desirability and feasibility and may lead to wider diffusion, as observed in our study sites.

Keywords: Adoption, Attitudes, Beliefs, Constraints, Diffusion.

References:

1. Meijer et al., 2015, INT J AGR SUSTAIN, pp.40-54, DOI: 10.1080/14735903.2014.912493

L13.2_O.10

Silvopastoral production system in the Argentinian Chaco : smallholders' motivations for adoption and policy insights

Tschopp M.[1] (maurice.tschopp@gmail.com), Bardsley N.[2], Ceddia G.[1], Ingguagiato C.[1]

[1] *Centre for Development and Environment, University of Bern, Bern, Switzerland*; [2] *University of Reading, Reading, United Kingdom*

Cattle production is a central livelihood for smallholders in the Argentinian Chaco. Small-scale "criollo" farmers oftentimes live in settlements in the middle of the forest. However, the Chaco forests and related ecosystems are under high pressure. The Argentinian Chaco currently experiences very high deforestation rates. This process has been driven mostly by the expansion of the agricultural frontiers, in particular for soy, as well by large-scale cattle ranchers [1]. Among the two main user groups of native forest, we find indigenous people, as well as small-scale "criollo" farmers. These smallholders raise cattle, mostly with management practices known as "campo abierto", a system under which cattle roam freely in the forest and feed from natural vegetation (trees, shrubs and rare natural pastures). In order to secure higher income for farmers, as well as to reduce pressure on forests, recent and private initiatives have developed silvopastoral production systems for smallholders. Most of these systems involve felling shrubs (either with tractor rollers or manually) and introducing new grass species (gaton panic, buffalo grass, etc.). These pastures provide forage during the dry season and thus contribute to reduced pressure on forests during this sensitive period, although this comes with important costs associated with preparation of land and fences. This article examines the current introduction of silvopastoral production systems in the Chaco salteño and their adoption by smallholders. We will present results from a survey conducted in August 2018 of 552 small-scale cattle rangers from the departments of Rivadavia and San Martin, Salta, Argentina. We will focus especially on the stated motivations of smallholders adopting these practices. This information will be combined with socio-economic profiles of the households (i.e. subsistence versus entrepreneurial farmers). We also examine diffusion channels of silvopastoral practices (networks and institutions involved). The article concludes with some policy implications for silvopastoral development in the Argentinian Chaco in the context of acute deforestation.

Keywords: Silvopastoral production, technology adoption, Chaco Salteño.

References:

1. Fehlenberg, V. et al. 2017. Global environmental change. 45: 24-34.

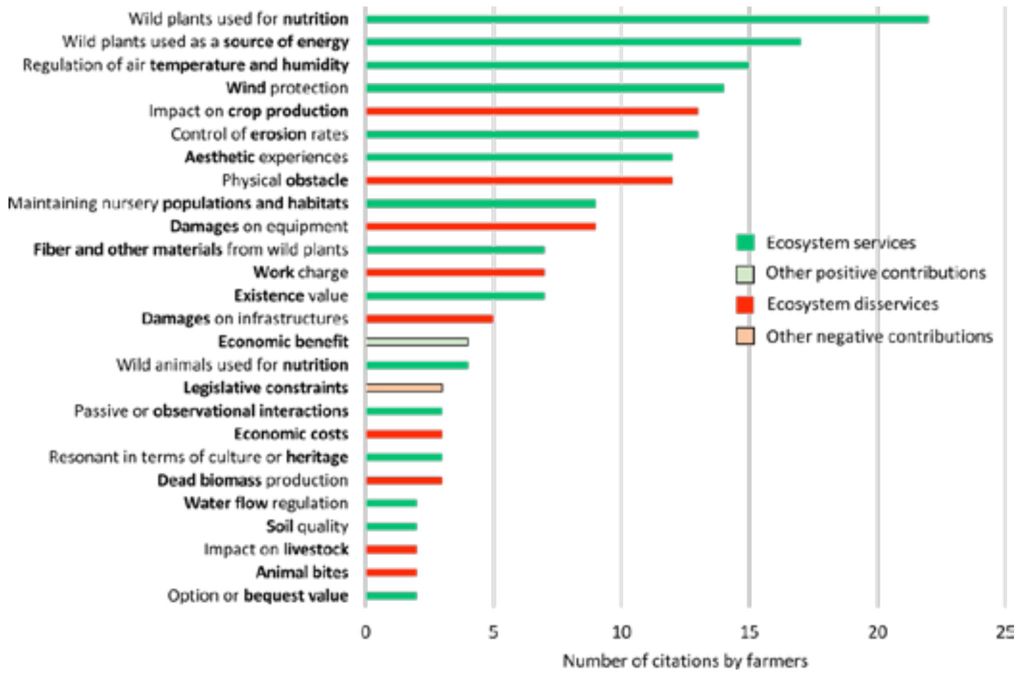
L13.P.01

Farmers compose with ecosystem services and disservices for managing rural forests: insights from a French case study

Blanco J.[1] (julien.blanco.pro@gmail.com), Sourdril A.[2], Deconchat M.[3], Andrieu E.[3]

[1] *LETG, Université d'Angers, Angers, France*; [2] *UMR 7533 Ladyss, CNRS, Nanterre, France*; [3] *Dynafor, INRA, Toulouse, France*

Rural forests, i.e. farm forests and trees outside forests (TOF), are part of traditional agroforestry systems in many European regions. Yet, the industrialization of agriculture has induced the decline of rural forests and promoted a physical and functional separation between trees and agriculture. Despite the recent promotion of TOF in the Common Agriculture Policy (CAP), most farmers do not reinforce them in their farms. In order to understand farmers' attitudes towards rural forests, we conducted 19 face-to-face interviews in southwestern France. Farmers identified 32 positive contributions, including 29 ecosystem services (ES), associated with rural forests. Similarly, they emphasized 25 negative contributions, including 21 ecosystem disservices (EDS). Contributions varied with the type of forested area. For instance, hedgerows had high levels of positive and negative contributions, while woods had high levels of positive and low levels of negative contributions. Finally, farmers identified 19 stakeholders and institutions, especially the CAP, that influenced rural forest management. In focusing on the balance between positive and negative contributions, our study enabled us to uncover the complex rationale of local rural forest management. Ecosystem disservices and CAP policies tended to discourage farmers to reinforce rural forests in their farms. Taking into account farmers' rationale and perceptions may give invaluable information to better target public policies.



Number of times each positive and negative contribution was cited by farmers.
Only contributions with at least two citations are represented.

Keywords: local knowledge, local perceptions, Common Agriculture Policy, Mental models, landscape-scale agroforestry.

L13.P.02

The Challenges for Agroforestry in Small Island Developing States in the Pacific: A study from Solomon Islands

Blumfield T. (t.blumfield@griffith.edu.au)

Environmental Futures Research Institute, Griffith University, Brisbane, QLD, Australia

Pacific Islanders are “natural” agro-foresters in as much as their gardens are dynamic mixtures of tree and ground crops within the context of shifting cultivation. However, coastal land with easy access for communities is at a premium with coconut plantations taking up a large area that could be considered disproportionate to the goods and services that they produce. But copra is one of the few avenues for subsistence farmers to earn hard cash and therefore coconuts command their position within the landscape.

The widespread planting of teak has brought further pressure on land within coastal communities, especially in those provinces where land pressure is highest (Malaita and Guadalcanal), the development of a formal agroforestry system was seen as a way of allowing people to earn a living from growing high value trees for export while utilising the land for food and cash crops. A project under the Australian Centre for International Agricultural Research was instigated to examine the introduction of novel systems for growing high value trees that would also allow crop production. Trial plots were established in communities and in selected vocational training centres (see image) with good results, but the initial enthusiasm was short lived. The paper will discuss the challenges the project has faced and also the agroforestry solutions that have been established to assist communities to have a sustainable livelihood in one of the worlds least developed counties.

Image 1: Teak trees and sweet potato being grown at Airahu Vocational Rural Training Centre in Malaita Province, Solomon Islands

Keywords: Pacific Islands, Challenges.

References:

1. Timothy J. Blumfield, Frédérique Reverchon, Vaeno W. Vigulu, 2018, Land Use Policy, 598-602
2. Vigulu, V., Blumfield, T.J., Reverchon, F. et al. 2018 New Forests https://doi.org/10.1007/s11056

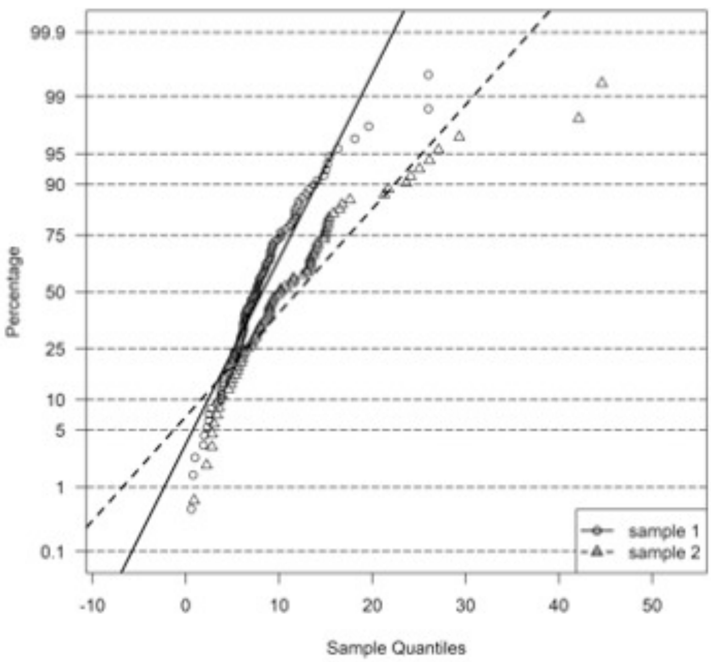
L13.P.03

The limits of firewood collection in the West African savannah agroforestry parklands

Callo-Concha D.[1] (d.callo-concha@uni-bonn.de), Harou L.[2], Krings L.[3]

[1] *Center for Development Research (ZEF), Center for Development Research, UniBonn, Bonn, Deutschland, Germany*; [2] *World Agroforestry Centre, Nairobi, Kenya*; [3] *German Society for Int. Cooperation-GIZ, Bonn, NRW, Germany*

Firewood is the main source of cooking energy in West Africa. In the savannah, firewood mostly comes from agroforestry parklands which are subject to increased environmental pressure. Failed predictions on the exhaustion of parklands as firewood stocks suggest that these warnings may have over-simplified the phenomenon, lacked the necessary data or underestimated the parklands' resilience. During 2014 and 2015, in the catchments of Dassari, Benin and Dano, Burkina Faso, we studied rural households (n=255) and parkland plots (n=206), to identify householders' firewood-management practices, quantified their consumption, and identified the favored species and the biomass stocks. Our results show that preferred species diverged from species conventionally asserted as firewood and there was a growing predilection for bushes and palms. A firewood trade had started to emerge, framed by scarcity and institutional control, and firewood gathering was being overcame by branching and selective cut. The average per capita consumption may be substantially higher if other uses are accounted for such as beer brewing (Figure). Our two-site study, contrasted production and consumption and their drivers, contributed to an understanding of the sustainability of firewood and shed light on other factors, such as religion prohibitions, that play a determinant role in firewood demand.



Probability distribution of the per-capita firewood consumption in Dano (circles) and Dassari (triangles) during the rainy season

Keywords: Firewood, Parklands, Sustainable consumption, Energy.

References:

1. Callo-Concha, D., Harou L., Krings L., et al. 2019. Farming adaptation. Senapkon K (Ed). Nova Publ.
2. Callo-Concha, D. 2018. Climate. 6(2)44.

L13.P.04

Non-economic motivations for the adoption of agroforestry: rethinking sustainability and place

Decre B. (decre@wisc.edu)

Nelson Institute for Env. Studies, University of Wisconsin - Madison, Madison, Wisconsin, United States

The conversation around agriculture in the U.S. is subject to a neoliberal framework that requires farmers to consider their practices in economic terms. As a result, the rationale behind any change in practices is often discussed in terms of bottom line and omits the environmental and social aspects that need to be considered for agricultural practices to be sustainable.
In the case of agroforestry, environmental benefits have been carefully studied and conversations about the adoption of practices have come to include these arguments. However, due to the challenge of measuring their impact, the social components, on the other hand, remain subordinate.
To counterbalance the power of economics in the agricultural discourse, an intentional focus on non-economic factors is necessary. Interviews conducted in Southwest Wisconsin using this methodology allowed agroforesters to discuss their practices in their own terms and revealed clear considerations of the environmental and social components of these practices. Most importantly, these conversations helped identify *place* as a useful concept to recognize the inherent embeddedness of these environmental and social elements.
Challenging the mainstream understanding of sustainability that separates environment, society, and economy and using the concept of *place* as a framework allows the social benefits of agroforestry to be further discussed and can make for a more balanced and wholesome conversation around these practices.

Keywords: motivations, social aspects, sustainability, place, discourse.

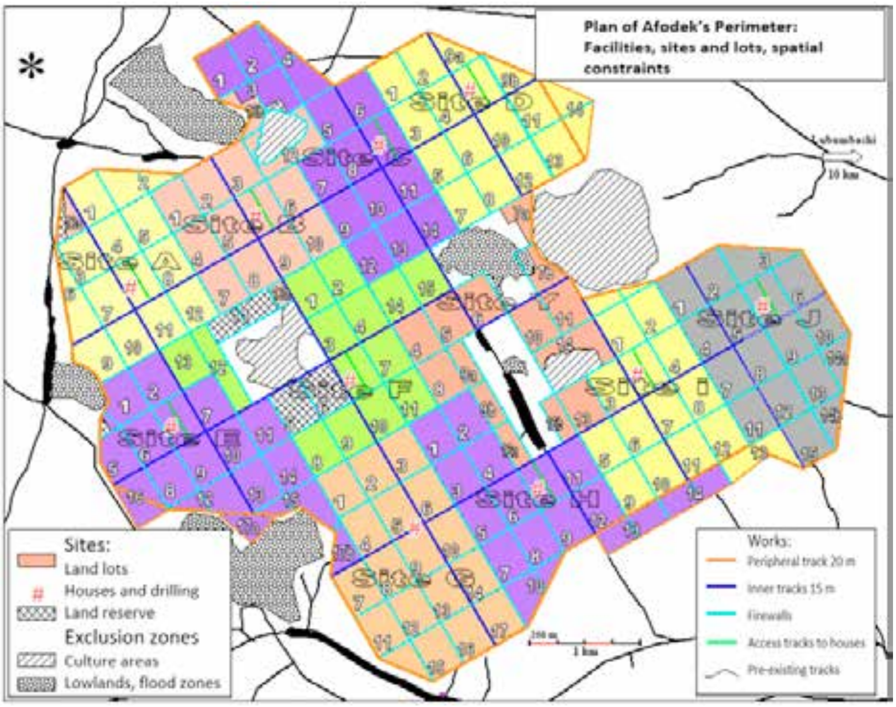
L13.P.06

Developing peri-urban agroforestry in Upper Katanga (D. R. Congo)

Fetiveau J.[1] (fetiveau@gret.org), Bracke C.[2], Ngoie M.[3], Procès P.[2], Boldrini S.[2]

[1] *Seren/GRN, Gret, Nogent sur Marne cedex, France*; [2] *Nature+ absl, Wavre, Belgium*; [3] *EREP, Université de Lubumbashi, Lubumbashi, Haut Katanga, Congo - Kinshasa*

The characteristic Miombo ecosystem of Upper Katanga is severely degraded on the outskirts of the city of Lubumbashi by charcoal production, slash and burn agriculture, urbanization, and the regular passage of fire. To jointly meet the objectives of food security and the fight against deforestation, the Afodek project (Agroforests for the Development of Kipushi, 2012-2017) implemented by Gret and Nature + with EU funding, supported the development of an agroforestry perimeter. 2,000 hectares where 150 families from the surrounding villages have been progressively settled and supported in the development of 12 ha lots exploiting the principle of improved (soil-building) fallows. The monitoring of tree growth and ecosystem services (carbon storage, non-timber forest products) is now carried out by the University of Lubumbashi in support of the Central Association of Agroforestry Perimeter Associations of Kipushi (CAPAK). This system of forest species planting whose main purpose is the production of timber or fuelwood is part of the initiatives in DRC carried out around *Acacia auriculiformis* and *Acacia mangium*. The project demonstrated how to adapt the *Taungya* system to the local soil, climate and socio-economical conditions by addressing the challenges of land quality and household capital heterogeneity. Achieving these results requires initiating a collective learning dynamic that leaves room for experimentation and adjustment.



Plan figuring allocated lots, housing, runways, firewalls, and spatial constraints (Gret and Nature+, 2017)

Keywords: Miombo, Deforestation, Agroforestry, Acacia auriculiformis, Kipushi.

L13.P.07

A functional trait approach to agroforestry design for biocultural restoration on a Pacific Island

Hastings Z.[1] (zchastin@hawaii.edu), Ticktin T.[1], Botelho M.[2], Bremer L.[3], Reppun N.[2], Kukea-Shultz K.[2]

[1] *Department of Botany, University of Hawaiʻi at Mānoa, Honolulu, HI, United States*; [2] *Kākoʻo ʻŌiwi, Kāneʻohe, HI, United States*; [3] *Economic Research Organization, University of Hawaiʻi at Mānoa, Honolulu, HI, United States*

Sustaining biodiversity while meeting global agricultural needs is a critical challenge. This is especially true in remote Pacific Islands like Hawaiʻi where over 25% of native plants are threatened or endangered and high labor and land costs make both native forest restoration and agricultural production economically challenging. Biodiverse, crop producing agroforests can address this issue and were widespread in Hawaiʻi before European contact, yet few remain today. While interest in agroforestry restoration is growing, designing systems that incorporate indigenous and local knowledge and produce desired ecosystem services remains challenging. Plant functional traits may facilitate the design process by serving as a tool to predict the connections between plants and ecosystem services; however, few studies have combined a functional trait approach to agroforestry design with explicit inclusion of cultural values. We tested a participatory design process to identify a list of culturally and economically important candidate species and then used a functional trait approach to select species that would also provide 1) erosion control and 2) early successional facilitation services. We established the two species mixes on a community farm using before-after-control-impact design and will monitor plant growth and survival, soil carbon, and erosion over time. We discuss the opportunities and challenges of this approach and describe the early stages of a long-term experiment.

Mahealani Botelho of Kākoʻo ʻŌiwi shares the farm's vision for agroforestry restoration at a community workday opening ceremony.

Keywords: biodiversity conservation, functional traits, ecosystem services, biocultural restoration, participatory design.

L13.P.09

Adoption of an improved fallow practices using *Acacia auriculiformis* in the Democratic Republic of Congo

Kachaka E. (etienne-yusufu.kachaka.1@ulaval.ca), Alison M., Nancy G., Damase K.

Department of wood and forest sciences, Laval University, Québec, Québec, Canada

An improved fallow agroforestry practice that involves planting *Acacia auriculiformis* trees to accelerate soil fertility recovery, was taught to 306 farmers on the Batéké Plateau in the Democratic Republic of the Congo from 1995 to 2001. This study assessed 1) the principal factors that determined the continuation of this practice as well as the perceived advantages and constraints to the adoptive farmers; and 2) the current place of traditional fallow and the perception of improved fallow by non-adoptive farmers from neighbouring sites. Quantitative as well as qualitative approaches were used. A multiple linear regression was constructed based on a survey of 121 farmers that adopted the new practice. Semi-structured interviews with adopters (12) and non-adopters (8) were also conducted. Linear regression models showed that the availability of labour based on the number of household members working in the fields, best explained the continuity of the improved fallow practice (P = 0.0898) although no model variable was statistically significant (p ≤ 0.05). Despite this, statements collected during the interviews revealed the benefits and difficulties of continuing this practice. Surveys of non-adoptive farmers confirmed the important role of traditional fallow and that there was no need for it to be urgently replaced. Insufficient knowledge of the improved fallow practices was identified as a greatest potential barrier to spreading this practice to non-adopters.

$$Y_i = \beta_0 + \beta_1 X_1 + \ldots\ldots \beta_n X_n + \varepsilon_i$$

Where: Yi Variable depending on intensity of fallow use; β_0: coefficient, systematic from the origin ; $X_{1..n}$: Explanatory variables ; $\beta_{1..n}$: coefficient of the slope ; ε_i : error term.

Table 1. Variables for multiple linear regression

Dependent Variable Y_i	
Area reserved for the fallow practice	Cultivated area in m^2
Explanatory variables $X_1 \ldots X_n$	
Age	Age in years of person in charge of operation.
Seniority	Number of years since installation in Mampu.
Size of household	Number of individuals in the household.
Use of collaborators	Use of the collaborative workforce. Yes (1) No (0)
Number of collaborators	Number of collaborating persons including the farmer
Number of family members working in the field	Number of family members working in the field
Paid labour	Use of paid labour. Yes (1) No (0)
Farm income	Annual revenue related to the sale of cassava and maize (in Congolese Francs)
Fuelwood income	Annual revenue linked to the sale of charcoal (in Congolese Francs)
Honey income	Annual revenue linked to the sale of honey (in Congolese Francs)
Livestock	Practice of maintaining livestock. Yes (1) No (0)
Secondary activity	Other employment outside the farm. Yes (1) No (0)

Keywords: Adoption, Improved fallow, traditional fallow, advantages, constraints.

L13.P.10

Diversifying orchards and vineyards in intensive Mediterranean agriculture: California's Central Valley as a case study

Kerr A.[1] (ackerr@ucdavis.edu), Brodt S.[1], Fontana N.[2], Archer L.[3], Gaudin A.[4]

[1] *Agricultural Sustainability Institute, UC Davis, Davis, California, United States*; [2] *Ecology Graduate Group, UC Davis, Davis, California, United States*; [3] *Graduate Group, Horticulture & Agronomy, UC Davis, Davis, California, United States*; [4] *Department of Plant Sciences, UC Davis, Davis, California, United States*

California is a global leader in high-value agriculture, producing half of all fruits and vegetables in the United States despite comprising only 5% of the land area. Most of this production occurs in the vast Central Valley. Its Mediterranean climate, combined with sophisticated systems for surface water and groundwater delivery, enables high yields while minimizing pest and disease pressure. However, success comes at a cost: the Central Valley is afflicted by land subsidence, soil and water pollution, salinization, and severe habitat loss for terrestrial and aquatic native species.

In recent years, economic forces have favored expansion of perennial crops (such as almonds, grapes, and walnuts) at the expense of annual crops (such as tomatoes, carrots, and alfalfa) in the Central Valley. These perennial crops – now more than 2 million acres – are high-input mechanized monocultures; they do not usually have lower inputs or higher biodiversity than annual crops. However, some Central Valley farmers are experimenting with adding species to their orchards and vineyards to augment ecosystem services and reduce environmental impacts. Here, we examine a small sample of early adopters and assess prospects for scaling up.

We interviewed 16 farmers with diversified orchards and vineyards, some of whom used more than one practice: (1) cover cropping (n=6); (2) intercropping vegetables (n=4); (3) grazing sheep in mature orchards (n=4); and (4) planting wild hedgerows (n=4). Respondents indicated a variety of benefits from these practices, including improved soil health (n=9), improved nutrient cycling (n=9), better pest control (n=5), and increased pollination (n=2). Drawbacks included additional labor (n=8), lack of farm equipment suitable for intercrops (n=4), and greater management complexity (n=4), especially regarding irrigation.

These diversified practices are currently very rare in the Central Valley. For example, data from Yolo County [1] suggests that only about 4% of field and road edges are maintained with hedgerows or other native vegetation. A US-wide analysis [2] found that only 1% of crop area is integrated with livestock; this is likely even lower in California due to strict food safety laws for fruits and vegetables [3]. This illustrates the challenge of diversification when financial and policy incentives are lacking and knowledge networks are sparse.

However, we also found reasons to be optimistic about diversification trends. For example, incentive programs may increase adoption. In 2017, California's new Healthy Soils Initiative gave out over US$7 million in grants for conservation practices, of which approximately 25% included diversification of orchards and vineyards. More research is needed on farmers' experiences and perceptions so that California's Central Valley becomes renowned not only for its agricultural output, but also for its diverse and sustainable perennial cropping systems.

Keywords: Mediterranean, orchards, vineyards, intensive, diversify.

References:

1. Brodt et al. (2009), Agroforestry Systems 76:195-206. doi:10.1007/s10457-008-9168-8
2. Garrett et al. (2017), Agric Systems 155: 136-146. doi:10.1016/j.agsy.2017.05.003
3. Garrett et al. (2017), Sustainability 9:473. doi:10.3390/su9030473

L13.P.11

Constrains and opportunities for agroforestry adoption in Northwest Vietnam

La N.[1] (L.Nguyen@cgiar.org), Nguyen M P.[1], Tran T H.[2], Dinh T T H.[3], Cam T P.[4], Vu T. H.[1], Nguyen V T.[1]

[1] *World Agroforestry Center (ICRAF), Hanoi, Vietnam*; [2] *DARD Yen Bai, Yen Bai, Vietnam*; [3] *DARD Dien Bien, Dien Bien Phu, Vietnam*; [4] *DARD Son La, Son La, Vietnam*

Agroforestry offers an integrated approach that can curb land degradation and deforestation, while securing the livelihoods of rural households. As well acknowledge that, the adoption level normally based on the real needs and interests grounded in socio-cultural and economic factor's contexts.

With the aim to bring agroforestry research results to application in Northwest Vietnam. The research framework combined different activities, started by understanding local ethnic group's knowledge on tree-soil interaction, their perception, the challenges and interests from adopting agroforestry. The participatory approach was carried out to design agroforestry systems, in which local knowledge and scientific knowledge are combined. These established trials were evaluated to find out suitable options and spread through farm visits and training sections, following by equipping basic skill based on farmer's needs and interests. The research findings and farmer's feedback were used to advisory policy makers on promulgate the development programs.

The study showed that the farmer's specific social circumstances influence their aspiration and constraints for agroforestry intervention. Perceived challenges to adopting agroforestry systems are varied among ethnic groups. Seven systems have been evaluated as higher economic and environmental performance compared to current farmer practice. The farm visits and trainings on various aspects of agroforestry, as laying out contour lines, establishing nurseries, preparing seedlings and designing agroforestry farms, benefiting more than 2,000 individuals, including farmers, extension workers, district and commune staffs. Based on the suitability agroforestry systems and trees and local farmer's needs and interests, eight group nurseries have been established with approximately 100,000 seedlings produced for 15 different fruit and timber tree species. 150 Farmer Demonstration Trials and six agroforestry Exemplar Landscapes (50 ha each) have been established. The research results on benefit of planting forage grass strips and *Docynia indica* have been embedded in Resolution 15/2015/NQ-HDND of Yen Bai province, which have been increased the number of adopter over the wider area. The area of *D. indica* based agroforestry system was increased 2,248 ha in the Yen Bai's mountainous area in period 2016-2017 since resolution promulgated. The research results on *D. Indica* processing techniques was transferred to private sector to produce different processed products, guaranty the opportunities for producers and markets for local traditional products.

Agroforestry technology adoption required the understanding of cultural character, farming behavior, challenge and interest of local people. Therefore, it is not one-size-fit-all process. It required to develop a strategy on research, ensure the research results are mainstreamed on the development policy in order to build resilient livelihoods and ensure future environment benefits.

Keywords: Agroforestry systems, Farmer demonstration trials, Exemplar landscapes, Policy, Adoption.

L13.P.12

Knowledge Hybridization: A Process towards Resilience through Reviving Alder–Cardamom Agroforestry in Nepal

Liu R. (liu.5811@osu.edu)

School of Env. and Natural Resources, The Ohio State University, Columbus, Ohio, United States

Both science-technologies and local knowledge can offer potential solutions to addressing the increasing vulnerability of mountain ecosystems and communities and building their resilience to natural hazards. However, a disjuncture between local and scientific knowledge on farming practices can have implications for rural livelihoods, ecosystem health and potential hazards when the two knowledges come together. So how can we resolve this disjuncture for reducing communities' vulnerability and increasing their resilience? Knowledge hybridization might be one such process towards resilience, "where traditional knowledge, practices, and beliefs are merged with novel forms of knowledge and technologies to create new knowledge systems" (Gómez-Baggethun et al. 2013). In eastern Nepal, farmers are changing their farming practices from traditional and scientifically-endorsed alder-cardamom agroforestry to monoculture cardamom plantations that can potentially trigger landslides. Many researchers and development agencies have endorsed a preferred agricultural practice for farmers in this region that aims to not only reinvigorate traditional agroforestry systems but also couple innovative climate-smart agricultural practices with the reinvigoration. During this process, this research postulates that sustainable resource management and disaster risk reduction measures derived from knowledge hybridization may (1) be nurtured with increased knowledge range, diversity and options for learning and problem-solving; (2) emerge as cultural built-in objects and situated practices, and (3) therefore be more intuitive to local farmers and more likely to be acted upon. As a result, a hybrid knowledge system, and a capacity and condition to cultivate such hybridity, could proffer pathways to resolving the disjuncture between local and scientific knowledges and contribute to enhancing farmers' resilience to environmental changes. This research is operationalized through an ethnography of risk-based agricultural decision-making and a field experiment of knowledge engagement through citizen-powered participatory digital mapping. The study examines the conditions in which local and scientific knowledge are produced and exercised, when they are compatible, and how they can be integrated to develop place-based resilience through reviving alder–cardamom agroforestry in Nepal. A mixed-methods approach has been used to collect qualitative and quantitative data. Both types of data will provide evidence for improving science communication and outreach by exploring potential alienation and ambivalence among local knowledge holders during adaptation knowledge engagement and interactions. Such psychological dimensions, if not well accommodated, can impede effectiveness in disseminating knowledge and practices that can reduce environmental threats and enhance community resilience.

Keywords: citizen science, local knowledge, knowledge hybridization, resilience, agroforestry.

References:

1. Berkes. 2007. Natural Hazards 41(2): 283–95. doi:10.1007/s11069-006-9036-7.
2. Gómez-Baggethun et al. 2013. Ecology and Society 18(4): 72. doi.org/10.5751/ES-06288-180472.
3. Sharma et al. 2007. Tropical Ecology 48(2): 189–200.
4. Liu et al. 2018. ISPRS International Journal of Geo-Information 7(2): 68. doi:10.3390/ijgi7020068.
5. Lauer et al. 2009. American Anthropologist 111(3): 317–29. doi:10.1111/j.1548-1433.2009.01135.x.

L13.P.13

Educational offer in agroforestry in the countries of the Pacific Alliance

Lizárraga A. (alizarraga@cientifica.edu.pe), Lino G., Quirós L.

Ingeniería Agroforestal, Universidad Científica del Sur, Lima, Peru

The Pacific Alliance is a platform composed of four countries, Chile, Colombia, Mexico and Peru, and «is a mechanism of political, economic, cooperation and integration that seeks to find a space to promote greater growth and greater competitiveness of the four economies that make it up» (Pacific Alliance, 2018). This agreement is related to the development and integration processes. In this sense, policies related to the promotion of education, and particularly on agroforestry systems (AFS), are considered as strategic elements for sustainability. There are several examples of the importance of education in agroforestry systems (Zulkberti, 1990; Tengnäs et al.; 2008, Okojía, 2018). Education is somehow related to the different characteristics of the four countries. Therefore, knowing the situation of agroforestry in the university system is important in order to perform a detailed analysis later. The information on the entire educational offer at the undergraduate and postgraduate levels of universities in the four countries was reviewed, based on the Webmetric Ranking data. The total of universities in the four countries was 618, of which 99 have degrees in Agronomic Engineering and 32 in Forestry Engineering. Within forestry careers are six (1% of the total) whose objectives are oriented to the management of agroforestry systems. In Colombia, 5% of universities have a degree in Agroforestry Engineering, while Peru has only 2%; Mexico and Chile do not have careers in agroforestry. None of the universities in these countries has a master's degree or doctorate in agroforestry. However, some universities with careers in Agronomic Engineering and/or Forestry Engineering in Colombia and Peru include some agroforestry courses: five in Colombia and 15 in Peru, equivalent to 8% and 10% respectively. There are differences between the relationship between the agricultural/forestry area and the number of universities. There are also differences in the relationship between the GDP of the countries and the number of agricultural careers. In both cases we considered a negative direction.

Keywords: Agroforestry, Pacific Alliance, Education, Latin America.

References:

1. Pacific Alliance. (2018). ¿What is the Pacific Alliance? https://alianzapacifico.net
2. The World Bank. FAO (2017). https://data.worldbank.org
3. CEPAL (2018). Database. http://estadisticas.cepal.org/
4. Tengnäs, B., Noor A., Hendrayanto, G. (2008). SEANAFE, Phase II SIDA. 93 p
5. Zulkberti, E. (1990). Agroforestry education and training programs: an overview. Agroforestry System

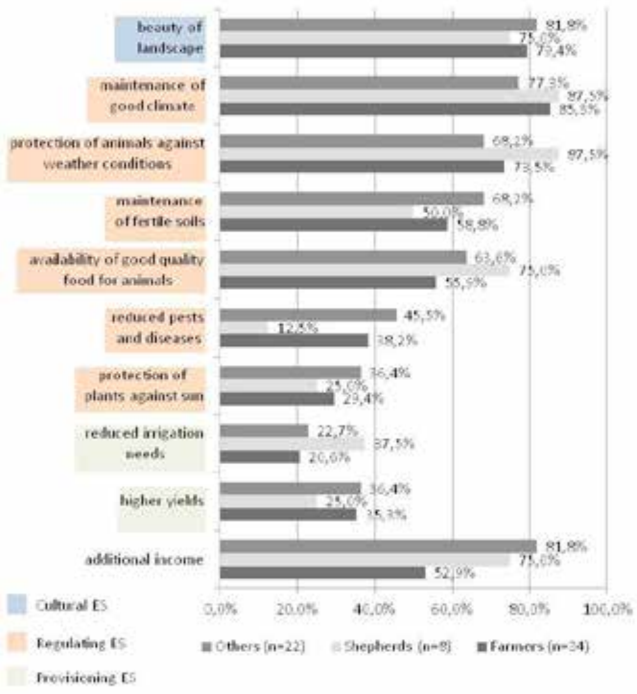
L13.P.15

Perceptions on the value of agroforestry for providing ecosystem services in a Greek Mediterranean landscape

Mantzanas K.[1] (konman@for.auth.gr), Guenzel J.[2], Pagella T.[2]

[1] *Aristotle University of Thessaloniki, Thessaloniki, Greece*; [2] *School of Natural Sciences, Bangor University Wales, Bangor, United Kingdom*

Agroforestry systems in Greece have a long tradition and were once actively managed. However, they have become increasingly neglected due to agricultural intensification and rural exodus. This has, in part been driven by the Common Agricultural Policy, which has promoted to remove trees in favour of intensive production systems. This study sought to assess local perceptions of the socio-economic contribution of old agroforestry systems for the livelihoods of the local population. Interviews were held with 64 farmers, shepherds and other actors from the villages Eratira and Sisani in Northern Greece to assess the contribution of agroforestry to ecosystem service provision.
The results showed that despite the need for economic income, agroforestry was highly valued for contributing to indirect benefits of ecosystems like the beauty of the landscape, climate regulation and protecting livestock against harsh weather. This corresponded with ecosystem services that were recognised as most important ones for supporting local livelihoods. Yet, the results showed that trees were increasingly being removed from the landscape due to economic pressure. In order to maintain the multifunctional character of the landscape, it is recommended to promote the valorization of non-monetary benefits from agroforestry practices and improve the cooperation between local and administrative level. Furthermore, continuous and strategic awareness-building on benefits of agroforestry is seen as crucial.



Advantages of integrating trees into cultivation areas and pastures according to the interviewees

Keywords: ecosystem services, agroforestry, multifunctional landscape, indirect benefits.

References:

1. Papanastasis et al., in: Agroforestry in Europe: Current Status and Future Prospects, 2008, Riguiero
2. Ibrahim & Sinclaur, in: Forests in the global balance – changing paradigms, 2005, Mery et al., IUFRO

L13.P.16

Evaluation of the timber based mixed farming/agroforestry systems: A case of farmers in Limpopo Province, South Africa.

Maponya P.[1] (maponyap@arc.agric.za), Venter S. L.[1], Du Plooy C. P.[1], Backeberg G. R[2], Mpandeli S.[2], Nesamvuni E.[3]

[1] *Agricultural Research Council, Pretoria, South Africa*; [2] *Water Research Commission, Pretoria, South Africa*; [3] *University of Venda, Pretoria, South Africa*

Agroforestry is a land use system that includes the use of woody perennial and agricultural crops and animals in combination to achieve beneficial ecological and economical interactions for food, fiber and livestock production.The aim of the study was to evaluate and classify the timber based mixed farming/agroforestry systems.The objectives of the study was to determine the potential constraint of rainwater on the establishment and expansion of agroforestry, to document farmer's perception on constraints to agroforestry competiveness, to review the current knowledge on agroforestry and to identify and describe the farmers' benefits from timber based mixed farming/agroforestry. A purposive sampling technique along with quantitative and qualitative designs were used to select 65 productive and potential timber based mixed farming/agroforestry systems classified as follows: Silvipasture; Agrosilvoculture; Agrosilvipasture and Apiculture.The socio economic data was also coded, captured and analysed using Statistical Package for Social Science (SPSS). Most of the potential classified agroforestry systems visited fell in areas of good rainfall and the results also indicated some important benefits and constraints identified by farmers. It is thus recommended that stakeholders should take note of the potential classified agroforestry systems, benefits and constraints identified by farmers in an attempt to increase agroforestry competitiveness and adoption in Limpopo Province.

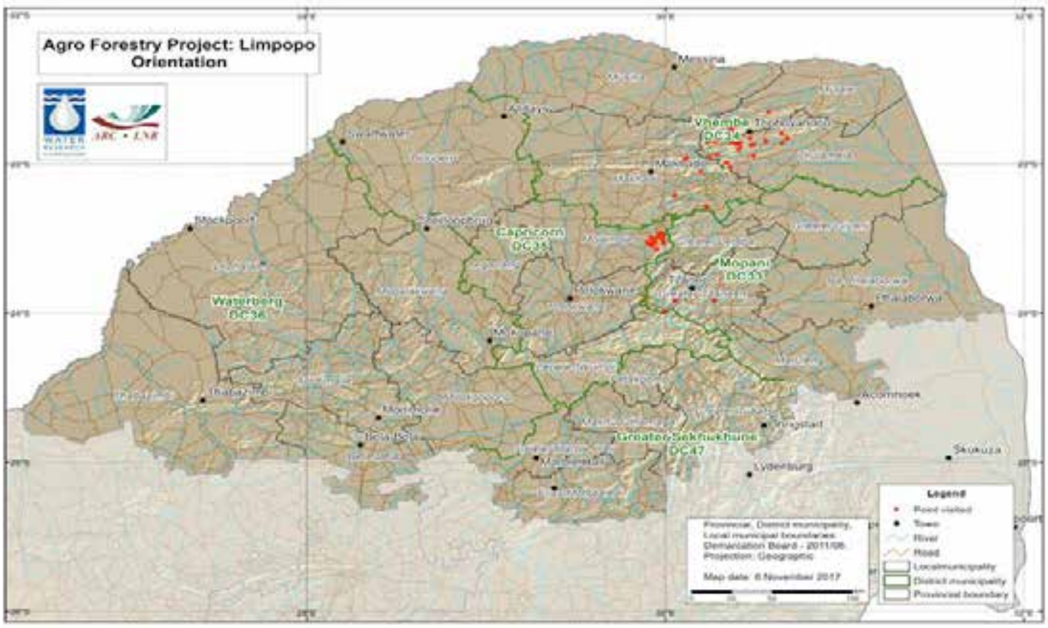


Figure 1: Limpopo Province map showing visited timber based mixed farms/agroforestry systems in red dots (ARC – ISCW, 2017)

Keywords: Farmers, Timber Based Mixed Farming Benefits, Potential Classified Agroforestry Systems, Limpopo Province, South Africa.

References:

1. Agricultural Research Council ISCW (ARC-ISCW). (2017). Pretoria, South Africa.

L13.P.17

Optimizing yield and sustainability through mechanization and improved land management practices?

Martinez L. (lenny.martinez@12tree.de)

12Tree Finance GmbH, BERLIN, Germany, Germany

Mechanization is common all-over Latin America (but in various ways, adapting to local traditions and cultures), in all kinds of contexts and by all sorts of companies with varied values[1]. It certainly disrupts dynamics in a rural landscape, but this where both context and how the company approaches it matters. We defend an approach specific to the project's socioeconomic and environmental context.

We are not suggesting that everybody should and can mechanize. In fact, in order to mechanize a farm, you need to design it and plan for that purpose from the very beginning. Mechanization entails considering the architecture of the tree and the topography of the land. Mechanization might make sense in specific projects, but it may not make sense for others. Combined with training courses, affordable, labor-saving tools could be more suitable in some contexts to increase sustainability (in particular for small farmers).

Nevertheless, mechanization, if done correctly, can positively affect not only the smallholders around a project, but also the local economy by sharing infrastructure or renting machines to local companies. In fact, some machines are not used throughout the entire year, and by renting and sharing equipment, we can maximize the machine's use and offer new services to the local area. Mechanized farms may lead to lower direct employment (in comparison to labor-intensive commercial farms), but they create more indirect employment opportunities (in services required for mechanization provided to the farm), as well as more qualified employment opportunities that offer higher wages and allow aspiring youths to remain in rural areas rather than push them to migrate to urban centers, fostering growth in the region. Mechanization also increases gender equality as it alleviates the physical demands of hard manual labor and enables women to take up farm worker (and manager) positions that previously were too physically demanding.

Finally, we don't want to omit the challenges of avoiding soil compaction resulting from the intensive use of machinery from this discussion. This means that particular attention needs to be paid to using proper equipment to limit soil compaction (e.g., cable transport systems instead of tractors), understanding soil dynamics, providing farmers and employees with training and educational documents on safe and optimal use, calibrating and maintaining the machinery and equipment.

Drawing on 12Tree's field experience in Central and South America, in this presentation we discuss the social and cultural challenges behind the mechanization of large-scale agroforestry plantations based on preliminary results from 12Tree's established agroforestry cacao projects.

[1]http://www.ifpri.org/blog/increasing-agricultural-mechanization-latin-america-will-take-more-coordination-investment

Keywords: Agroforestry Systems, Mechanization, Social and Environmental Impact, Investment, Soil Restauration.

References:

1. The Present and Future of Agricultural Mechanization in Latin America, Event Date: 11/04/2016
2. Deininger, Klaus & Byerlee, Derek, 2012. «The Rise of Large Farms in Land Abundant Countries
3. The role of mechanization in agricultural sustainability (FAO website)

L13.P.18

Socio-economic determinants of agroforestry technology adoption in Casamance, Senegal

Mbaye T.[1] (tamsirmbaye76@gmail.com), Toure K.[2], Cisse M.[3], Ndiaye S.[4], Ngom D.[5], Diagne M.[6], Fall D.[7], Gning F.[3], Diallo O.[3], Toure I.[3], Ndiaye A.[3], Dieng M.[8], Sarr M. S.[9]

[1] *Centre National Recherches Forestières, Institut Sénégalais Recherches Agricoles, Dakar, Sénégal, Senegal*; [2] *Socio économie, Ecole Nationale Supérieure d'Agriculture, Thies, Senegal, Senegal*; [3] *Agroforesterie, Université Assane Seck, Ziguinchor, Senegal, Senegal*; [4] *Production végétale, Ecole Nationale Supérieure d'Agriculture, Thies, Senegal, Senegal*; [5] *Biologie végétale, Université Cheikh Anta Diop, Dakar, Senegal, Senegal*; [6] *Production végétale, Agrhymet, Niamey, Niger, Niger*; [7] *Centre National Recherches Forestières, Institut Sénégalais Recherches Agricoles, Dakar, Senegal, Senegal*; [8] *Centre recherches agronomiques, Institut Sénégalais Recherches Agricoles, Saint Louis, Senegal*; [9] *Centre National Recherches Forestières, Institut Sénégalais Recherches Agricoles, Dakar, Senegal*

This study analyzes the socio-economic determinants of garden plank technologies and horticultural grafting adoption of Adansonia digitata L. (baobab) in Kolda and Sedhiou regions in southern Senegal. The main interest of this study is twofold: on the one hand, it focuses on the preservation factors of A. digitata and the durability of its exploitation in the two regions. On the other hand, it shows that A. digitata can play a major role in improving the income of rural populations through the sale of products and in food and nutritional security. The methodology used is based on surveys and interviews with populations, but also on statistical estimates. The results show that the adoption and non-adoption factors are multiple and depend on the interest of the populations studied. For the majority of the sample (74%), adoption is determined by water availability, access to seeds and land, and the possibility of selling or buying baobab products in markets. People are also adopting technologies for their interest in improving incomes. The results also show that the land tenure mode ($p = 0.046$) and the household size ($p = 0.049$) significantly determine the adoption of horticultural vegetable and horticultural grafting technologies of A. digitata by local populations. «Land ownership» is therefore a factor that promotes adoption as well as a «household size». In other words, improved access to land and increased household size facilitate the level of adoption of agroforestry technologies in Kolda et Sedhiou areas.

Keywords: socio economic determinants, adoption, garden plank, horticultural grafting, Baobab.

L13.P.19

Cocoa agroforestry systems in Centre and South Cameroon: innovation or relic of the past ?

Michel I.[1] (isabelle.michel@supagro.fr), Carrière S. M.[2], Manga Essouma F.[3], Levang P.[2]

[1] *Institut des régions chaudes, Montpellier Supagro, Montpellier, France*; [2] *IRD, Montpellier, France*; [3] *IRAD, Yaoundé, Cameroon*

From urban margins to the remotest forest areas, multistrata and biodiversity-rich cocoa agroforestry systems dominate the agricultural landscapes of Centre and South Cameroon Regions. For a long time, the development of cocoa production benefited from the strong support of the Cameroonian State. Local farmers rapidly adopted the new crop and adapted their swidden agriculture practices, developing an original agroforestry system rich in biodiversity. Progressively they introduced the improved hybrid seeds, shade regulation techniques and chemical inputs promoted by an active national extension network. Unfortunately, the major economic crisis of the late 1980s and following structural adjustment plans put an end to State support and left the Cameroonian agricultural sector in stagnation for two decades. The decline and volatility of cocoa price, population migrations (rural to city, rural to forest areas), and major socio-economic changes induced a profound transformation of the cocoa production sector. Nowadays, cocoa growers' profiles and strategies are highly diverse, a diversity which in turn impacts cocoa plantations. Comparing four ecologically and socially contrasted sites in Centre and South Cameroon, a multidisciplinary study thoroughly investigated 170 farmers and 71 cocoa plantations. Ten major types of cocoa plantations were identified and characterized in terms of species composition of trees and vegetation structure (number of trees and basal area per stratum), and cocoa technical management. In the two oldest sites (Obala and Akongo) agroforestry systems have persisted, though evolving somehow. In the more densely populated areas near Yaoundé (Obala), the intermediate stratum (8 to 25 m high) has become richer in fruit trees, the cocoa stand has been renewed with new varieties and treated with pesticides. In Talba, where population pressure is increasing in a forest area, the natives and in-migrants from Obala have opted for cocoa plantations rich in forest trees with a predominance of the high stratum (from 25 to more than 60 m), mixing old/new cocoa varieties and mobilizing pesticide treatments. On the forest margins of Mintom, where population pressure is still low, more complex agroforests (in number of strata and specific diversity) have remained, with old cocoa varieties and less pesticide mobilization; they have been even developed by recent in-migrants from Obala. However, in Mintom as well as Talba, new cocoa plantations with simple structures, new cocoa varieties and high intensity of pesticide treatment, have been established by new stakeholders, mainly urban elites investing non-agricultural capital in cocoa production, and seeking short-term financial gains. Demographic pressure, the forest environment, the origin of farmers and their strategies are the major factors that determine the farmer's choice between complex agroforests, intensively managed cocoa plantations or a hybridization of the two.

Keywords: technical management, vegetation structure, specific richness, demographic pressure, diversity of farmers.

References:

1. Jagoret, P., H. Todem Ngnogue, E. Malézieux, and I. Michel. 2018.European Journal of Agronomy
2. Sonwa, D.J., S.F. Weise, B.A. Nkongmeneck, M. Tchatat, M.J.J. Janssens. 2017. Agroforestry Systems
3. Bisseleua, D.H., and B.S. Vidal. 2008. Biodivers. Conserv

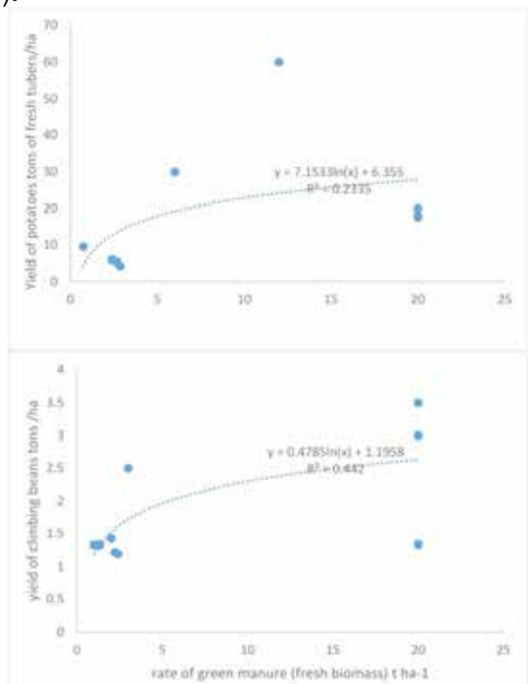
L13.P.20

Finance and productivity: key determinants of Alnus acuminata green manure adoption by Farmers in Gishwati-Rwanda

Musana Segatagara B.[1] (bernard.musana@rab.gov.rw), Muthuri C.[2], Bucagu C.[3], Mukuralinda A.[2], Ndayambaje J.D.[4]

[1] *Soil and water management, Rwanda Agriculture Board, Kigali, Rwanda*; [2] *World Agroforestry Center (ICRAF), Nairobi, Kenya*; [3] *Crop Research and Extension, Rwanda Agriculture Board, Kigali, Rwanda*; [4] *Forestry and Agroforestry, Rwanda Agriculture Board, Kigali, Rwanda*

Resource poor farmers in Gishwati area face the challenge of low crop productivity as a result of land degradation. Inorganic fertiliser is expensive and not environmentally friendly. Agroforestry offers an affordable solution through the use of fertiliser trees. A popular multipurpose tree species in the area is *Alnus acuminata*. In order to clarify incentives and disincentives to adopt agroforestry, this paper investigated yield and financial performances of potatoes (*Solanum tuberusum*) and climbing beans (*Phaseolus vulgaris*) under fertilizer options with *A. acuminata* green manure. Records from participatory trials conducted by the project "Trees for food security" between 2014 and 2016 and farmers' practices outside trials assessed in 2016 were used to explore determinants of green manure application rates. The farmers applied between 1 t ha^{-1} and 60 t ha^{-1} of fresh biomass.Climbing beans received 48.8% less green manure of *A.acuminata* compared with potatoes. Regression models fitted between yield without application of green manure, application rate and response to green manure, showed that climbing beans had a clearer response to green manure across soil fertility gradient (R2=58.8) but farmers' application rates had a greater alignment with yield potential without green manure (R2=64.8%).



Trend of rate of A.acuminata green manure and response as practiced by farmers of Kadahenda cell, Nyabihu district

Keywords: Alnus acuminata, Agroforestry, fertilizer trees, socio-economic determinant, adoption.

References:

1. Chasek et al.,2015. Journal of Arid Environments. doi: http://dx.doi.org/10.1016/j.jaridenv.2014.05.
2. Chivenge et al. 2011. Plant and Soil, 342(1-2), pp.1-30. doi: 10.1007/s11104-010-0626-5
3. Gitari et al., 2018. Agricultural Water Management, 208, pp.59-66. https://doi.org/10.1016/j.agwat.2
4. Jerneck, A., & Olsson, L. , 2013. Journal of Rural Studies, 32(0), 114-125. Doi: http://dx.doi.org/1
5. Ndoli et al., 2017. Field Crop Research. 213 (2017) 1–11. https://doi.org/10.1016/j.fcr.2017.07.020

L13.P.21

Training stakeholders in agroforestry by the Agrof MM – ERASMUS+ procedure

Papadopoulos A.[1] (ampapadopoulos@teiste.gr), Pantera A.[1], Burriel C.[2], Herdon M.[3], Tamás J.[3], Lamaison M.[4], Musquar C.[4], Seeman M.[5], Athanassova S.[6], Grozeva N.[6], Escural J. M.[7], Fico F.[8], Devernay S.[9], Levasseur E.[9], Lavoyer S.[10], Balaguer F.[10], Papanastasis V.[11], Mantzanas K.[11], Fotiadis G.[1]

[1] *Agricultural University of Athens, Karpenissi, Greece*; [2] *AGROSUP DIJON, Dijon, France*; [3] *University of Debrecen, Debrecen, Hungary*; [4] *ALIENOR EU, Brussels, Belgium*; [5] *Friends of Nature, Beirut, Lebanon*; [6] *Trakia University, Stara Zagora, Bulgaria*; [7] *CFPPAF de Mirecourt, Mirecourt, France*; [8] *AFTD, Tirana, Albania*; [9] *EPLEFPA Le Valentin, Die, France*; [10] *Association Française d'Agroforesterie, Auch, France*; [11] *Aristotle University of Thessaloniki, Thessaloniki, Greece*

Agroforestry is a traditional land use system that may represent the answer to many present and future environmental problems. However, many farmers who practice agroforestry do not identity it as agroforestry nor even accept such identification. So far, there is not an organized training method on agroforestry apart the Agrof MM method. The Agrof MM, «Agroforesterie – Formation - Mediterannee et Montagne», was a 3-year KA-2 ERASMUS+ educational project that aimed to i. Train between 130 and 150 agricultural professionals in Europe, ii. Improve and develop the education tools to enable agroforestry training to be sustainable, and, iii. Develop a unique agroforestry qualification program in each European country. It was coordinated by AgroSup Dijon, France. Thirteen partners from ten different countries participated in the program by contributing a wide range of knowledge, experiences and ideas. Within the framework of the Agrof MM project, European stakeholders were trained based on a general format (Core content) that differentiated based on the location. The training contained lectures, examples and a field trip. Interestingly, the priorities of the participants differed depending on their educational level and their age. European stakeholders were satisfied by the training format and stressed the need and willingness for interaction with other farmers and experts (Fig 1).

Fig 1. Suggestions by stakeholders for the training

Keywords: education, Mediterranean, mountain, European.

References:

1. AGROF MM project, http://agrofmm.eu/
2. Burriel C, Herdon M, Tamás J, Várallyai L,2017,Knowledge databank and repository service for AgrofMM

L13.P.22

Agroforestry in french territories overseas

Pinard C. (christophe.pinard@agriculture.gouv.fr)

DGPE, Ministère de l›agriculture et de l›alim., Paris, IDF, France

Agroforestry is an agricultural system where crops and/or cattle are associated with woody perennials. Rediscovered some decades ago, agroforestry is today becoming more and more popular, mostly due to the provisioning of ecosystem services it enables. In France, agroforestry is being promoted through the National Agroforestry Plan (NAP), a strategy aiming at developing agroforestry practices nationwide. The 5 French Overseas Departments (FODs, Martinique, Guadeloupe, Reunion Island, Mayotte and French Guyana) are territories characterised by their geographical isolation, a tropical climate and a specific economic context. As a consequence, agroforestry systems found in FODs are very different from those found in continental France, and the question of how to implement the NAP there arises. In the framework of the NAP, this study aims at developing a better understanding and description of agroforestry systems in FODs, focusing on three examples: shifting cultivation in French Guyana, shade-crops on Reunion Island, and creole gardens, a form of tropical homegarden. Financial incentives promoting agroforestry are also analysed. Data is collected through a review of existing literature and interviews of local stakeholders. From the results, tools that could potentially be used to promote agroforestry overseas are presented and discussed.

Keywords: overseas, tropical agroforestry, agro-ecology.

L13.P.23

Biodiversity conservation and the reasons for small-scale farmers to implement agroforestry in north-eastern Brazil

Sagastuy M. (machisagas@hotmail.com)

Environmental Sciences, Gothenburg University, Göteborg, Västergötland, Sweden

Agroforestry practices support agricultural resilience against climatic variability, increase soil productivity, can diversify and increase farmers' incomes, and support native fauna in agricultural landscapes. However, many farmers are still reluctant to implement agroforestry practices. Based on a comprehensive literature review we investigated the habitat potential of agroforestry systems for the golden-headed lion tamarin (Leontopithecus chrysomelas), the maned sloth (Bradypus torquatus) and the golden-bellied capuchin (Sapajus xanthosternos) in Brazil's Atlantic Forest region. We sent questionnaires to 75 agroforestry and 64 "conventional agriculture" small-scale farmers in southern Bahia to identify the motivations and limitations to implement agroforestry practices. We found five important factors that supported the three analyzed species in agroforest systems: absence of hunting; absence of domestic dogs; canopy connectivity; occurrence of food plants; and close proximity to forest remnants. In addition, we found four main reasons why farmers worked with agroforestry: higher income generation (89%); diversification of the production system (86%); increase in the land's quality and productivity (86%); and increase in self-sufficiency (82%). The three most common mentioned reasons for "conventional agriculture" farmers not shifting to agroforestry practices were: uncertainty if the system would work (62%); reduction in yield of the main agricultural crop (43%); and a lack of models and knowledge in the region (41%). Agroforestry in Brazil's Atlantic forest region can support native fauna, but farmers need to be educated about agroforestry practices and encouraged to switch from "conventional agriculture" to agroforestry through an increase in available technical assistance and capacitation/training in agroforestry practices.

Keywords: cabruca cocoa plantations, biodiversity conservation, small-scale farmers, technical assistance, Atlantic Forest.

References:

1. Cassano, C. et al., 2009, Biodivers Conserv 18 (3), 577–603
2. Yamada, M. et al, 2002, Agroforestry Systems 55 (2), 81-87
3. Martini, A. et. al, 2007, Biodivers Conserv 16 (11), 3111–3128
4. Cardozo, E. et. al, 2015, Agroforestry Systems 89 (5), 901–916
5. Cassano, C.et al., 2014, Biological Conservation 169, 14–22

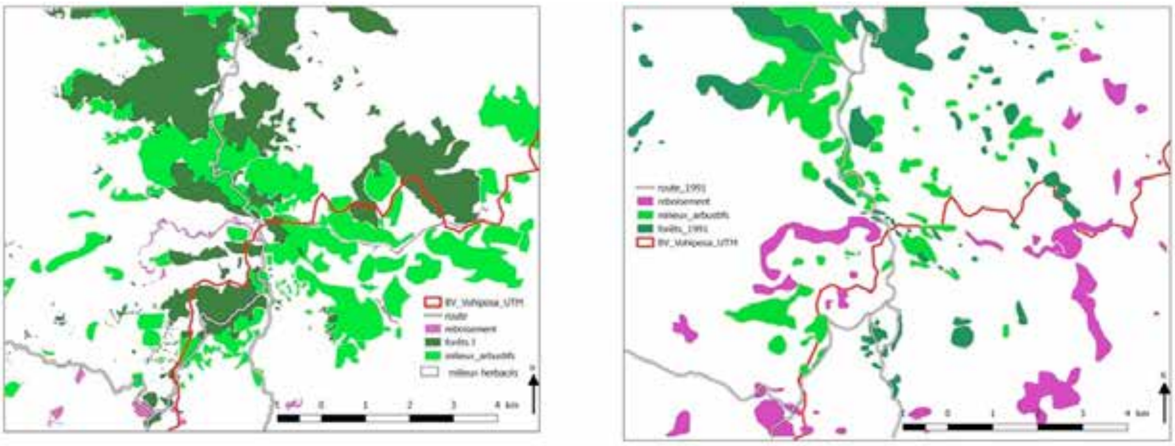
L13.P.25

Forest and agro-forest dynamics on Malagasy Highlands

Serpantié G.[1] (georges.serpantie@ird.fr), Ramana H.[2], Randriamalala J.[2], Carrière S. M.[1], Rakotonirina A.[3]

[1] *UMR GRED, IRD, Montpellier, France*; [2] *Forest department, Université d'Antananarivo, ESSA, Antananarivo, Madagascar*; [3] *Rhyvière Project, GRET, Antananarivo, Madagascar*

Recent "post-forest" landscapes of Madagascar result generally from combined processes: forest conversion to agriculture, forest degradation, ecologically regressive dynamics, and regeneration thanks to practices that favor the protection or regeneration of trees. "Agri-forestry" (when agriculture and trees are on different plots) and agroforestry practices have been analyzed in a Highland district in order to identify the possible levers for a landscape transition towards more trees. The approach focused on the ecological characterization of habitats and their dynamics in a recent post-forest zone, the link between practices and dynamics, and the ecosystem services expected by farmers and other stakeholders. The spatial and ecological analysis showed a double process of forest fragmentation and degradation: agro-industrial exploitation of large post-forest areas; over-exploitation of forest remnants; and barriers to regeneration processes due to bush fires. However, several forestry or agro-forestry initiatives mitigate this worrying diagnosis, including initiatives that are politically-based, project-based, community-based, or initiated by individuals to generate several types of ecosystem services from trees. By promoting other types of services (like watershed regulation or carbon sequestration), initiatives should be federated and supported by water, wood, energy, agro-industrial or carbon value chains, and adapted to the main limiting factors, especially fire risk.



Former dynamics of a Highland forest landscape: Fiadanana (Upper Matsiatra, 1957 to 1991). Reduction and fragmentation of forest habitats and shrubs, expansion of exotic reforestation of fire-tolerant trees

Keywords: Madagascar, Deforestation, Ecosystem services, Agroforestry, Practices.

L13.P.26

Socio-economic factors Determining agroforestry practices in Kabe watershed, Northern Ethiopia

Taltamo T.[1] (tesfayemi@du.edu.et), Bongers F.[2], Giller K.[3], Amede T.[4]

[1] *Forest and Environmental Techniques, University of Sopron, Sopron, Hungary*; [2] *Forest Ecology and Management, Wageningen University, Wageningen, Netherlands*; [3] *Plant Production Systems, Wageningen University, Wageningen, Netherlands*; [4] *International Crops Research Institute, ILRI, Addis Ababa, Ethiopia*

Multispecies agroforestry is widely acknowledged for its sustainable production while maintaining the resilience of the landscape. Despite recognized advantages, its adoption is challenged by various factors. This study aimed to assess the role of socioeconomic attributes in the adoption of agroforestry systems in drought-prone Kabe watershed in northern Ethiopia. Sixty sample farms were selected using stratified random sampling. The watershed was grouped into three classes (Downstream, Midstream, and Upstream) for fair representation of farms and 20 households were selected from each elevation category. Subsequently, households were categorized into four farm types based on resource endowment that depended on farm size, livestock ownership and annual income from non-farm activities. Socio-economic data and woody species, stem number and niches of plantation were recorded in each farm. Tree and shrub diversity indices and density were calculated and compared across farm types and with the socio-economic attributes. Twenty tree and shrub species were identified. Tree and shrub species richness and abundance significantly differed among the four farm types. High resource endowed farmers possessed higher species diversity and density compared with less resource endowed farmers. Farm size and age of the household head were positively correlated with on-farm species diversity and density whereas family size and farm distance from village center showed a strong negative relationship with on-farm species diversity and density. From the results, it could be explained that richer farmers with larger farm size and better income may not be constrained by food shortages for households and allocate a significant part of the land for tree plantation. In contrast, poor farmers invest in their land for quickly growing annual crops to satisfy the immediate need of food for the households. Finally, it is concluded that tree and shrub species diversity and abundance in the farms are influenced by socio-economic factors. Therefore, it is important to identify the socio-economic constraints on the households, particularly resource endowment status prior to the introducing tree and shrub species in the farms for the adoption of the agroforestry system in the Kabe watershed and in areas with similar biophysical, socio-cultural settings.

Keywords: Agroforestry, Adoption, Farm-type, Socio-economic, Kabe.

References:

1. Abebe et al, 2013. Agroforestry Systems v 87, P 1283-1293
2. Dennis et al, 2010. Food Security. pp. 197–214.
3. Duguma and Hager, 2010. Small-scale Forestry 9:153–174. DOI 10.1007/s1184
4. K.E. Giller, et al, 2011. Agricultural Systems 104: 191–203
5. S. Franzel, 1999. Agroforestry Systems 47: 305–321.

L13.P.27

Contribution of Agroforestry to tree species conservation and firewood supply around Melap Forest Reserve, West Cameroon

Temgoua L. F.[1] (temgoualucie@yahoo.fr), Fadi Y. M.[1], Bikoumou Manga R.[2], Ko Agathe G.[1]

[1] *Department of Forestry, University of Dschang, Dschang, Cameroon*; [2] *National Forestry Support and Developme, Foumban, Cameroon*

The Melap Forest Reserve in west Cameroun is encroached by local populations for agriculture and wood extraction. This reserve is also the main source of firewood supply of the surrounding cities and gradually the activities carried out there have led to its degradation. Around this reserve however, local populations plant trees in their farms. The objective of this study was to assess the contribution of these agroforestry systems to the conservation of species and firewood supply. The methodological approach consisted of interviews with farmers in the five surrounding villages. Field surveys and inventories were carried out in 50 agroforestry plots in order to identify and characterise woody species. The results showed that 16 species (figure) belonging to 6 families have been inventoried. The most frequent species was *Eucalyptus* sp and introduced trees were more abundant (93.75%). These associated trees provide food, medicines as well as wood. 33% of species were planted primarily for firewood supply. The main constraints to the introduction of trees in farms are land tenure and the lack of arable lands (cited by 25% of respondents); the competition of trees with crops and shading (13.75%) that decrease the yields of the associated crops; the lack of quality seeds and seedlings (12.50%); the slow growth of trees (6.5%) and bushfires (5%). For a better contribution of agroforestry systems to firewood supply, farmers must be trained in nursery and tree management techniques.

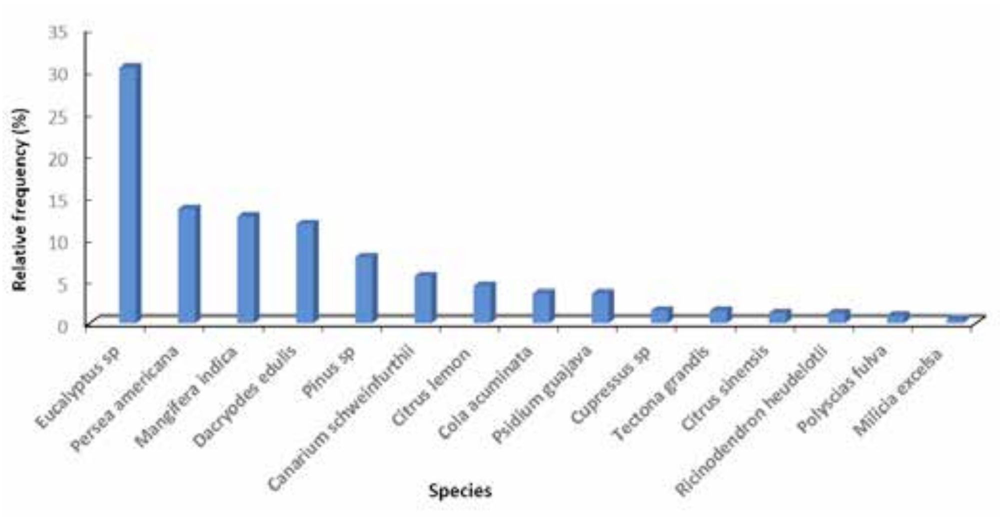


figure 1: Relative frequency of tree species identified in agroforestry systems

Keywords: species conservation, agroforestry, forest reserve, firewood, west Cameroon.

L13.P.29

A paradigm shift for agroforestry in Guadeloupe islands: toward a value-enhancement of cultivated forests ecosystems

Vinglassalon A.[1] (syaprovag@gmail.com), Apatout M.[1], Gilles E.[1], Noglotte T.[2]

[1] *SYAPROVAG, Petit-Bourg, Guadeloupe*; [2] *Cecil Consultants, Petit-Bourg, Guadeloupe*

A project on the ecosystemic value-enhancement of forests (Valab) emerged at the initiative of the Agricultural Union of Vanilla Producers (Syaprovag) in the Guadeloupean archipelago. This paper analyses the contextual elements – with a focus on the insular context – that led these producers to start the project. It presents their vision of agroforestry in Guadeloupe and the local challenges the project has had to face.

In the early 20th century, agroforestry systems were located in spontaneous forests, in most cases itinerant, and based on a great agrobiodiversity found in Guadeloupe. Those systems were progressively abandoned because of their own constraints and because of socio-economic changes on the archipelago (1). In the 1990s, programs to revive the coffee and vanilla sectors led to the creation of farmers' organisations. Among them, the Syaprovag was created in 1993 and received financial support for vanilla plantations. However, vanilla monoculture did not provide sufficient income for the farmers due to the long return on initial investment, climate hazards, lack of technical knowledge, and international competition magnified in the remote insular context.

In 2011, the Syaprovag farmers put forward the alternative of diversified activities in the forest, inspired by the historical Guadeloupean forest gardens. They designed the concept of "Integrated ecosystemic value-enhancement of the Guadeloupe forest agrobiodiversity" (Valab). The objectives were to: 1) assure incomes to farmers through diverse quality products; 2) preserve ecosystemic services provided by the forests to society; and 3) maintain a threatened socio-cultural heritage. Moving away from long promoted sectorial approaches, these producers decided to adopt a systemic vision of the forest plot and related issues. Then, they designed the Valab project and recruited local partners for its implementation. They chose to talk about "forest valorisation" (value-enhancement) instead of "agroforestry" to distinguish their approach from tree plantations in open field systems.

Valab aims to address different issues of the Guadeloupean archipelago: economic issues (viability, creation), environmental issues (preserving endemic biodiversity as well as water quality and stock for the islands, balancing carbon stocks and sinks), as well as social issues (providing quality product that meets local demand while maintaining cultural heritage and enhancing agriculture's contribution to the well-being of the population).

The VALAB project is currently being implemented. It proposes a paradigm shift in the approach to agroforestry in Guadeloupe: first, through the development of systems by and for farmers; and secondly, through the objective of achieving global value-enhancement of the forest leading farmers to envision and build new roles as biodiversity managers.

Keywords: Guadeloupe, Islands, Forest garden, Stakeholder empowerment, Ecosystem services.

References:

1. Catro-Nunes M. T., 2018, Mémoire de Master 2, Université Toulouse III

L13.P.30

Revisiting land reform in the oil palm agroforestry system: land rights, access, and soil fertility management

Yemadje R. H.[1] (rolandyemadje@yahoo.fr), Lammoglia S.-K.[2], Mongbo R.[3], Saïdou A.[3], Kuyper T.[1], Crane T. A.[4]

[1] *Soil Quality Department, Wageningen University, Wageningen, Netherlands*; [2] *UMR SYSTEM F-34398, CIRAD, Montpellier, France*; [3] *Faculté des Sciences Agronomiques, Université Abomey-Calavi, Abomey-Calavi, Benin*; [4] *Centre for Integrative Development, Wageningen University, Wageningen, Netherlands*

In the oil palm agroforestry system on the Adja Plateau (West Africa), land titling plays an important role. Landowners argue that oil palm fallow (*dekan*) restores soil fertility, but in the long-term it is also an instrument in the struggle for control over land. A land-titling programme in the study area allowed an analysis of the relationship between titling and soil fertility management that showed two different institutional effects with socio-technical consequences. *Titling* increased land security for landowners and, although this security initially reduced access to land for tenants, a subsequent introduction of *witnessed paper-based contracts* enhanced tenants' access to land and improved their security of tenure. Improved titling and more secure tenure reduced conflicts over land and opened possibilities for agricultural intensification. This change was associated with a shift from long-term oil palm fallow to shorter-term land-management practices where tenants and landowners increasingly invested in land through rotations between maize and cowpea (rather than maize mono-cropping) and the use of mineral fertilizers, without increased use of household waste (organic amendment). The paper suggests that sustainable agricultural intensification in agroforestry systems requires institutional changes, based on a mixture of customary and formal rules, in both landownership and rental agreements to access land.

Keywords: Bricolage, Customary land rights, Oil palm agroforestry, Political ecology, soil fertility.

ABSTRACTS

Agroforestry adoption

Adopting the future of land use

- L14 -

Agroforestry landscapes

Delivering benefits for people, food and nature

Across much of the world, agricultural systems, ecosystem health, and rural resource-based livelihoods are in crisis. Over the next 50 years, agriculture will be forced to go through an extraordinary transition to meet production needs sustainably, in the context of climate change, growing populations, and economic transformation. Biodiversity and ecosystem conservation efforts will need to shape new strategies in the face of agricultural growth. Populations and businesses will need to find new ways to manage their natural resource base to secure the full range of goods and services needed from their landscapes, to find the synergies and reduce the tradeoffs. Integrated management of agricultural landscapes (ILM) will be an essential building block towards that transition. Landscape-level platforms and partnerships are the mechanisms by which inclusive green growth and Sustainable Development Goals will be implemented. Agroforestry systems and practices promise to play a major role in the sustainable transformation of agriculture within sustainable landscapes. This Session on Agroforestry Landscapes will examine:

- the roles of agroforestry in multi-stakeholder strategies for integrated landscape management in diverse agroecosystems,
- the evidence on multi-objective performance of agroforestry at landscape scale
- strategies for scaling agroforestry through multi-stakeholder landscape partnerships
- tools for analyzing agroforestry adoption and impacts at landscape scale
- drivers, processes, and social-ecological impacts of expansion or decline of agroforestry systems at landscape scales.

L14_O.01

Scaling-up agroforestry to transform landscapes, with examples from Ecuador and Northeast USA

Buck L.[1] (leb3@cornell.edu), Bosco S.[2], Burgoa G.[3], Higgenbotham C.[3], Meecham J.[3], Lassoie J.[1], Rodgerson F.[3], Scherr S.[4], Trujillo L.[5]

[1] *Natural Resources, Cornell University, Ithaca, NY, USA*; [2] *Plant Science, Cornell University, Ithaca, NY, USA*; [3] *Global Studies, Cornell University, Ithaca, NY, USA*; [4] *Policy, EcoAgriculture Partners, Washington, DC, USA*; [5] *International Programs, Cornell University, Ithaca, NY, USA*

Increasingly agroforestry is considered as a foundation for multi-functional, socio-ecological landscape transformation. Yet the barriers to large scale agroforestry adoption are legendary, rooted in the misalignment between risk-takers (small scale farmers) and beneficiaries (society at large) (Franzel et al., 2001). Integrated landscape management (ILM) offers a strategy for scaling up agroforestry, by mobilizing collaborative efforts among multi-sector stakeholders. This study evaluates the application of ILM strategies in agroforestry initiatives in three diverse landscapes: the Amazon Production Transformation Agenda (ATPA) project of the Ecuadorian Ministry of Livestock and Ministry of Environment, the Chocó-Andean Bio-Corridor in Ecuador, and the Nut Tree Based Agroforestry initiative in New York. Integrated landscape management (ILM) frameworks provided the conceptual basis for analysis (Denier et al., 2015, Sayer et al., 2013; Scherr, et al., 2012; Tonen et al., 2018). Other landscape examples were incorporated into the analysis.
The agroforestry initiatives represent a public policy, government led approach (ATPA); a civil society grassroots and international NGO led approach (Chocó-Andean Bio-Corridor); and a value chain led approach (Nut Tree Agroforestry). All include indigenous peoples' lands and organizations. The analyses highlight characteristics that are advancing the scaling-up of agroforestry; blockages to progress; prospective levers of change to unlock the blockages; and the partners, partnership formation and strengthening processes, activities, roles, and responsibilities that can advance momentum for landscape transformation. Integrating value chain and landscape governance perspectives and critical partners can accelerate scaling, and create incentives that attract multiple sources of finance to sustain the initiatives.

Keywords: Agroforestry landscapes, Integrated landscape management, Landscape partnerships, landscape transformation, scaling up.

References:

1. Denier,in: The Little Sustainable Landscapes Book, 2015, Denier, 1-58.
2. Franzel et al., 2001, Development in Practice, 1364-9213; 10.1080/09614520120066792
3. Sayer et al., 2012, PNAS,8349-8356;https://doi.org/10.1073/pnas.1210595110
4. Scherr et al.,2012,Agriculture & Food Security,1-12;10.1186/2048-7010-1-12
5. Tonen et. al,2018,Environmental Management,1-14;10.1007/s00267-018-1055-0

L14_O.02

Trees on Farms as a negotiation tool to bridge food production and conservation goals

Zinngrebe Y.[1] (a.gassner@cgiar.org), Edwin G.[2], Winter E.[3], Gassner A.[4], Dobie P.[5], Parmutia M.[5], Hauck J.[6]

[1] *George-August-Universität Göttingen, Göttingen, Germany*; [2] *CATIE, Tegucigalpa, Honduras*; [3] *Leibnitz Universität Hannover, Hannover, Germany*; [4] *Worldagroforestry Center (ICRAF), Los Banos, Philippines*; [5] *Worldagroforestry Center (ICRAF), Nairobi, Kenya*; [6] *Helmholtz Centre Environmental Research, Leibzig, Germany*

An advancing agricultural frontier is one of the key causes for tropical deforestation and present a major obstacle towards the global target for sustainable agriculture (CBD-Aichi target 3). In one of Central Americas most dynamic areas in Eastern Honduras, main agricultural land-uses replacing native forests are coffee, cattle ranging and grains. Production systems and the respective actors operate to large extents in silos and do neither engage with each other nor with conservation initiatives. Continous droughts and low market prices for cattle products increase the vulnerability of cattle rangers and lead to questioning existing farming practices.
We applied and adjusted the NET-MAP approach as a negotiation tool to bring together different landscape actors to agree on an objective for a landscape approach. The NET-MAP is a tool for analysing social networks of local actors related to trees on farms both on the national level and in the case study region around Catacamas, Olancho (Schiffler et al. 2010, Reed 2009). Focus group discussions brought together stakeholders from governmental agencies, NGOs, business and farmer organisations as well as academic actors to analyse the influence of actors on trees on farms. In a four step analytical process, we first identified and categorised relevant actor groups. Secondly, linkages regarding the exchange of information, financial flows and regulatory influence were mapped. Thirdly, participants rank the influence of actors in an ordinal scale. Finally, results and observations were discussed.
As key result, cattle rangers and coffee association were found to have the strongest potential in influencing trees on farms. After having been a driving force in land-use change, cattle farmers got aware of the potential of forming coalitions for multi-functional approaching expanding their sources of income, accessing the know-how for sustainable, shaded pasture management practices. Besides local coalitions for alternative management approaches, national biodiversity policy actors were connected to different farmer groups presenting new innovative potential for implementing biodiversity targets in agricultural landscapes.
While producing both quantitative and qualitative information, our results highlight the potential of net-map to structure learning processes for transformative sustainability science (Lang et al. 2012). Net-Map presents a methodology that is both scientifically solid as well as flexible and practical to be applied as analytical tool in transdisciplinary development projects.

Keywords: negotiations, NET-Map, actor, intersectoral, land-use.

References:

1. Schiffer, E., & Hauck, J. (2010) Field Methods, 22(3), 231-249.
2. Reed, Mark S. et al (2009) Journal of environmental management 90 (5), pp. 1933-1949
3. Lang, D. J., et al (2012) Sustainability science, 7(1), 25-43.

L14_O.03

Benefits of temperate agroforestry landscapes - economic evaluation of the marketable and the non-marketable outcomes

Kay S.[1] (sonja.kay@agroscope.admin.ch), Graves A.[2], Palma J.[3], Moreno G.[4], Roces-Díaz J.[1], Crous-Duran J.[3], Aviron S.[5], Chouvardas D.[6], Măcicăsan V.[7], Mosquera-Losada R.[8], Szerencsits E.[1], Torralba M.[9], Herzog F.[1]

[1] *Agroecology and Environment, Agroscope, Zürich, Switzerland*; [2] *Cranfield University, Bedfordshire, United Kingdom*; [3] *Forest Research Centre, University of Lisbon, Lisbon, Portugal*; [4] *Forestry Research Group, Universidad de Extremadura, Plasencia, Spain*; [5] *UMR BAGAP, Inra-Agrocampus Ouest-ESA, Rennes, France*; [6] *Forestry and Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece*; [7] *Taxonomy and Ecology, Babes-Bolyai University, Cluj-Napoca, Romania*; [8] *Crop Production and Project Engineering, Universidad de Santiago de Compostela, Lugo, Spain*; [9] *Faculty of Organic Agricultural Sciences, University of Kassel, Witzenhausen, Germany*

Temperate agroforestry landscapes provide economic and environmental benefits; however, these benefits are only partly financially valued by farmers and society.
Against this background we assessed the economic performance of marketable ecosystem services (ES) and non-marketable ES in contrasting landscapes dominated by agricultural or agroforestry land use in twelve case study regions in Europe. The focus was on the evaluation of the annual biomass production as marketable outcomes and groundwater recharge, nutrient retention, soil preservation, carbon sequestration and pollination as non-marketable outcomes (Kay et al. 2018). Our findings showed, that agroforestry landscapes had slightly lower market outputs than agricultural areas if the focus was only on marketable ES. However, when monetary values for non-marketable ES were included, the relative profitability of agroforestry landscapes increased. This was due to the fact that nutrient and soil losses were reduced, and additional benefits could be gained from carbon sequestration. This trend was of similar relevance in all three major biogeographical regions of Europe (Figure 1).
Our outcomes showed how a market system that includes the value of broader ES would result in landscapes including multifunctional agroforestry systems and underlined that there is a critical gap in economic assessments that fails to account for ecological and social benefits.

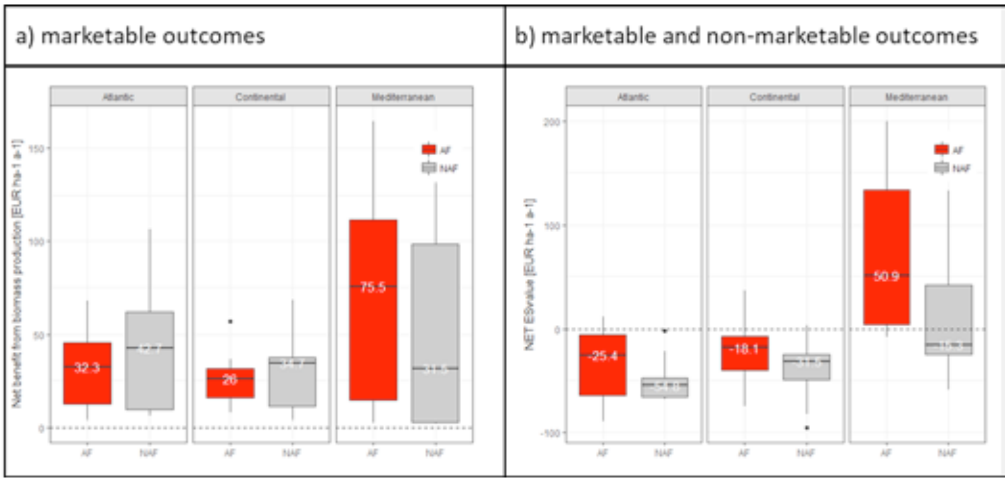


Figure 1: a) Average net financial benefit of biomass production in € ha-1 a-1 of 11 cases study regions in biogeographical regions, b) Net ecosystem service value in € ha-1 a-1 of 11 cases study regions in biogeographical regions

Keywords: ecosystem services, external costs, biomass production, carbon storage, nutrient loss.

References:

1. Kay et al, 2018, Agroforestry Systems 92, 1075-1089

L14_O.04

Agroforestry for Conservation: planning sustainable landscapes in the Colombian Amazon

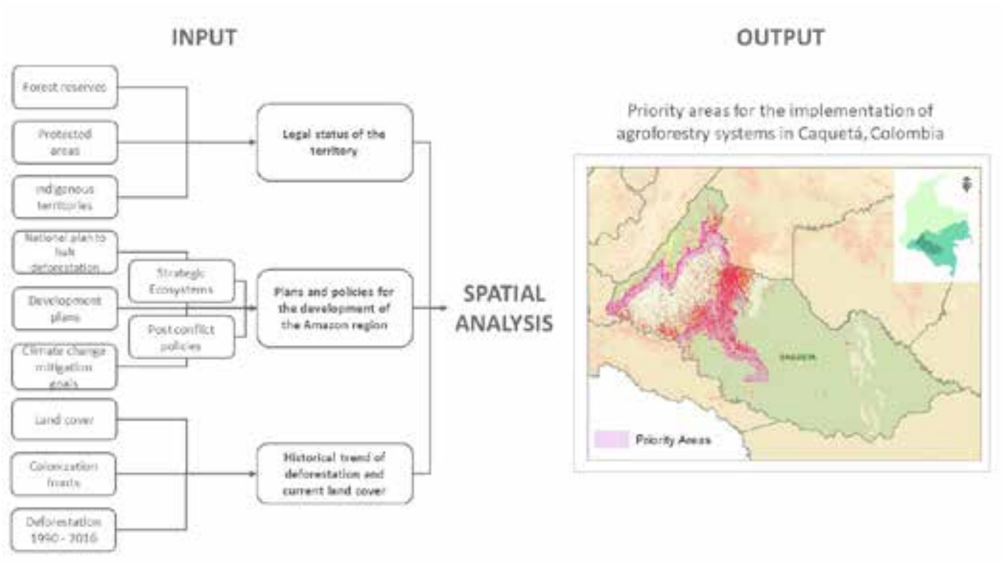
Ordonez M.[1] (maria.ordonez@tnc.org), Arango D.[2]

[1] *Lands Strategy, The Nature Conservancy, Bogota, Bogota, Colombia*; [2] *Science Team, The Nature Conservancy, Bogota, Bogota, Colombia*

The vast area of the Colombian Amazon region spans close to 39 million hectares. A gateway to the Andean Amazon, the Department of Caqueta, is one of the most affected areas by the armed conflict and it is currently the country's highest deforestation hotspot, representing 30% of national deforestation in 2017. To build a territory of peace implies several challenges for conservation and the sustainable development of the Amazon and its inhabitants.

The Agroforestry for Conservation (A4C) project, an initiative developed by The Nature Conservancy and the Amazon Conservation Team under the International Climate Initiative, aims to restore natural and productive degraded ecosystems and to reduce deforestation in Caquetá by promoting the implementation of agroforestry practices. The A4C project developed a methodology for a comprehensive technical landscape planning process for Caquetá considering three criteria: 1. Legal status of the territory, 2. Plans and policies for the development of the Amazon region, and 3. Historical trend of deforestation and current land cover.

The spatial analysis of these criteria allowed the identification of priority areas for the implementation of agroforestry systems that can fulfill several objectives: increased forest cover and biodiversity protection and connectivity; increased carbon storage contributing to climate change mitigation; and increased productivity and profitability for farmers and indigenous peoples depending on forests.



Landscape planning process for Caquetá Amazon region

Keywords: Landscape, Planning, Agroforestry, Colombian Amazon, Sustainability.

L14_O.05

Filming agroforestry: producers shaping landscapes

Bories O. (olivier.bories@educagri.fr), Fontorbes J. P., Granié A. M., Cazenave J. M.

Haute Garonne, ENSFEA - UMR CNRS 5193 LISST DR, Toulouse, France

We aim at presenting our research movie : *Agroforestry, agroforesters and landscapes,* it is a scientific documentary showing with the help of audiovisual tools how landscapes benefit from agroforestry. If we lack knowledge on the qualification of agroforestry landscapes we do know that refurbishing the landscapes is part of the agroforesters involvement.
Firstly agroforestry is part of those agricultures generating landscapes which are at the core of a renewal of the scenery. Between modernity and tradition, agroforestry redraws and recomposes lines, reorganizes plots, in moving or creating lines it replaces boundaries at different scales.
Secondly we choose to use audiovisual aids in three interwoven work registers and questionings:
- the life trajectories and social conceptions of farmers producing agroforestry landscapes, focusing on their motivations and feelings in order to understand the signification of their actions in landscape
- those partices, technical actions and activities that solidify their purposes
- the aesthetics of agroforestry shapes and landscapes, here we questions the shapes ans traces, the powerful marks of agroforestry in the local settings.

The result is a movie produced at CNRS 5193 Lisst-Dynamiques rurales research team, in partnership with Arbres et Paysages d'Autan, supported by the Fondation de France and the French Ministry for Ecology.

agroforestry landscape: drone view

Keywords: agroforestry landscape, movie search, agroecological transition, agroforestry farmers.

References:

1. Bories O., 2015. Filmer l'artificialisation d'une terre agricole périurbaine, Projet de Paysage, 15
2. Bories O., 2017. Quand des agroforestiers nous parlent d'arbre et de paysage, Projet de Paysage, 23
3. Bories O., 2018. Des films en géographie qui font du paysage un personnage, Methodo visuelle, 14
4. Fontorbes J-P., 2013. La mise en scène des identités, HDR, UT2 ESAV
5. Granié A-M., Figures de constructions identitaires. Regards croisés. Le film..., HDR, UT2 ESAV

L14_O.06

Land use change and driving factors in a fragile coastal rainfed lowland rice - sugar palm system of southern Thailand

Dumrongrojwatthana P.[1] (dpongchai@hotmail.com), Wanich K.[2], Trébuil G.[3]

[1] *Department of Biology, Science Faculty, Chulalongkorn University, Bangkok, Thailand*; [2] *Environmental Science, Graduate School, Chulalongkorn University, Bangkok, Thailand*; [3] *CIRAD, Innovation joint research unit, Montpellier, France*

For centuries, rainfed lowland rice production associated to sugar palm (*Borassus flabellifer*) hedges planted in the paddy field bunds (RLR-SP) has been an emblematic cultural agroforestry system in the indianized Southeast Asian countries. But recent changes in communication infrastructure, commercialization, urbanization, private and state interventions are driving the rapid transformations of these multi-functional systems. In the absence of in-depth analyses documenting the socio-ecological impacts of such change on household livelihoods and landscapes, a case study on the transformations, over the past four decades, of one of the most sophisticated coastal RLR-SP agroforestry system was implemented in Sathing Phra peninsula, Southeastern Thailand. Chronological series of satellite images and ground truthing were used to characterize and quantify land use change during 1983-2015, and 120 interviews with concerned stakeholders were carried out to understand agro-ecological, social, and economic effects of the driving factors of change on their livelihood systems. We show a process of diversification of farming (and off-farm) activities along their gradual market integration, since the opening of bridges and all-weather roads linking the area to neighboring cities in the 80s. We found that the traditional RLR-SP agroforestry system survived, almost unscathed, a first series of agrarian change. It was characterized by attempts at introducing irrigated rice, shrimp farming small perennial tree plantations in the paddies, or converting deep-water rice areas into small-scale integrated farming systems. The much improved communication infrastructures, and lack of irrigation water to switch from the low and unstable RLR yields to higher-value cash crops, increased the mobility of family farm laborers. They sized wage-earning opportunities, in the village or in fast developing urban centers, and escaped the drudgery of tapping sugar palms, in increased numbers. But a rising and profitable demand for sugar palm fruits from caning factories allowed the maintenance of the multiple functions of dense and healthy palm groves. A more recent "palm narang" government policy, supported by the establishment of new palm oil companies in the area, promoted small oil palm plantations in abandoned paddy fields to raise farm incomes. As the conversion to oil palm plots was the most important land use change observed during the last decade, it seems to be a more serious threat to the survival of the RLR-SP agroforestry system. In addition to these impacts of peri-urbanization combined with private and state interventions, an increase in the frequency of extreme rainy and windy events was also uncovered. This is underlining the need for the collaborative design of land-use scenarios and related collective and coordinated action plans to adapt this, diverse but increasingly vulnerable, iconic agroecosystem to future challenging socio-ecological circumstances.

Keywords: rice, Borassus flabellifer, crop diversification, market access, climate change.

L14_O.07

Agroforestry within broader anthropogenic landscapes: indigenous and local knowledge, concepts and practices

Aumeeruddy-Thomas Y.[1] (yildiz.thomas@cefe.cnrs.fr), Caillon S.[2], McKey D.[3]

[1] *Interactions Ecology and Societies, CEFE-CNRS UMR5175, Montpellier, Héraut, France*; [2] *Interactions Ecology and Societies, CEFE-CNRS UMR5175, Montpellier, Hérault, France*; [3] *Interactions Ecology and Societies, CEFE University Montpellier UMR5175, Montpellier, Hérault, France*

Agroforestry systems across the planet are elements of larger anthropogenic landscapes. These include a range of environments, from forests to areas mainly used for the intensive production of cereals, tubers or forage for domestic animals. We examine 'traditional' agroforestry systems to decipher how indigenous and local knowledge creates continuities and connectedness among the different elements of these larger anthropogenic landscapes. The societies that have devised these systems and shaped these landscapes conceive of nature and culture as intimately interconnected. These conceptions are linked to multiple practices, including choice of crops and how each crop is propagated, management of wild species as part of food systems, soil management, and management of vegetation mosaics at the landscape level. These societies use the wide range of environments in multiple activities for subsistence and for trade. Given these interconnections, focusing only on the part of the landscape seen as 'agroforestry' prevents us from understanding the structure, functioning and dynamics of the overall system. Using case studies from Indonesia, Madagascar, Morocco, Sicily, France, Vanuatu and Amazonian forests, we will show how agroforestry is embedded within social-ecological systems. We emphasize the importance of understanding how societies use indigenous and local knowledge to manage landscape-level interconnections and how practices are related to their conceptualization of nature. We will also show how these practices create and maintain diversity at different levels, from intraspecific genetic diversity of their crops to landscape-level biodiversity, and thereby contribute to the resilience of agroforestry and the well-being of societies that increasingly depend on it.

Keywords: Nature-Culture, Connectedness, Domestication_Diversification, Local knowledge, anthropogenic landscapes.

References:

1. Aumeeruddy-Thomas et al. (2012) Ecology and Society 17(2): 12
2. Aumeeruddy-Thomas Y. et al. (2017) Regional Environmental Change 17:1315-1328
3. Caillon et al. (2017) Ecology and Society 22(4): 27
4. Thomas M. & Caillon S. (2016) Ecology and Society 21: 13
5. Rival, L., & McKey, D. (2008). Current Anthropology, 49(6), 1119–1128

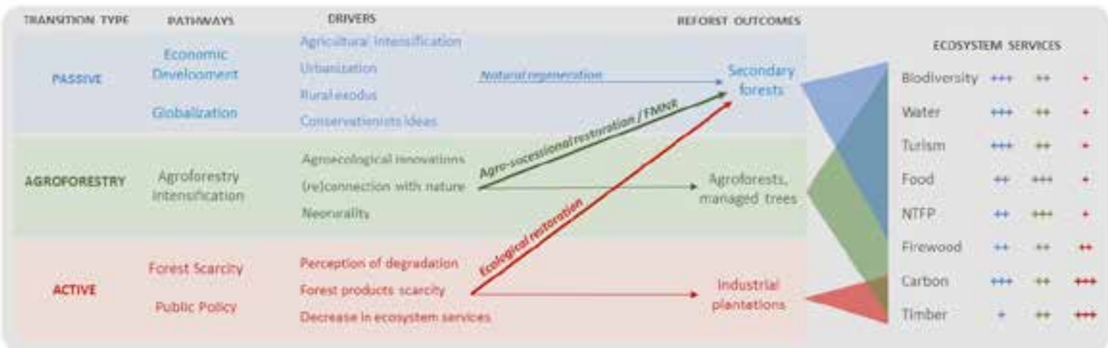
L14_O.08

(Agro)Forest Transitions: Upscaling Landscape Restoration through Agroforestry

Tubenchlak F.[1] (f.tubenchlak@iis-rio.org), Pepe I.[1], Felippe E.[2], Siqueira A. P.[3], Strauch G.[4], Scarano F.[5], Strassburg B.[1]

[1] *International Institute Sustainability, Rio de Janeiro, RJ, Brazil*; [2] *Agroecologia Rio Ltda, São José do Vale do Rio Preto, RJ, Brazil*; [3] *PPGCTIA, UFRRJ, Seropédica, RJ, Brazil*; [4] *EMATER RIO, Niterói, RJ, Brazil*; [5] *Ecologia, UFRJ, Rio de Janeiro, RJ, Brazil*

Large-scale restoration goals have been targeted globally and achieving those requires further understanding on how different restoration options are perceived. This study analyzed the potential of Agroforestry systems (AFS) for upscaling landscape restoration, considering Forest Transition theory and pathways (Lambin & Mefroydt, 2010; Wilson et al., 2017). We combined literature review, interviews, focus group and participatory observation about AFs in Rio de Janeiro state: 128 experiences were mapped, of which 18 were visited. Data about the AFS objectives and the species composition were collected, along with stakeholders' perceptions about them. Different types of AFS were observed, with different species, designs and management strategies, which subsidized a discussion about the role of different AFS in the restorative continuum. According to the stakeholders, the main benefits of AFS are: quality and diversification of food production, soil recovery and the sense of (re)connection with nature. Challenges include: access to knowledge and labor, inputs and markets, as well as legal insecurity in managing forests and land tenure. Results expand the understanding on Forest Transitions, identifying new factors that promote agroforestry adoption and forest gain. This understanding is fundamental for planning effective restoration projects, based on diverse strategies, contributing to climate change mitigation, adaptation, biodiversity conservation and human wellbeing.



Expanded framework on Forest Transition pathways, their drivers and relative outcomes. We identified new drivers that promote agroforestry adoption and forest gain at landscape scale, showing it's potential for promoting multifunctional landscapes and achieving global targets. Based on Wilson et al. (2017). FMNR = Farmer-Managed Natural Regeneration; NTPF = Non-Timber Forest Products

Keywords: Forest Transition, Ecological Restoration, Agro-sucessional Restoration, Forest Landscape Restoration, Farmer-Managed Natural Regeneration.

References:

1. Lambin, E. F. & Meyfroidt, P., 2010. Land Use Policy, 108-118
2. Wilson, S. et al., 2017. Ecology and Society. 38

L14_O.09

Application of wildfire simulators for the management and protection of Mediterranean agroforestry systems

Arca B.[1] (b.arca@ibimet.cnr.it), Casula M.[1], Salis M.[1], Pintus G. V.[1], Ventura A.[1], Duce P.[1], Franca A.[2], Re G. A.[2], Sanna F.[2]

[1] *Institute of Biometeorology (IBIMET), National Research Council of Italy, Sassari, Italy*; [2] *ISPAAM, National Research Council of Italy, Sassari, Italy*

Wildfires represent one of the most extensive disturbances of the agroforestry systems, as other land use systems of the Mediterranean basin. As Mediterranean rural landscapes are often characterized by a complex matrix of grasslands, open wooded pastures, shrublands and broadleaf forests, these heterogeneous conditions may limit the prediction of wildfire behavior and severity and in turn affect the sustainability and effectiveness of fire prevention and fire management activities carried out by the fire protection agencies. For these reasons, fire prevention and suppression actions should be supported by analytical tools (simulators and decision support systems) and data provided by monitoring technologies (satellite imagery, unmanned aerial vehicles with vision–based systems, automatic weather station networks, short–term weather forecasts) able to provide assistance in evaluating the most appropriate fire prediction and management strategies. Analytical tools can help managers considering in an integrated way the complex relationships among variables that affect wildfires: fire ignition and current location, vegetation and fuel characteristics, weather conditions and other landscape characteristics.

The aims of this work are (1) to present a wildfire simulator designed to provide support to wildfire prevention and management operations in Sardinia (Italy) and (2) to provide a probabilistic application of wildfire simulators devoted to estimate burn probability in Sardinian grazed forests considering different scenarios of grazing pressure and weather conditions.

The wildfire simulator is based on in–house developed codes for the estimation of high resolution wind field maps from local area weather forecasts by a mass–consistent model, and the simulation of wildfire spread by a level–set approach which uses as input the vegetation characteristics summarised as fuel models, the weather conditions and the topography. The simulator is specifically designed to simulate the wildfire propagation on different temporal and spatial domains. The wildfire simulator were run using a random sample of ignition points in order to determine fire probability and severity maps for different treatments and environmental conditions.

The probabilistic application of wildfire simulators provided useful data and maps to assess the effects of grazing pressure on fire behaviour, to identify the areas with high probability of burning, and to plan the fire prevention and fire management practices.

The study confirmed that regulated pastoral activities could provide a valuable support in wildfire management, particularly if linked to a higher involvement of farmers in the surveillance and prevention policies of Mediterranean areas; this role could be even supported by the public institutions through specific programmes and incentives.

Keywords: fire behaviour, fire spread, fire management, grazing.

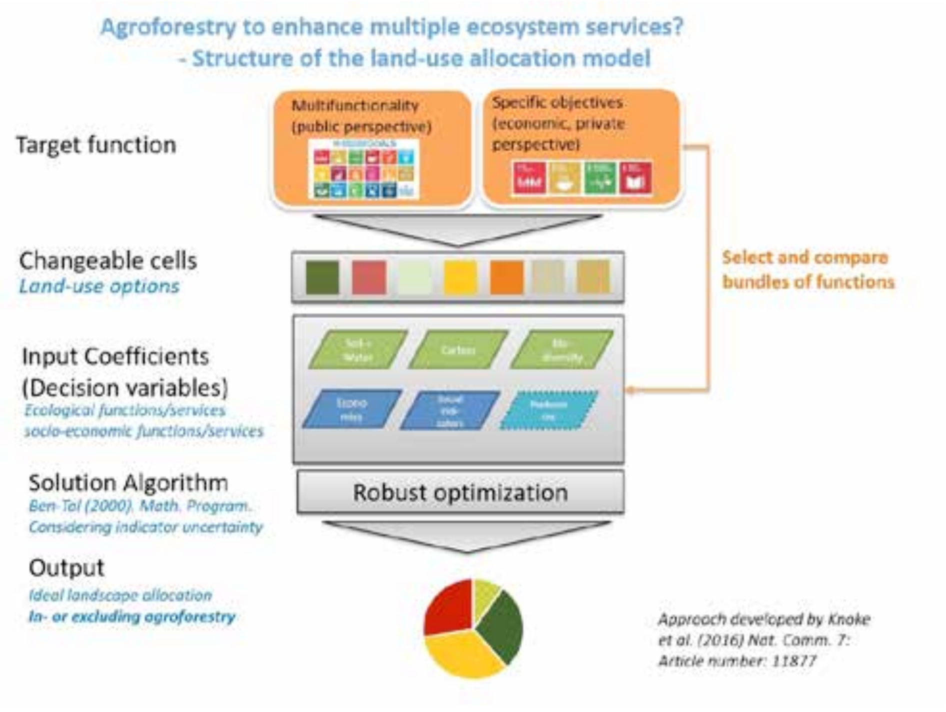
L14_O.10

Can agroforestry enhance multiple ecosystem services? Examples from a modelling approach in three tropical landscapes

Paul C.[1] (carola.paul@uni-goettingen.de), Reith E.[2], Gosling E.[2]

[1] *Forest Econ. & Sust. Land-use Planning, University of Göttingen, Göttingen, Germany*; [2] *Institute of Forest Management, Technische Universität München, Freising, Germany*

Agroforestry (AF) is promoted as a key strategy to increase the level and stability of multiple ecosystem services. Yet, this may not be true for all landscapes and all systems. As it is usually impossible to empirically test different landscape designs and AF systems, we rely on modelling approaches. We propose a multi-objective land-use allocation model for investigating different land-use strategies. Being parsimonious in nature, the model draws on a set of indicators and their uncertainties to optimize land-use allocation. We include and exclude agroforestry systems to investigate whether they can actually help to increase levels and stability of multiple ecosystem services. We present example applications of the approach from Panama, Ecuador and Indonesia. We find that in forested landscapes agroforestry did not contribute to multifunctional landscapes, while in agricultural dominated landscapes, they could help to improve service provision. The modelling approach may help to better understand the conditions under which agroforestry and specific systems should be promoted.



Keywords: Land-use allocation, robust optimization, ecosystem functions, multifunctional landscape, compromise solution.

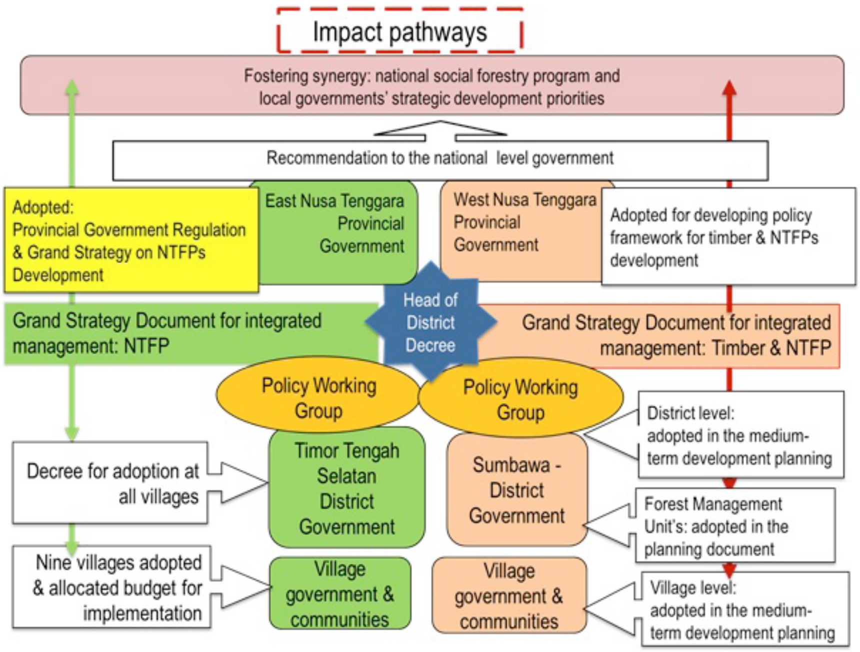
L14.P.01

Operationalizing landscape approach in Indonesia: grand-strategy for integrated management at the landscape level

Adiwinata Nawir A.[1] (a.nawir@cgiar.org), Syafii S.[2], Nomeni Y.[3], Raharjo A. S.[4], Yumn A.[1], Julmansyah J.[5], Danayasa P.[6], Abdurahman M.[7], Koenunu C.[6], Hakim M. R.[2], Muslimah S.[1]

[1] *Sustainable Landscapes and Food Systems, CIFOR, Bogor, West Java, Indonesia*; [2] *Coral Triangle Program, WWF (World Wildlife Fund) Indonesia, Mataram, West Nusa Tenggara, Indonesia*; [3] *Coral Triangle Program, WWF (World Wildlife Fund) Indonesia, Kupang, East Nusa Tenggara, Indonesia*; [4] *The Research, Development and Innovation, Ministry of Environment and Forestry, Solo, Central Java, Indonesia*; [5] *Forest Management Unit, Ministry of Environment and Forestry, Sumbawa, West Nusa Tenggara, Indonesia*; [6] *Forest Management Unit, Ministry of Environment and Forestry, Soe, East Nusa Tenggara, Indonesia*; [7] *Faculty of Agriculture, Mataram University, Mataram, West Nusa Tenggara, Indonesia*

The landscape-based approach has been promoted to overcome the multi-faceted direct and indirect causes of deforestation. Efforts are needed to move toward operationalising it into practice. In Indonesia, challenges include the lack of integrated planning at the landscape level. The conceptual framework is clear, integrated grand strategy based on sustainable business model considering the ecosystem characteristics and supported by complementary policy framework, and this is crucial for facilitating a sustainable integrated forest-landscape management. Using Participatory Action Research Approach, two documents of grand strategy in two-district case studies in eastern Indonesia have been developed considering multiple management objectives of different stakeholders and government agencies at the landscape level. Watershed used as the workable landscape unit of the analysis. The policy working group was initiated and formally appointed by the head of the district. Challenges included the newly imposed act of recentralisation governance system at the national level, in which Forest Management Unit's authority was shifted from district to provincial level. The grand strategy has provided the district government as the negotiation-tool in dividing the management plans between the two-government authorities. Cases in these two districts have provided a good lessons-learnt on multi-stakeholder negotiation for effective acceptable solutions.



Impact pathways: from district to village and provincial levels.

Keywords: Operationalisation landscape approach, Grand-strategy, Policy Framework, Integrated agroforestry management.

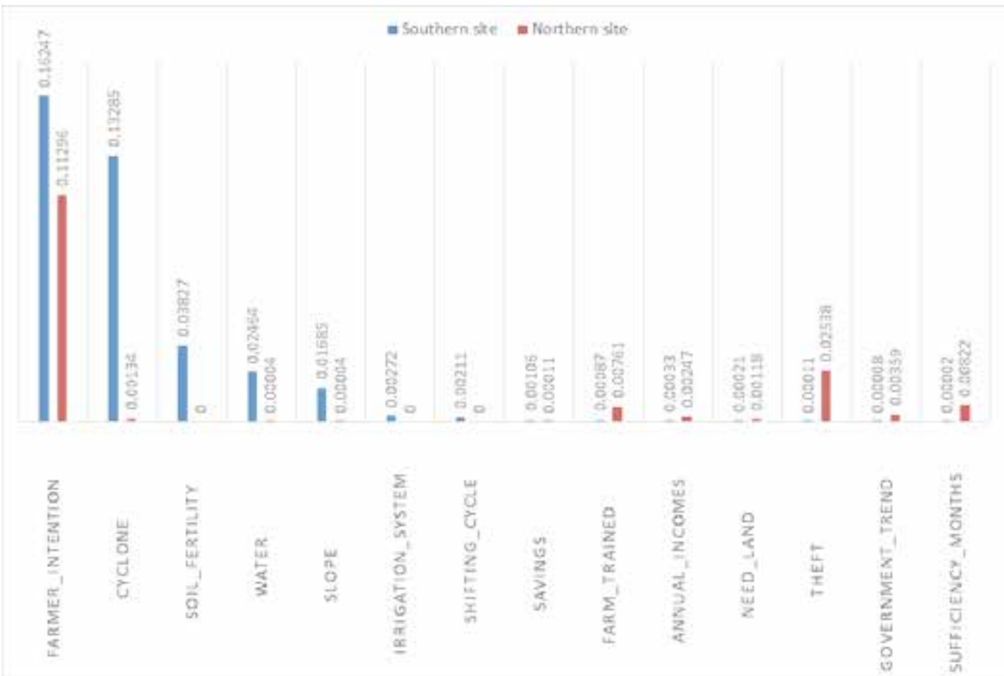
L14.P.02

Drivers of expansion of Agroforestry system within landscape of North-Eastern Madagascar

Andriatsitohaina N.[1] (ntsiva_intel@yahoo.fr), Celio E.[2], Rabemananjara Z.[1], Grêt-Regamey A.[2], Ramamonjisoa B.[1]

[1] *ESSA_Forêts, Antananarivo, Madagascar*; [2] *ETH-PLUS, Zurich, Switzerland*

Agroforestry system is expanding in North-Eastern landscape of Madagascar. Farmers establish their vanilla and clove plantation in a mixed-agroforest, combine also pastures and cloves plantation. This expansion are due to many factors and has socio-ecological impacts. This contribution would like to fill the knowledge-gap on drivers of agroforestry expansion in this part of Madagascar.
Our study took place in two landscapes in Northeastern Madagascar that are featured by a small-scaled agriculture with dynamic developments in the vanilla and clove production. We used a participatory Bayesian network-based land-use decision modelling approach which aims to set-up the conceptual model and to analyze future land-use development in a spatially explicit way. We first analyzed the model's sensitivity to investigate which factors influence land-use decisions of farmers on intensifying and/or extending agroforestry system (AFS) and then evaluated its extent on landscape.
Results (Cf. Figure) suggest that intention of farmer is the most important factor for adopting and/or keeping the agroforestry system in overall case study area. In the Southern site of our case study area, biophysical context such as slope, soil fertility and water followed intention. In contrast, in the Northern site, socio-economic factors such as rice sufficiency of households, theft were ranked as most important after intention. Furthermore, agroforestry landscape is likely developing in the area.



Mutual information between LU_t1 and influence factors

Keywords: Modelling, Agroforestry, Land-use, Bayesian networks, Drivers.

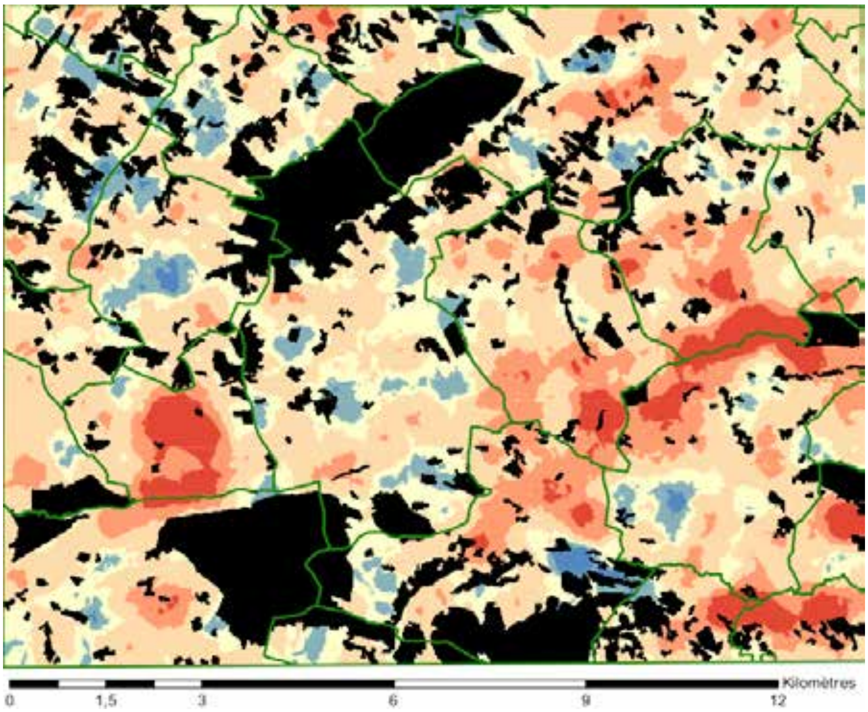
L14.P.03

Trees in agricultural landscapes: understanding past changes for a better management strategies

Andrieu E.[1] (emilie.andrieu@inra.fr), Ladet S.[1], Calatayud F.[1], Blanco J.[2], Sourdril A.[3], Deconchat M.[1]

[1] *UMR 1201 Dynafor, Inra, Castanet Tolosan, France*; [2] *UMR 6554 LETG, Université d'Angers, Angers, France*; [3] *UMR 7533 Ladyss, CNRS, Nanterre, France*

Habitat temporal continuity influences plant and animal communities and species spatial distribution, according mainly to their dispersal capacities and lifespan. Considering habitat history to the long and mid-term is then crucial to understand thow past landscape changes affect current biodiversity patterns. Moreover, the knowledge of the socio-economic causes of past landscape changes allows a better anticipation of their future changes and more efficient habitat or landscape management strategies. We thus reconstructed the history of rural forests in an agroforestry landscape in South-Western France, composed of farm forests and trees outside forests. Thanks to retrospective photo-interpretation of airborne images, we traced back and quantified their evolution from 1962 to 2010. We first attempted to understand both ecological and sociological determinant factors of these rural forest changes illustrated here for hedgerows. We focused on their location within exploitations and showed how changes are dependent of farm dynamics but also patrimonial and cultural backgrounds. We underline as well their potential contribution as ecosystem services providers (windbreak and erosion). Second, in order to detect whether changes in structural farm forest connectivity translate into changes in functional connectivity, we assessed its dynamics for plant species differeing by their dispersal capacities.



Changes in hedgerow density from 1962 to 2010 in the studied area, from dark red (strongest density decrease ie -9 to -4,5 km by km²) to dark blue (strongest density increase ie +1,5 to + 2,7 km by km²).

Keywords: Landscape ecology, history, rural forests, ecosystem services, connectivity.

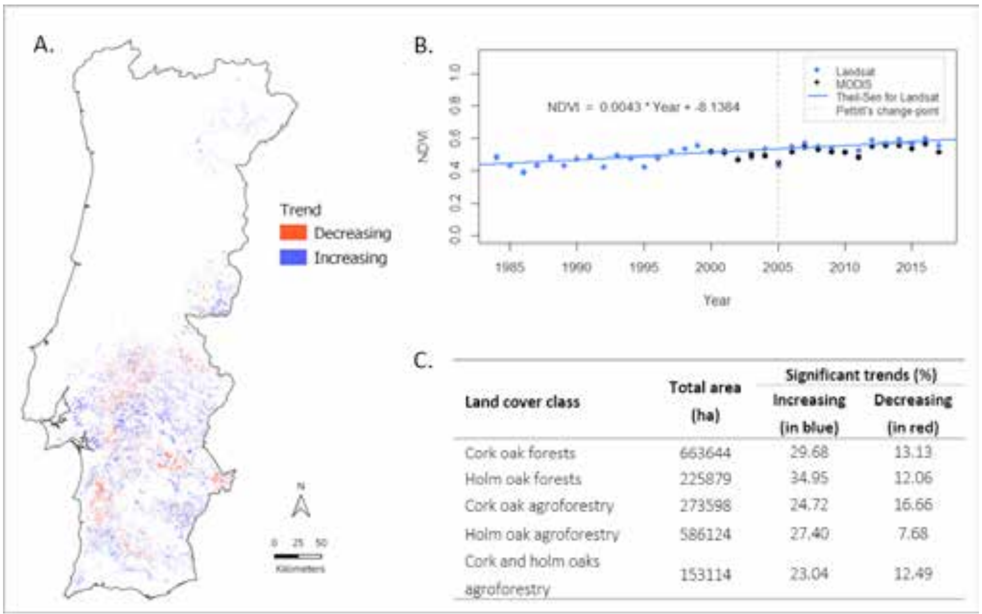
L14.P.04

Google Earth Engine based monitoring of cork and holm oak woodlands NDVI trends in Portugal

Aubard V. (vaubard@isa.ulisboa.pt), Paulo J. A., Silva J. M. N.

Forest Research Centre, University of Lisbon, Lisbon, Portugal

Oak woodlands are declining in many regions of southern Europe (Brasier, 1992; Costa *et al.*, 2010). With the goal of assessing this process, long-term trends of the Normalized Difference Vegetation Index (NDVI) were derived and mapped at 30 m spatial resolution for all areas with a stable land cover of cork oak (*Quercus suber* L.) and holm oak (*Quercus ilex* L.) forests and agroforestry systems in mainland Portugal. NDVI, a good proxy for forest health and productivity monitoring, was calculated between 1984 and 2017 using Landsat-5 TM and Landsat-7 ETM+ imagery. TM values were adjusted to those of ETM+. The spatiotemporal trend analysis was performed only with the July and August NDVI values, in order to minimize the spectral contribution of understory vegetation and its phenological variability, and thus focus on the tree layer. Signs and significance of trends were obtained with the Contextual Mann-Kendall test and their slope with the Theil-Sen estimator (Neeti, 2011). MODIS NDVI time series and data from long-term forest inventory plots located in oak woodlands allowed validating the methodology and results. Thirty percent of the Portuguese oak woodlands area reveal significant decreasing trends. During the development of the methodology, Google Earth Engine platform proved to be a powerful tool, allowing to assess the productivity of oak woodlands and other types of forests.



Land cover class	Total area (ha)	Significant trends (%)	
		Increasing (in blue)	Decreasing (in red)
Cork oak forests	663644	29.68	13.13
Holm oak forests	225879	34.95	12.06
Cork oak agroforestry	273598	24.72	16.66
Holm oak agroforestry	586124	27.40	7.68
Cork and holm oaks agroforestry	153114	23.04	12.49

Graphical abstract. A. Contextual Mann-Kendall significant NDVI trends for cork and holm oak areas in Portugal (1984-2017). B. Example of the Landsat and MODIS July-August NDVI time series (1984-2017) for one study site, with Theil-Sen linear regression estimate and Pettit's change-point for the Landsat trend. C. Total area and proportion of the areas with significant increasing and decreasing NDVI trends per land cover class.

Keywords: Quercus suber L., Quercus ilex L., Time series, Contextual Mann-Kendall, Normalized Difference Vegetation Index.

References:

1. Brasier, 1992, Nature, 539.
2. Costa et al., 2010, Ann Forest Sci, 204. doi: 10.1051/forest/2009097
3. Neeti, 2011, Trans GIS, 599-611. doi: 10.1111/j.1467-9671.2011.01280.x

L14.P.05

Assessing vulnerability to wildfire of an agroforestry landscape mosaic of Sierra de Gata, southwestern Spain

Bertomeu M.[1] (mbergar@unex.es), Corbacho J.[2], Pulido F.[1], Navalpotro J.[2], Palomo G.[2], Giménez J. C.[1], Moreno G.[1]

[1] *INDEHESA. University of Extremadura, Plasencia, Cáceres, Spain*; [2] *Mosaico-Extremadura, Plasencia, Cáceres, Spain*

Wildfires have increasingly become a threat to the Mediterranean mountain forests of southern Europe. Extensive afforestation with flammable pine species, abandonment of traditional land management practices, and longer and more intense droughts due to climate change result in larger and more frequent and intense forest fires. Mosaic landscapes consisting of a mix of different land cover and use type are considered to be less vulnerable than forests to wildfire. Interspersed patches of crops, pastures, and grazed shrubs and forests break-up the continuity of hazardous fuels across the landscape, and provide safer zones from which fires can be suppressed. Also the economic opportunities generated from farming and forestry activities in mosaic landscapes contribute to reduce the ignition of fire as a form of protest against restrictive and punitive policies common in centrally-managed forest landscapes.

Sierra de Gata is a mountainous area in southwestern Spain prone to anthropogenic fires. It extends over 150,000 ha, of which 70,000 ha are forests of *Pinus pinaster*, and comprises a population of 22,728 in 20 villages. Since 2016, after a wildfire that burned through more than 8,000 ha and forced the evacuation of 3 villages, the Mosaico-Extremadura project is being implemented to restore a mosaic landscape resilient to fire. A multidisciplinary team of technicians facilitate farmer planning and implementation of agricultural and forestry livelihood interventions (e.g., tree farming; grazing management, resin tapping), training, and negotiation and coordination with local government and forestry authorities. The project rests on the idea that agricultural interventions at strategic locations within forests and at the forest-agriculture interface will function as effective, and productive firebreaks.

Since project inception to date about 166 interventions have been proposed, of which 35 are being implemented. However, whether these interventions will nudge the current landscape towards a more fire resilient one remains uncertain. The purpose of this study is, therefore, to assess the vulnerability to fire of the hypothetical landscape mosaic that would result if all proposed interventions were implemented. The study will use the vulnerability assessment framework (VAF) proposed by Vaillant et al. (2016) and the Wildfire Analyst (WFA) software for the simulations. VAF components, exposure, sensitivity, and resilience, will be measured first in a retrospective assessment (after the wildfire) of landscape vulnerability, followed by a predictive, comparative assessment under different scenarios of project success, including the 'business as usual' (without project). We hope this study will help forestry authorities and local government officials to make better informed decisions on land management and ultimately, to achieve fire resilient communities and landscapes in the region.

Keywords: agroforestry, fire risk, mosaic landscape, vulnerability, resilience.

References:

1. Vaillant, et al., 2016, Curr Forestry Rep, 201–213, DOI 10.1007/s40725-016-0040-1

L14.P.06

Land Use Change and Climate-Smart Agriculture in the Sahel since 1975

Cotillon S.[1] (scotillon@biotope.fr), Reij C.[2], Tappan G.[3]

[1] *International Office, Biotope, Meze, France*; [2] *WRI, Nijmegen, Netherlands*; [3] *USGS, Sioux Falls, SD, United States*

In the 1970s and 1980s, the Sahel experienced recurrent drought and famine. Farmers and their development partners reacted to this crisis by developing climate-smart agricultural practices, including water harvesting techniques to restore degraded land to productivity. In several densely populated parts of the Sahel, farmers began to protect and manage woody species that regenerated naturally on their farmland. Farmer-Managed Natural Regeneration (FMNR) is a foundational practice that produces multiple benefits, such as maintaining or improving soil fertility, which raises crop yields, and increasing the production of tree-based fodder, fruit and firewood. In Niger's Maradi and Zinder Regions alone, farmers have applied FMNR practices on 4.2 million hectares. The findings suggest that the future of agriculture in the Sahel will be largely determined by whether or not low income smallholder farmers will manage to improve soil fertility which will depend on maintaining substantial densities of on-farm trees.

Faidherbia albida improves soil fertility and produces fodder for livestock. Farmers like high on-farm densities of this species as they increase crop yields

Keywords: Farmer-Managed Natural Regeneration, Sahel, agricultural intensification, land use change, on-farm tree cover.

L14.P.07

Criteria and indicators for sustainable management of agroforestry systems: a case of Akola district, Maharashtra, India

Deshmukh H.[1] (hkdeshmukh1@rediffmail.com), Taide Y.[2], Chinchamalatpure U.[3], Ilorkar V.[4], Walke D.[2], Walke R. D[5], Tingre A.[6]

[1] *Silviculture and Agroforestry, Navsari Agricultural University, Navsari, Navsari, Gujarat, India*; [2] *Forestry, Dr. PDKV, Akola, Maharashtra, India, Akola, Maharashtra, India*; [3] *Extension Education, Dr. PDKV, Akola, Maharashtra, India, Akola, Maharashtra, India*; [4] *Forestry, Dr. PDKV, Akola,Maharashtra, India, Nagpur, Maharashtra, India*; [5] *Statistics, Dr. PDKV Akola, Maharashtra, India, Akola, Maharashtra, India*; [6] *Agricull-tural Economics, Dr. PDKV, Akola, Maharashtra, India, Akola, Maharashtra, India*

The first Earth Summit at Rio in 1992, it was realized that Sustainable Forest Management (SFM) is an important element of Sustainable Development. It is an imperative now to preserve the tree resources on farmlands and manage them sustainably so as to ensure livelihood security of the marginal farmers. With view to harness the degradation and overexploitation of forest resources in Agroforestry systems,its periodic monitoring is essential. The Criteria and Indicators (C&I) is one of the world-recognized tools for SFM. The present study was conducted in Akola district, Maharashtra, India to identify set of indicators for Sustainable Management of Agroforestry systems for forests in Akola district. The methodological framework developed by IIFM, Bhopal was used with essential modification for evolving criteria and indicators for sustainable management of agroforestry system in Akola districts with community participation and different stakeholders together with approach for their data collection and analysis of sustainability. In total 8 criteria along with 40 set of indicators had been identified for sustainable management of agroforestry systems in Akola district (Table 1). The similar kind of finding were also recorded by Prasad and Prasad.(2001) and Solanki and Bisaria (1999). The outcome of the research will be directly benefited to forest dwellers and the government functionary for the assessment of the sustainability of the agroforestry systems in study area.

Table 1 Criteria and Indicators for Sustainable Management of agroforestry systems in Akola District

Category	Sr. No.	Criteria	No. of Indicators
Ecological	1	Increased in the extent of forest resources through agroforestry	02
	2	Maintenance, conservation and enhancement of area under agroforestry components and biodiversity	05
	3	Maintenance and enhancement of health of agroforestry ecosystem and vitality	06
Socio-cultural	4	Maintenance and enhancement of social , cultural and economic benefits	03
Economical	5	Conservation and maintenance of soil and water resources through agroforestry system	04
	6	Maintenance and enhancement of productivity of agroforestry systems	04
	7	Maintenance and enhancement of productive functions and utilization of agroforestry system products	10
	8	Adequacy of policy, legal and institutional framework for establishment of agroforestry systems and their management on private land	06
		Total Indicators	40

Table 1. Criteria and Indicators for Sustainable Management of agroforestry systems in Akola District

Keywords: Agroforestry system, Sustainable management, criteria, indicators.

References:

1. Prasad, R. and R. Prasad., 2001. Criteria and indicators for sustainable management of dry forests i
2. Solanki, K. R. and A.K. Bisaria, 1999. Agroforestry for sustainable development in Central India, In

L14.P.08

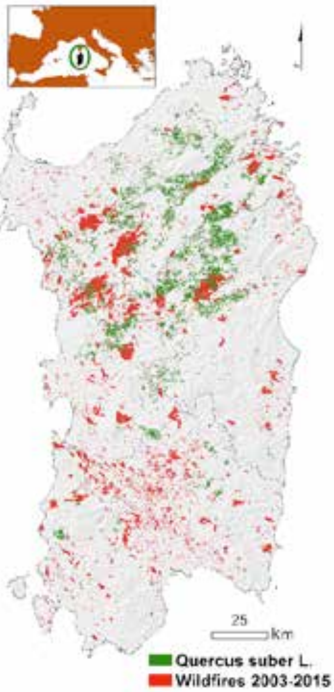
Analyzing wildland fire dynamics in *Quercus suber* L. woodlands in Sardinia (Italy)

Duce P.[1] (p.duce@ibimet.cnr.it), Arca B.[1], Pellizzaro G.[1], Ventura A.[1], Dettori S.[2], Fernandes de Oliveira A. S.[2], Spano D.[2], Bacciu V.[3], Salis M.[1]

[1] *Institute of Biometeorology, National Research Council, Sassari, Italy*; [2] *Department of Agriculture, University of Sassari, Sassari, Italy*; [3] *CMCC Foundation, Sassari, Italy*

Cork oaks (*Quercus suber* L.) play a relevant role in Mediterranean landscapes and provide a number of goods and ecosystem services (EEA 2006). Many studies reported that cork oak ecosystems are in decline and are affected by several disturbance factors (wildland fires, climate change, forest and rural areas degradation and abandonment, overgrazing, etc.) (Aronson et al. 2009; Dettori and Filigheddu 2016), with wildfires representing one of the most relevant disturbances (Catry et al. 2009). The incidence and effects of wildfires on *Quercus suber* L. stands is a key issue for land managers, planners and policy makers, due to the strategic, economic, ecological and cultural importance of cork oaks woodlands for small rural and forest communities.

In this work, we investigated the wildfire dynamics on cork oak stands in Sardinia (Italy) for the period 2003-2015. In that timeframe, about 15,500 ha of cork oaks were affected by wildfires (Figure 1), with remarkable economic and ecological losses. The main goals of this work are 1) to characterize the spatial extent and the main environmental and social conditions of *Quercus suber* L. areas in Sardinia; 2) to analyze the recent dynamics (e.g., extent, frequency, seasonality, and spatio-temporal variation) of wildfires that affected cork oak stands in the study area; 3) to evaluate, using a logistic regression modeling, to what extent social and environmental variables affected wildfires occurrence in Sardinian cork oak areas.



Perimeters of the wildland fires (red color) that affected the study areas in the period 2003-2015.
The Quercus suber L. woodlands are presented in green color.

Keywords: Cork oaks, Mediterranean areas, Forest fires, Fire management, Land management.

References:

1. Aronson et al., Cork oak woodlands on the edge, 2009, 352 pp
2. Catry et al., 2009, Eur J For Res, 128: 231-240, 10.1007/s10342-009-0259-5
3. Dettori and Filigheddu, 2016, Ital J For Mt Environ, 71(6): 331-343, 10.4129/ifm.2016.6.02
4. European Environment Agency, European forest types, 2006, 114 pp

L14.P.10

Potential of Agroforestry as Forest Landscape Restoration Tool to Solve Sudan Forest Cover Loss cum Food Security

Gadallah N.[1] (nasri8025@gmail.com), Adewole N.[2]

[1] *Forest Conservation and Protection, University of Khartoum, Khartoum, Khartoum, Sudan*; [2] *Wood Products Engineering, University of Ibadan, Ibadan, Oyo, Nigeria*

Forest Cover Loss (FCL) is considered one of the most critical environmental problem that devastates biodiversity, natural resources, affect food production and instigates food insecurity. The continuous rate of Sudan FCL in the last decades is alarming. This study assesses the potential of agroforestry as Landscape Restoration (FLR) remedy tool for Sudan's FCL in Tozi and Wad Al-Bashir forests in Sennar and Gedaref States respectively. Structured questionnaire, Key Informant Interview and on-the-spot assessment were used to collect primary data, where 179 respondents and 14 key informants where chosen purposively. Records from Sudan Forest National Corporation (FNC), Satellite-Images and literatures supplied Secondary data. The FCL were determined using Landsat-images of 1988-1989-2008-January-2018.The Primary data were analyzed using descriptive statistic, while Landsat-images were analyzed via supervised classification. Findings revealed that consistent but unpredictable magnitudes of FCL are taken place in the study areas with the communities encroaching the forests unabated. Encroached landed areas are mostly used for crops and animal farming, recreation, and nomadic activities with crops and animals accounts for more than 70%. Impacts of FCL had initiated farmlands, water and food contestations without evidence of robust plan to arrest FCL. An appropriate and robust Agroforestry framework has been developed for use in achieving FLR to check growing FCL. This study recommends collaborative effort between Sudan FNC and the local communities in Tozi and Wad Al-Bashir forests vicinities drive the adaptation of the Agroforestry System.

Keywords: Agroforestry, Forest Landscape Restoration, Forest Cover Loss, Sudan.

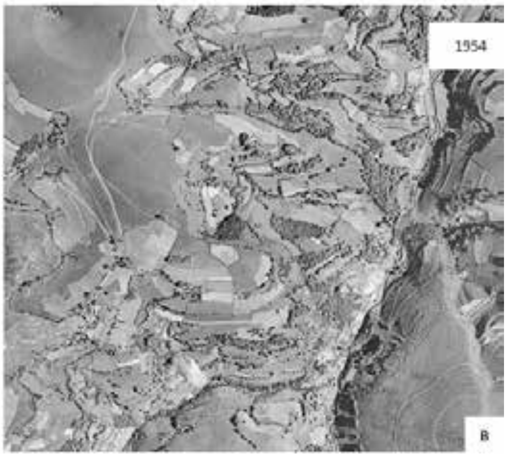
L14.P.11

Evolution of traditional agroforestry landscapes and development of invasive species: lessons from the Pyrenees (France)

Guillerme S.[1] (sylvie.guillerme@univ-tlse2.fr), Maire E.[1], Marais-Sicre C.[2], de Munnik N.[1], Barcet H.[1]

[1] *GEODE, CNRS, Toulouse, France*; [2] *CESBIO, CNRS, Toulouse, France*

Agroforestry is promoted as practices maintaining or even enhancing biodiversity. But the relationship between agroforestry and invasive species is rarely addressed. However the spread of invasive species is an important issue not only ecologically but also economically and socially. Over the past few decades, humans have greatly accelerated the process of biological invasions, to the point that they are now recognized as the second cause of accelerated decline in biodiversity. Some research shows that – at least in tropical conditions - agroforestry systems provide less favourable habitats for exotic species, filtering them from the understory, although the mechanisms that select against exotic species remain unknown. But what about temperate environments? Our objective was to study the evolution of traditional agroforestry systems in the Pyrenean foothills where invasive species are abundant. Here the abandonment of agricultural land (as in other parts in Europe) is a major problem due to the environmental, socio-economic and landscape implications.
By several surveys our research highlighted the local stakeholders' perception of invasive species, their qualification and their challenges for these traditional agroforestry landscapes. We also used archival documents. In addition we carried out a detailed mapping of the fronts along the vegetation edges and the areas occupied by invasive plants using very high-resolution spatial technologies using UAV's and satellite images.



Evolution of traditional agroforestry landscapes of the Pyrenees (Oussouet valley, Trébons commune, France, 1954-2016). The landscapes enclosure process is the result of the abandonment of agricultural and pastoral activity that maintained them ; the latter also favoured the overgrowth by different invasive species.

Keywords: traditional agroforestry, landscape dynamics, invasive species, stakeholders strategies, agroforestry decline.

L14.P.12

Payments for environmental services on agricultural land: The case of evergreen agriculture in Ethiopia

Haile K. (haile@merit.unu.edu), Tirivayi N., Tesfaye W.

UNU-MERIT, Maastricht, Netherlands

Despite the economic and environmental benefits, the uptake of evergreen agriculture by farmers in sub-Saharan Africa remains very low (Garrity *et al*., 2010; Glover *et al*., 2012). The households' decision to invest in evergreen agricultural innovation is a sacrifice of their current income for anticipated higher utility from future net income gains. Drawing on the reference-dependent utility model (Köszegi and Rabin, 2006), the lack of uptake of evergreen agriculture by smallholder farmers can be explained by the overemphasis farmers give to the loss in utility as a result of a decline in their reference (i.e. status quo) consumption level. The standard policy intervention in the face of positive environmental spillovers is to introduce incentives so that private individuals benefit from the use of environmentally responsible practices.

In recent years, researchers and policymakers alike have advocated payments for environmental services (PES) as an incentive-based approach to internalizing the positive externalities of resource use decisions. Designing and implementing PES schemes that benefit poor and vulnerable farming households will ensure sustainable land use and Pareto-efficient provision of environmental services (Reed *et al.*, 2015; Börner *et al.*, 2017). The first step should involve understanding which attributes of a PES scheme influence participation of poor farmers in the program. Therefore, eliciting farmers' stated preferences will uncover how they value the attributes of a proposed PES contract before launching the program.

To that end, this study examines farmers' preferences for adopting contractual evergreen agriculture and identifies factors that significantly affect their choice behavior. A discrete choice experiment was conducted with 200 farmers in Ethiopia to elicit their willingness to participate in a hypothetical payment for environmental service (PES) program that incentivizes integrating *faidherbia albida* (a fertilizer tree) in their mono-cropping farming system. Attributes evaluated are "payment amount", "number of planted trees", "payment type", and "contract period". A Generalized Multinomial Logit (G-MNL) and latent-class conditional logit (LCL) models were used in the choice analysis. All the attributes considered in the PES program are statistically significant, and hence provides evidence for the relevance of the attributes that are chosen. As expected, farmers drive higher utility from higher amounts of payments. Farmers also strongly prefer food as the mode of payment than cash. Moreover, low numbers of mandatory planted trees and short-term contract periods are found to be important attributes that positively affect farmers' decisions to take-up a contractual evergreen agriculture. These findings shed light on the design considerations that must be accounted for when implementing PES schemes that promote evergreen agricultural innovations within smallholder farming systems in sub-Saharan Africa.

Keywords: Evergreen agriculture, Payment for environmental service, Discrete choice experiment, Faidherbia albida, Ethiopia.

References:

1. Börner et al., 2017, World Development, 96, 359–374. http://doi.org/10.1016/j.worlddev.2017.03.020
2. Garrity et al., 2010, Food Security, 2, 197–214. http://doi.org/10.1007/s12571-010-0070-7
3. Glover et al., 2012, Nature, 489, 359–361. http://doi.org/10.1038/489359a
4. Köszegi and Rabin, 2006, The Quarterly Journal of Economics, CXXI(4), 1133–1165
5. Reed et al., 2015, J Environ Manage, 151, 472–485. http://doi.org/10.1016/j.jenvman.2014.11.010

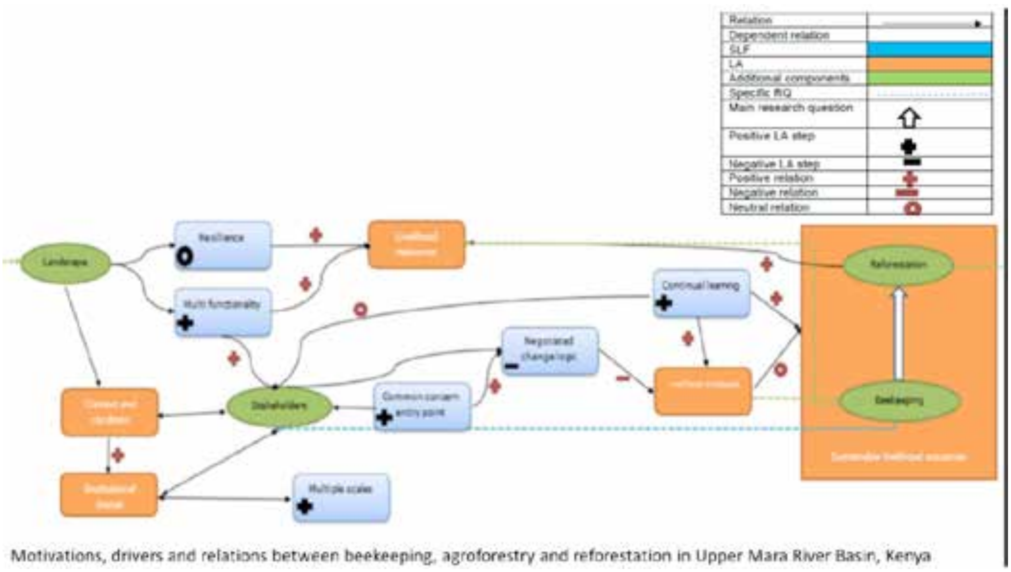
L14.P.13

Impacts of beekeeping and agroforestry initiatives, Upper Mara River Basin, Kenya

Ingram V.[1] (verina.ingram@wur.nl), Kirui R.[2], Hitimana J.[3], Koopmans D.[4], van Rooij S.[5]

[1] *Forest & Nature Conservation Policy, Wageningen University & Research, Wageningen, Gelderland, Netherlands*; [2] *MAMASE, Kericho, Kenya*; [3] *School of Natural Resource & Environment, University of Kabianga, Kericho, Kenya*; [4] *Forest & Nature Conservation Policy, Wageningen University & Research, Wageningen, Netherlands*; [5] *Wageningen Environmental Research, Wageningen UR, Wageningen, Netherlands*

Training and support for beekeeping and agroforestry were part of the 4 year Mau Mara Serengeti Sustainable Water initiative (MaMaSe), aiming to improve water safety and security, support structural poverty reduction, sustainable economic growth and conservation of the Mara River Basin's ecosystems. Working with beekeepers, Community Forest and Water Resource Users Associations and their members, we assessed how beekeeping affected incomes and reforestation, and how agroforestry contributes to livelihoods. Beekeeping was found to contribute mostly modestly to farmer's livelihoods: providing income, food, timber and woodfuel and pollinating crops. Beekeepers are active in planting trees and protecting forests, attributing value to riparian natural forests contributing to protect the watershed, but not significantly more than non-beekeeper farmers. Whilst farmers and their organisations had planted trees, these are not well integrated into farming systems. Participatory action research, literature reviews and traditional knowledge resulted in 6 economically viable agroforestry options being identified for the 3 altitudinal zones, involving 75 indigenous and exotic species, with 36 tree species identified as valuable multi-use species, 118 indigenous and 74 exotic melliferous species. Farmers are concerned about the changing landscape and climate, however drivers to participate in projects to improve the environment are no different for beekeepers than non-beekeepers.



Motivations, drivers and relations between beekeeping, agroforestry and reforestation in Upper Mara River Basin, Kenya

Keywords: agroforestry, beekeeping, reforestation, agroforestry and tree value chains, livelihoods.

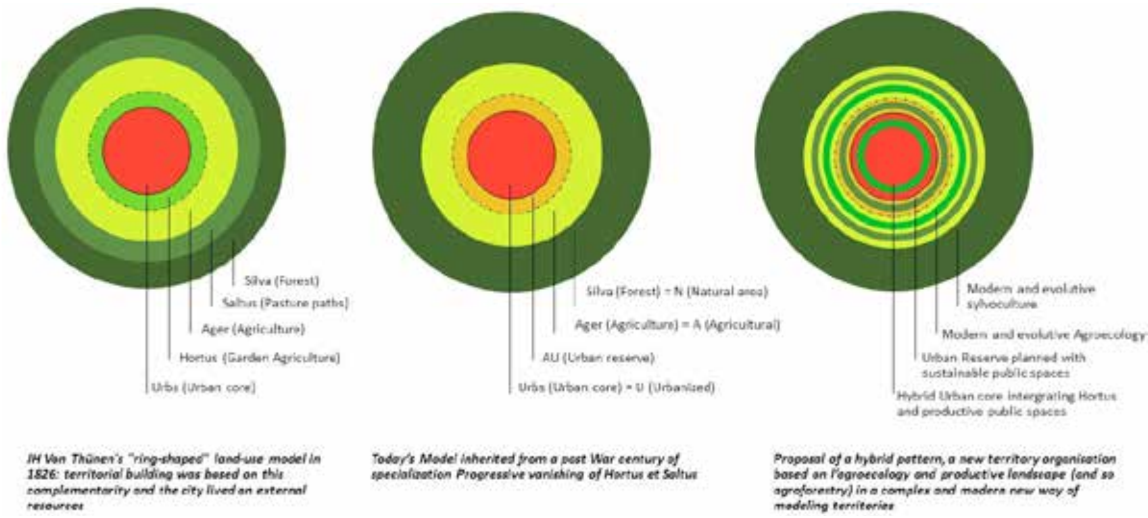
L14.P.14

Agroforestry, a solution for territorial transition ?

Lacourt S. (lacourtsimon@gmail.com), Petit Berghem Y.

Larep, Versailles, France

Agroforestry questions the way separated cultivation practices shape the territory. In France, until the creation of the Forest Code in 1827, the farmer took advantage of the wood close to the cultures and practiced silvopastoralism. According to JH Von Thünen's «ring-shaped» land-use model in 1826: Urbs / Hortus/ Ager / Saltus / Silva, the territorial building was based on this complementarity and the city lived on external resources. This system has lost its complexity with a specialized modern agriculture, reducing the importance of Hortus and Saltus in the territory organization. Today, legal planning documents divide French territory into 'Areas' (U: Urban, AU: Urban Reserve, A: Agricultural, N: Natural).
If it is agreed that the farmer is a landscape creator, his practice is not considered as constitutive part of land development. The specialization of agriculture makes him a resource producer more than landscape producer. In a context of climate change and major crises, France since 2015 pledges on an agroecological project and planners and local actors are asked to start the territorial transition. If agroforestry proposes a hybrid solution for complementary and sustainable resources, can it also be a hybrid solution of planning, a new way of shaping the territory? The landscape architect must integrate new agricultural models to prepare the territorial transition, to find a complementarity between Urbs and Ager by productive landscape, the return of Hortus and Saltus?



Territorial patterns, from Van Thünen rings to modern Agroecology

Keywords: Landscape, Productive landscape, Territorial transition, Hybridation.

References:

1. Olivier Nougarede et al., Des hommes et des forêts, 1993, Gallimard, 128 p
2. Marcel Mazoyer et al., Histoire des agricultures du monde, 2002, Le Seuil, 533 p
3. J H von Thünen, Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie, 1826

L14.P.15

Visual assessment of agricultural landscapes featuring agroforestry intercropping systems in Quebec, Canada.

Laroche G.[1] (genevieve.laroche@fsaa.ulaval.ca), Domon G.[2], Gelinas N.[3], Olivier A.[1]

[1] *Phytologie, Université Laval, Québec, Québec, Canada*; [2] *Urbanisme et architecture de paysage, Université de Montréal, Montréal, Québec, Canada*; [3] *Sciences du bois et de la forêt, Université Laval, Québec, Québec, Canada*

In agricultural areas where crops and trees grow apart, the integration of agroforestry intercropping systems introduce new features in the landscape. These changes may be perceived differently by the residents bounded by a close relation to the landscape and by the tourists who appreciate these features from an external point of view. Mixing trees and crops may also be perceived differently whether agroforestry systems are introduced in intensive or declining agricultural landscapes or depending on their specific design parameters (tree row spacing, species, etc.). The visual impacts of the introduction of these systems in agricultural areas need to be investigated to better understand their desirability in agricultural contexts of intensification and decline. The aims of this study are 1) to assess and compare the visual appreciation of four common agricultural landscapes and six intercropping system designs by residents and non-residents of two contrasted agricultural areas, 2) to determine the influence of tree diversity and row spacing on the visual assessment tree-based intercropping systems, 3) identify social characteristics influencing the visual assessment, and 4) identify some of the reasons underlying the visual appreciation of specific landscapes. Residents and non-residents from two contrasted agricultural areas of Quebec (Canada) were surveyed online using a non-probabilistic method. Respondents rated on a 1-10 scale their visual appreciation of twelve landscapes: six agroforestry scenarios following a complete factorial 2x3 design testing two variables: tree row spacing (two levels, 15 m and 30 m) and tree diversity (three levels: monospecific, mixed tree species and mixed trees and shrubs) and six common rural landscapes (deciduous forest, conifer forest, herbaceous fallow, forage field, wheat field and corn field. A second section captured the reasons underlying their appreciation of five of the landscapes previously rated. In the third section, participants chose, for a given basic landscape, the landscape change they prefer between four options. A fourth section captured the respondent's profiles. Statistical analysis were performed on landscape ratings and were crossed with individual characteristics. Results shed light on the visual appreciation of specific agroforestry intercropping system designs compared to common agricultural landscapes and inform about the reasons underlying these appreciations by residents and tourists. They inform about the desirability of intercropping systems in various agricultural contexts for residents and tourists, thus guiding future landscape planning and design decisions.

Keywords: Visual assessment, Agroforestry intercropping system, Residents, Tourists, Landscapes.

L14.P.16

Integrating agroforestry systems in contrasted agricultural landscapes: a SWOT-AHP analysis of stakeholders' perceptions

Laroche G.[1] (genevieve.laroche@fsaa.ulaval.ca), Gélinas N.[2], Doyon M.[3], Domon G.[4], Olivier A.[1]

[1] *Phytologie, Université Laval, Quebec, Quebec, Canada*; [2] *Sciences du bois et de la forêt, Université Laval, Quebec, Quebec, Canada*; [3] *Économie agroalimentaire, Université Laval, Quebec, Quebec, Canada*; [4] *Urbanisme et architecture de paysage, Université de Montréal, Montreal, Quebec, Canada*

Agroforestry intercropping systems fulfill multiple functions at the landscape level. While the integration of these systems in agricultural landscapes is mostly investigated on the ecological angle, the social context in which they are integrated still needs to be enlightened. Our study used the SWOT-AHP procedure to investigate the factors influencing local stakeholders' (farmers, forestry and farm advisors, local authorities and urban planners) decision to integrate agroforestry intercropping systems in two contrasted agricultural landscapes (very intensive and very extensive) in Quebec (Canada) and their perception of the relative suitability of three system designs (crop-, tree- and landscape aesthetic-oriented). On the 24 influencing factors identified by stakeholders, 22 related to the social sphere, emphasizing the importance of the social context on agroforestry decision-making. The relative value given to the decision factors varies greatly across stakeholders' categories and areas. Agroforestry intercropping systems designed to meet crop production needs or landscape aesthetic purposes are globally perceived as more suitable in both agricultural contexts than the tree-oriented design (fig. 1). However, major differences appear between stakeholder categories, suggesting that consensus may be difficult to reach in a collective decision process. Our results highlight crucial issues for agroforestry system deployment in various agricultural contexts.

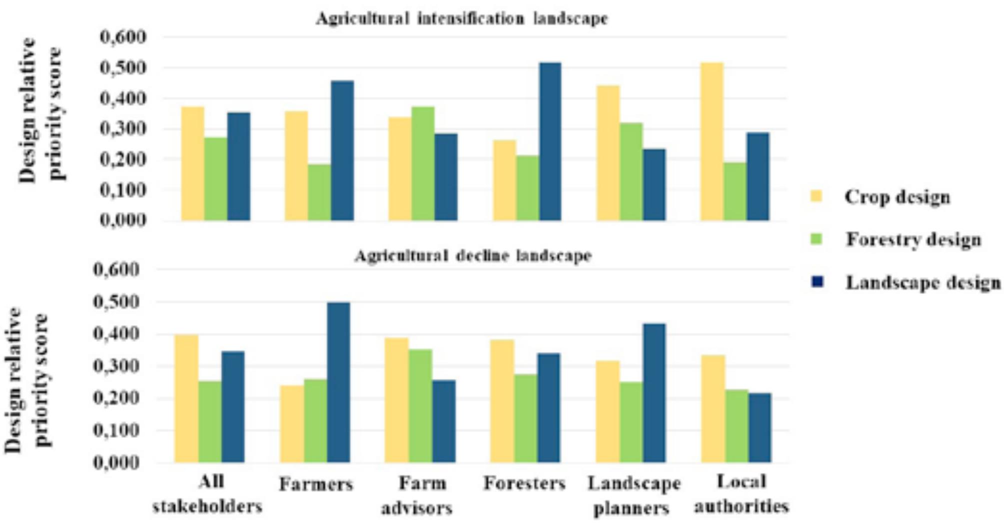


Fig. 1. Relative priority scores given to the three agroforestry intercropping system designs (crop design, forestry design and landscape design) by all stakeholders and each stakeholder category (farmers, farm advisors, foresters, landscape planners and local authorities) in the agricultural intensification landscape (up) and the agricultural decline landscape (down).

Keywords: SWOT-AHP, Agroforestry intercropping systems, Agricultural landscapes, Stakeholders, Perceptions.

L14.P.17

Beyond the stand: Reviewing landscape fragmentation dynamics on biodiversity and ecosystem services in Southeast Asia

Lo M.[1] (michaelalo39@gmail.com), Laumonier Y.[2]

[1] *Sustainable Landscapes and Food, CIFOR, Bogor, Indonesia*; [2] *UR 105 Forests and Societies, CIRAD, Montpellier, France*

Forest and agriculture landscapes dominate across Southeast Asia. Agricultural systems are highly diverse ranging from traditional swidden and agroforestry, to the more recent intensive industrial oil palm plantations. These management approaches have fabricated distinct fragmented landscapes that could yield significantly varying impacts on biodiversity and ecosystem services. Our systematic styled review compares fragmentation in industrial oil palm (IOP) and smallholder agroforestry (SH) landscapes, and how this influences biodiversity (soil fauna, avifauna, and vegetation) and ecosystem services in Southeast Asia. Two literature searches were carried out capturing fragmentation studies in IOP and SH settings. After devising a selection criteria, we identified relevant studies, assessed the type of landscape metrics used, and synthesized research findings.

After screening 2301 studies, 26 passed our selection criteria; avifauna was the most widely studied group for biodiversity outcomes (n=9), and isolation was the most popular landscape measure (n=13). 50% of studies focused on IOP in Malaysia and none focused on IOP in Indonesia despite being the world's largest oil palm producer. We found too few studies on interactions between ecosystem services and landscape dynamics to draw meaningful comparative findings. Studies in SH systems provided cases of well-connected and diverse forest-agriculture mosaics that successfully supported all biodiversity. In IOP landscapes, we found mixed effects, which depended on the dispersal range of species, their adaptive ability along habitat gradients, and how actors managed forest fragments.

Land use research is dominated by land use level comparisons, and rarely do studies measure landscape interactions, which is evident in the lack of studies in our review. Few studies addressed more complex, yet important measures, such as the permeability and pattern of the landscape matrix[1]. Assessing fragmentation processes over time addresses the resilience of landscapes to different agricultural practices[1], and the critical threshold that determines the recoverability of forests and biodiversity[2]. Understanding these underlying recovery mechanisms contributes to supporting sustainable restoration efforts and agroforestry intensification programs.

The current Southeast Asian trend in which landscapes are moving away from swidden and agroforestry practices to industrial plantations could significantly impact biodiversity and ecosystem health. We recommend the following for future research:

i) Greater accountability of landscape metrics in assessing spatial interactions with biodiversity and ecosystem services, particularly in smallholder agroforestry systems, and how this can facilitate integrated management of agricultural landscapes.

ii) Review threshold studies in the context of landscape dynamics to increase our understanding of resilience in fragmented landscapes, and what role this has for restoration efforts.

Keywords: matrix, oil palm, resilience, restoration, mosaic.

References:

1. Kupfer et al., 2006, Global Ecol. Biogeogr., 8-20; DOI: 10.1111/j.1466-822x.2006.00204.x
2. Desmet, 2018, Biological Conservation, 257-260; https://doi.org/10.1016/j.biocon.2018.03.025

L14.P.18

The Iris Garden: an urban agroforestry case study to promote the traditional olive trees-iris landscape in Tuscany

Maienza A.[1] (a.maienza@ibimet.cnr.it), Fabrizio U.[1], Stazi S. R.[2], Camilli F.[1]

[1] *Ibimet, CNR, FIRENZE, Firenze, Italy*; [2] *DIBAF, Università della Tuscia, Viterbo, Viterbo, Italy*

The Iris Garden of Florence hosts a historical botanical collection of Irises cultivated in an olive grove on the slopes of the hillside area of the town (Fig.1), giving rise to an outstanding Tuscan agroforestry system. The Garden embodies a strong cultural meaning for the city, as the Iris is the symbol of Florence, but also for the rural landscape around it.The *Iris pallida* Lam., is one of the varieties cultivated in the Garden since 1954, and is "famous" for the traditional pharmaceutical and cosmetic uses of its rhizomes. Today, *Iris pallida* represents a niche production but, in the past, suiting hostile environments (shallow rocky soils on southern slopes), it was widely cultivated among olives trees on the Chianti hills. Starting from the Iris Garden, this work aims to study the supply of ecosystem services of the olive grove-iris agroforestry system. Using a holistic approach, quantitative data gathered from the biodiversity and soil carbon analysis will be integrated with qualitative data from interviews with citizens, tourists, garden managers (the Italian Iris society) and land owners (the Municipality of Florence). The investigation will elicit the environmental characteristics and strengths, weaknesses, opportunities and threats of the Iris Garden contributing to outline preliminary guidelines to promote the Garden and the olive trees-iris intercropping in terms of cultural values, environmental protection, landscape amenities and citizenship well-being.

Figure 1. The iris cultivation in the Iris Garden of Florence (picture from http://societaitalianairis.com)

Keywords: Urban Garden, Ecosystem Service.

References:

1. http://societaitalianairis.com

L14.P.19

Smallholder agroforestry parkland landscape diversity in three climatic zones of Burkina Faso

Neya T.[1] (neyatiga@gmail.com), Neya O.[2], A. Abungyewa A.[3]

[1] *Civil Engineering, Kwame Nkrumah University of Sciences, Ouaga, Burkina Faso*; [2] *Ecosystem services, WASCAL, Ouaga, Burkina Faso*; [3] *Agroforestry, Kwame Nkrumah University of Sciences, Kumasi, Ghana*

Agroforestry plays an important role in food security and farmer's resilience to climate change and variability in West Africa and diversity of landscape has been seen to be more resilience to climate change according to the diversity of ecosystem services that they can offer. However agroforestry parkland diversity at landscape level in the climatic zone in Burkina Faso is not well known. Therefore, the mosaic of agroforestry parkland landscape in three climatic zones of Burkina Faso was studied. Thirty (30) farmlands in each climatic zone representing about 35 ha were randomly selected on which systematic woody species inventory and dendrometry data collection was undertaken. Diameter classes' distribution and agroforestry parkland typologies representing their mosaic using Importance Value Index analysis were also done. The results showed 42, 31 and 34 woody species respectively in Sudanian, Sudan-Sahel and Sahel strict zones with corresponding density of 37, 30 and 35 trees/ha. Agroforestry parklands in Sudan-Sahel zone appeared to be unstable compared with the two others climatic zones. One parkland landscape of Vitellaria paradoxa was observed in the Sudanian zone while three parklands landscape of Vitellaria paradoxa, Parkia biglobosa and Bombax constatum were observed at the given farmland area in the Sudan-Sahel and Multi-parkland landscape of Adansonia digitata, Azadirachta indica ,Balanites aegyptiaca , Faidherbia albida, Lannea microcarpa and Sclerocarya birrea were observed at the same given area of farm in Sahel strict zones. The investigation revealed that the main reason of mixing crop and trees was to diversify the sources of production to secure food security and multi-agroforestry landscape is to cope more with climate variability affecting crop production. Thereby, Multi-agroforestry parklands landscape observed in the Sahel strict zone appeared to be the most resilient to climate variability and change and could therefore be advised as a strategy to cope with the adverse effects of climate variability on rural livelihood. Keywords: Parkland typology, woody species, density, smallholders, ecosystem services

Keywords: Parkland landscape, woody species, tree density, smallholders.

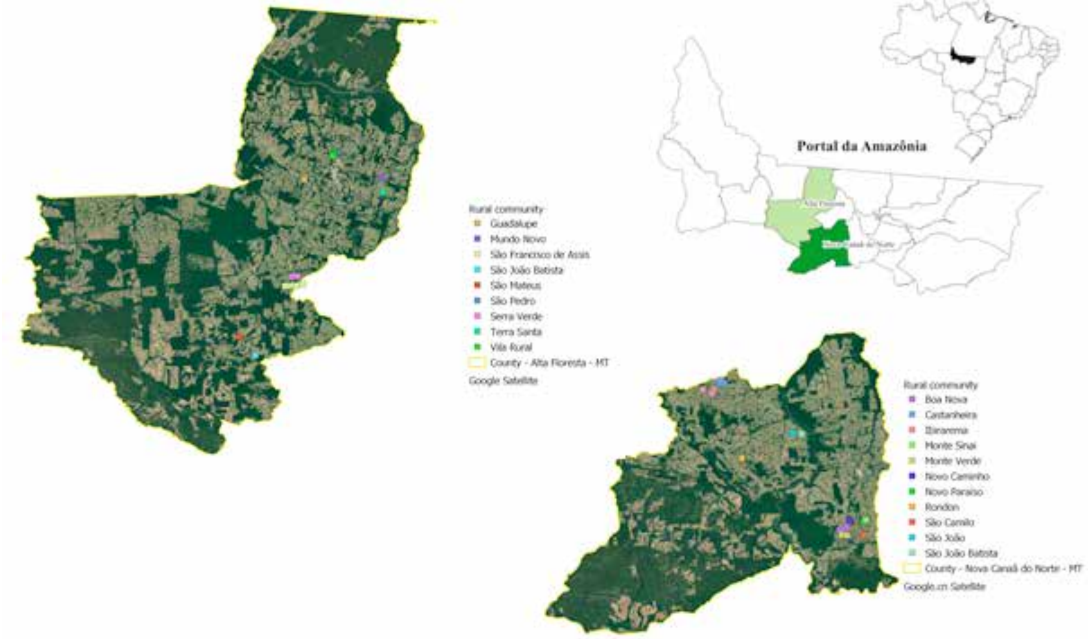
L14.P.20

Agroforestry systems adoption as multifunctional land use strategy for forest landscape restoration in Amazonia, Brazil

Oliveira R.[1] (reolivei@ufscar.br), Sais A.[1], Souza V.[2], Pereira A.[2], Alcântara L.[3], Arantes V.[4]

[1] *Rural Development Department, Universidade Federal de São Carlos, Araras, SP, Brazil*; [2] *PPGADR, Universidade Federal de São Carlos, Araras, SP, Brazil*; [3] *Universidade Federal do Mato Grosso, Cuiabá, MT, Brazil*; [4] *Instituto Ouro Verde, Alta Floresta, MT, Brazil*

Agroforestry systems (AFS) are multifunctional land use strategies that can be used in forest landscape restoration. The "Portal da Amazônia" Territory was established through recent colonization with high rates of deforestation. Currently, 84% of its properties are managed by family farmers. We have mapped 19 rural communities of two counties and surveyed the food and medicinal species cultivated in 44 agroforestry homegardens, identifying those which are commercialized by the families and the main places where they are sold. AFS are not traditional land use systems in this region, they were implemented by the NGO Ouro Verde Institute, with BNDES (National Development Bank)/Amazonia Fund support, aiming to diversify agricultural production in these agroecosystems. We found 131 food species and 151 medicinal plants chosen to be cultivated by the families, with 96 species being already sold in local markets. There are species occupying all strata (trees, shrubs, herbs, lianas and epiphytes), which indicates their potential for the establishment of multiple agroforestry consortia. We found a high number of tree species, both for food (109) and medicinal (36) uses. The results show the potential of AFS to bring back the arboreal component into the properties and to improve food security and income generation to families, which will certainly stimulate their adoption by family farmers and maybe promote the expansion of AFS and forest restoration at landscape scales in Amazonia.



Spatial distribution of rural communities with agroforestry homegardens in two counties, highlighting the deforested areas

Keywords: Landscape restoration, Tree species, Homegardens, Family farming, Amazonia.

L14.P.21

Are landscape complexity and type of semi-natural habitat influencing wild-bees diversity and foraging choices?

Rivers-Moore J.[1] (justine.rivers-moore@inra.fr), Andrieu E.[1], Vialatte A.[1], Ouin A.[2]

[1] *INRA - UMR DYNAFOR, Auzeville-Tolosane, France*; [2] *ENSAT - UMR DYNAFOR, Auzeville-Tolosane, France*

In this study, we investigate if different semi-natural habitats provide a diversity of pollen resources with potential consequences on wild bee diversity and foraging choices. More specifically, the following questions were tackled: (1) Does the diversity of wild bee communities vary with the type of semi-natural habitat and with landscape complexity? (2) Does the diversity of pollen carried by wild bees depend on the type of semi-natural habitat and on landscape complexity? (3) Do the plant – wild-bees interaction networks depend on landscape complexity?
Our study took place in south-western France, in a region characterized by a mosaic of small woodlands, permanent grasslands and crop fields. We selected 30 landscapes (500m buffer) along two independent gradients of semi-natural habitats: woodland and grassland proportions. In each landscape, wild-bees were captured next to three types of semi-natural habitats: a hedgerow, a wood edge and a grassland. All the bees were identified and the pollen carried by the more abundant species (N>4) was identified at species level. Botanical records were carried out in each semi-natural habitat sampled for bees. A level of pollen resources provision (LP index) was calculated for each type of habitat. We then combined our data to assemble 30 bipartite networks of realized plant-pollinator interactions (landscape level network). A regional network combining all the data was established to estimate the full set of potential interactions between all plant and wild-bee species in the region.
530 wild-bees of 77 different species were caught, and pollen of 76 plant species were found on them. 75% of the bees carried pollen of only one species. The hedges and wood edges presented quite similar plant – wild-bees interaction networks, due to their low bees and plant species richness, whereas grasslands exhibited more diverse communities and a bigger plant-pollinators interaction web.

Keywords: Semi-Natural Habitats, Landscape complexity, Wild-bees, Interaction networks.

References:

1. Vialatte et al., 2017, Landscape ecology, 32(3), 465-480
2. Olesen et al., 2002, Ecology, 83(9), 2416-2424
3. Spiesman et al. 2016, Ecology, 97(6), 1431-1441
4. Kremen et al., 2007, Ecology letters, 10(4), 299-314.

L14.P.23

Landscape performance assessment: knowledge transfer from Global Land Programme to World Agroforestry Congress

Scherr S.[1] (sscherr@ecoagriculture.org), Buck L.[1], Celio E.[2]

[1] *EcoAgriculture Partners, Washington, DC, USA*; [2] *Planning of Landscape and Urban Systems, ETH Zürich, Zürich, Switzerland*

If Sustainable Development Goals (SDGs) should be met, the strategic goals must be implemented at a scale that is manageable and effective. As the landscape level is considered as the scale that allows adopting a truly integrated perspective to balance multiple stakeholders interests, initiatives at this level are potentially very effective. Globally, hundreds of integrated landscape initiatives (ILIs) have been identified (Zanzanaini et al., 2017; Reed et al., 2017; Garcia-Martin et al., 2016). Their outcomes and impacts though, were rarely measured due to organizational and methodological challenges. Sayer et al. (2017) proposes an approach to measure the effectiveness of such ILIs from a scientific perspective. From the practice perspective, organizations such as Verra or EcoAgriculture Partners develop tools for landscape performance assessment. However, the broad implementation and evaluation of these concepts is still pending.

This contribution aims to discuss the state of the art in the assessment of the landscape performance in general and with a special focus on agroforestry landscapes. Building on a conference session to compare and contrast the approaches of universities, research centers and NGOs.

To this end, we collect insights in session specifically focused on landscape performance at the Global Land Programme (GLP) Open Science Meeting (OSM) (https://glp.earth/osm-2019) preceding the World Agroforestry Congress (WAC) by one month. Hence, an inter-community discussion will be facilitated and insights will be fed back to both communities. The seven presentations at the GLP-OSM are content analyzed. Findings undergo a review by the presenting authors and finally, the insight are summarized for the presentation at the WAC.

We present evaluation approaches that inform (agroforestry) landscapes using different methodological foundations: Remote sensing and geodata to assess the landscape condition with the help of ecosystem services; participatory methods to evaluate landscape governance and the process quality in the integrated landscape initiatives. By putting these approaches into the overarching discussion of landscape performance assessment, future landscape initiatives as well as their monitoring and evaluation will profit from this inter-community dialogue.

Keywords: Landscape, Performance, Monitoring, Evaluation, Integrated Landscape Management.

References:

1. Zanzanaini et al., 2017, Landscape and Urban Planning, 11-21
2. Reed et al., 2017, Land Use Policy, 481-492, http://dx.doi.org/10.1016/j.landusepol.2017.02.021
3. Garcia-Martin et al., 2016, Land Use Policy, 43-53
4. Sayer et al. 2017, Sustain Sci, 465-476, http://dx.doi.org/10.1007/s11625-016-0415-z

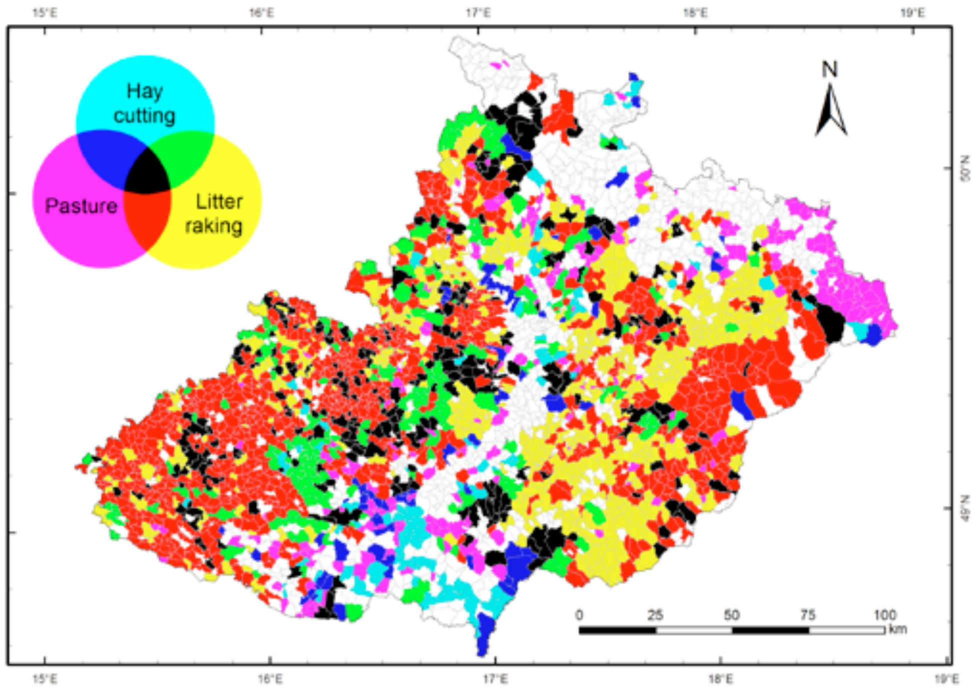
L14.P.24

Traditional agroforestry in the Czech Republic: distribution, characteristics and drivers of decline

Szabó P.[1] (peter.szabo@ibot.cas.cz), Suchánková S.[1], Havlíček M.[2], Müllerová J.[1]

[1] *Institute of Botany of the CAS, Pruhonice, Czech Republic*; [2] *VÚKOZ, Pruhonice, Czech Republic*

Agroforestry uses (such as grazing, hay cutting and litter raking) were once important parts of forest management and played a major role in ecosystem development through biomass removal. This poster will present unique and comprehensive data on agroforestry uses from 3500 settlements in the Czech Republic from the 16th to the 20th century to show the extent to which these uses were present in preindustrial forests at the landscape scale and how the contemporaries related to them. We will describe the potential drivers behind the distribution of agroforestry uses in the past as well as the drivers for their subsequent decline. Lastly, the poster will illustrate the potential of agroforestry uses in sustainable forestry in the future.



Agroforesty uses in Moravian (eastern Czech Republic) in the 19th century.

Keywords: forest management, traditional uses, litter raking, hay cutting, landscape scale.

L14.P.25

Assessing multiple ecosystem functions of linear woody-features in the agricultural landscape

Tsonkova P.[1] (penka.tsonkova@b-tu.de), Böhm C.[1], Ehritt J.[2], Hübner R.[3]

[1] *BTU Cottbus-Senftenberg, Cottbus, Germany*; [2] *NABU Brandenburg, Potsdam, Germany*; [3] *Technical University of Munich, Freising, Germany*

Anthropogenically developed linear woody features, such as hedgerows, windbreaks, and riparian buffer strips, served a multitude of purposes within agricultural landscapes in the past. Currently, they are of minor importance for farmers in Germany, who are typically not allowed to manage them, due to nature protection regulations. The aim of this study was to classify existing linear woody features within agricultural landscapes and to assess them in relation to relevant ecosystem functions and services, such as production, wind and water protection, habitat provision, and landscape aesthetics. For the classification of woody features, 45 categories were obtained by the combination of general characteristics such as hedgerow type, hedgerow structure and degree of naturalness (Fig. 1). The condition of each ecosystem function was assessed by low, medium, and high for each category according to the literature. The application of this assessment in a study area of 4 km^2 in southern Brandenburg revealed a prevalence of tree dominated woody features and an overall low to medium condition of the assessed ecosystem functions. The assessment method can aid decision making regarding the condition of multiple ecosystem functions under consideration of potential synergies and conflicts between functions. Allowing farmers to utilise the production function of hedgerows is necessary for their rejuvenation and maintenance in a good condition.

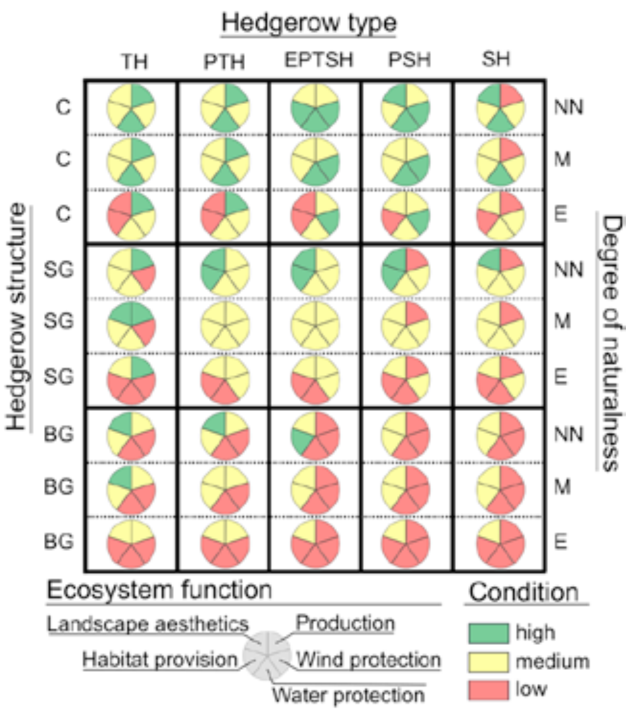


Figure 1. Condition of ecosystem functions according to hedgerow type: tree hedgerow (TH), predominantly tree hedgerow (PTH), equal proportion of trees and shrubs (EPTSH), predominantly shrub hedgerow (PSH), shrub hedgerow (SH); hedgerow structure: closed (C), with small gaps (SG), with big gaps (BG); and degree of naturalness: near natural (NN), mixed (M), exotic (E)

Keywords: Production, Wind protection, Water protection, Habitat provision, Landscape aesthetics.

L14.P.26

Visualization as a tool to raise the debate on agroforestry in urban contexts

van Dooren N. (noel.vandooren@hvhl.nl), van der Meulen S., Noortman A.

Delta Areas and Resources, Van Hall Larenstein, Velp, Netherlands

In many parts of the world, agroforestry is a known practice, for diverse motives, including the desire to win back degraded land. In the Netherlands with its focus of highly productive agricultural production, oriented on the global market, agroforestry is a rather unknown practice. Recently, however, the phenomenon receives a lot of attention, also due to the attention for so-called food forests, which can be considered a close-by practice. Reasons for such growing attention can be found in the debate on climate change, for example, and on city-region food systems. As the Netherlands are highly urbanized, and landscape is considered a cultural product, the impact of agroforestry on landscape is of interest, be it negative or positive. We notice a widespread lack of insight what the spatial implications of agroforestry, especially large-scale developments, can be. Therefore, within our larger research program, together with students first attempts were done to visualize agroforestry developments two-dimensionally and three-dimensionally. Especially the combination of multicropping and the need for an efficient system of management and harvesting reveals the lack of best practice in different landscapes. This exercise, therefore, not so much counts as predictable visualization, as well as a visual starting document for debate and knowledge exchange. In that respect, it contributes to the further development of agroforestry as such, and the implementation in local contexts.

Preliminary image of agroforestry development in the Nijmegen region (Berlijn, V. et al, 2018)

Keywords: agroforestry, visualisation, landscape, city-region food system.

References:

1. Vaarst, M. et al. (2017) Agroecology and Sustainable Food Systems, p686-711 Published online: 04 Oct

ABSTRACTS

Agroforestry adoption

Adopting the future of land use

- L15 -

Urban and peri-urban agroforestry for food and nutritional security

Permaculture, agroforestry, and homegardens: the urban ticket to nutritional yumminess

The world has been experiencing unprecedented levels of urbanization in the past few decades, a trend that is expected to continue so that food and nutritional security is emerging as one of the principal concerns in many cities. Another major concern is 'regreening', as, much too often, the conversion of agricultural and forest land to urban land has been done with little or no concern for environmental quality, leading to loss of tree cover and ecosystems services. Developing agroforestry in the urban and peri-urban remaining green spaces, as long as they are not impacted by pollution, may respond to these concerns: combining the production of food and the rehabilitation of a tree and plant cover with its various ecosystem services, it would increase food and nutritional security for the urban poor and reconnect the urban people to nature.This session will explore whether and how agroforestry can contribute to both food security and environmental betterment of cities.

Although open to any kind of scientific presentation, case studies are especially welcome. Case studies may include aspects related to agroecology, permaculture, agriculture and forestry, in an urban context; they may also cover a wide range of scales from local to global, and any kind of geographic setting. The papers presented for this session will be written-up with a view to publish them as a special issue of an international journal such as Agriculture, Ecosystems and the Environment, Agroforestry Systems or Forests, Trees and Livelihoods, or alternatively, as a stand-alone edited volume.

L15_O.01

Linking urban homegarden agroforestry and child nutrition: A case study from Kampala, Uganda

Mollee E. M.[1] (e.mollee@bangor.ac.uk), McDonald M. A.[1], Kehlenbeck K.[2]

[1] *School of Natural Sciences, Bangor University, Bangor, Gwynedd, United Kingdom*; [2] *Faculty Life Sciences, Rhine-Waal University of Applied Science, Kleve, Germany*

Uganda faces serious challenges in providing sufficient healthy foods for its growing and urbanizing population. This paper aims to explore the contribution of urban agroforestry homegardens to child nutrition in Kampala. A repeat 24-hour dietary recall including information on food sources was conducted with 49 children (aged 2-5) and 31 of their caretakers (aged 18-49). Dietary Diversity Scores (DDS), Food Variety Scores (FVS) and household food insecurity levels (HFIAS) were calculated and anthropometric measurements taken. A total of 70 edible plant species were recorded in the 49 homegardens. We found a correlation between child and caretaker for DDS (Spearman's rho = 0.861, $P<0.01$), FVS (Pearson R = 0.870, $P<0.01$) and fruit intake (Spearman's rho = 0.637, $P<0.01$). A logistic regression indicated that children from wealthier households were more likely to have higher DDS ($P=0.007$) and fruit intake ($P= 0.011$). Homegardens provided 5% of the food items consumed, particularly fruits and vegetables (Fig. 1). Higher garden agrobiodiversity had no influence on dietary diversity and nutritional status of children during the dry season, but the surveyed children had a generally good nutritional status. During harvest season urban homegardens may contribute more to family nutrition. To ensure a more food secure city, researchers, policy makers and urban planners need to become aware of the potential value of urban homegardens and prioritise them in future development plans.

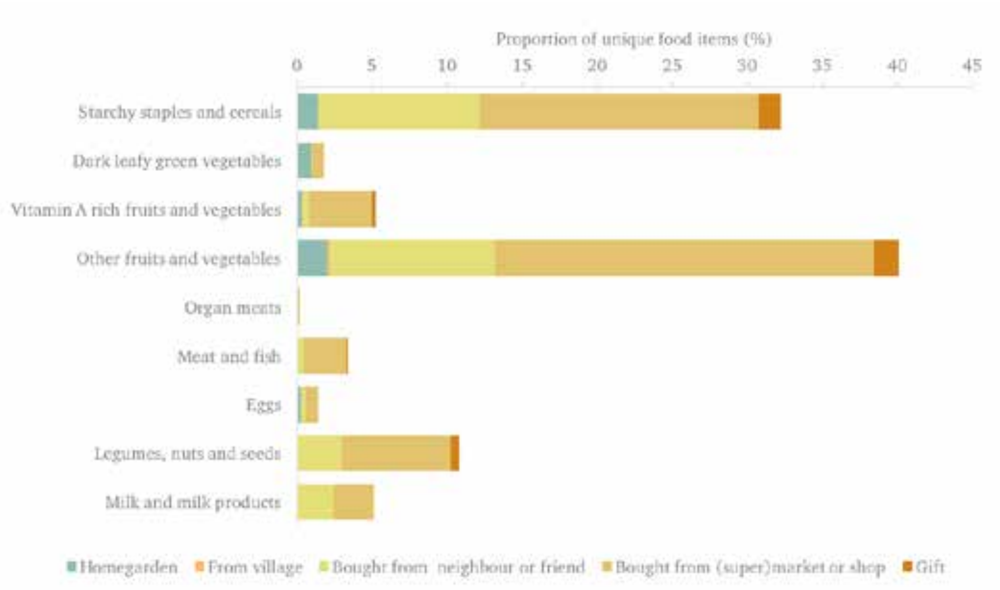


Figure 1 Proportion of food groups and their sources of the unique food items consumed by the 49 children during a repeat 24-hour recall in Kampala (Uganda) 2015, taken during dry season.

Keywords: Food security, agrobiodiversity, homegardens, child nutrition, Dietary Diversity.

References:

1. Arimond et al., 2010, J Nutr. 140(11):2059S–69S
2. Kumar & Nair, 2004, Agroforestry Systems, 61-62(1-3):135–152
3. Lwasa et al., 2014, Urban Climate, 7(C):92–106
4. Steyn et al., 2006, Public Health Nutrition, 9(5):644–650

L15_O.02

Food forests as complex agroforestry systems for creating multifunctional urban green spaces through community gardening

Schulz J. (jennifer.schulz@uni-potsdam.de), Lipp T., Zurell A.

Earth and Environmental Science, University of Postdam, Potsdam, Germany

Growing demands from citizens for urban gardening, edible cities, for biodiversity habitats in green spaces, but also the need for residential green areas that provide climate regulation have become apparent in recent years in German and other European cities. Examples from the benefits of urban food forestry projects in the United States and the United Kingdom (Clark & Nicholas, 2013) have led us to investigate the feasibility for implementation of this concept in German cities. Food forests imitate the multi-layered structure of natural woodlands. In contrast to alley cropping systems, they consist mainly of fruit and nut bearing trees and shrubs, as well as a vegetable and herb layer. Through their structural similarity to natural woodlands, ecological and climatic functions (e.g., cooling, soil conservation, biodiversity habitat) may approach the ecological functions of forests with increasing age of the system. Hence food forest enable the production of food with the improvement of multiple ecological functions in urban areas (Clark & Nicholas, 2013), which go beyond short term urban gardening activities with annual species carried out in planting boxes.
To assess the feasibility of the concept of urban food forests we carried out interviews and questionnaires with all relevant authorities at city level and in different quarters of Berlin, Germany. This was accomplished by assessing potential user groups and the response of different urban gardening initiatives towards the concept. Based on this, a series of participatory workshops, bringing together civil society actors, green spaces administration, nature protection agencies and scientists was used for focussed discussing concerning the level of public access, options for coordination between public green spaces management and users duties and options for long term land definition within the public planning regime.
Intermediate results reveal the large array of demands and regulations on different types of urban green spaces in Germany and strong conflicts of interest on green spaces, which seem to be a barrier for the long term access to land for implementing this complex agroforestry system. While civil society actors are articulating demands for long term urban gardening setups and some sort of reliability concerning site availability and agroforestry development options, government authorities are hesitant concerning longer term definitions. This is true, despite of the recognition of the ecological and social benefits that food forests may bring in the long term, as well as the potential benefits of a collaborative management form for urban green spaces in terms of management costs. As any type of agroforestry requires a long term perspective, the development of innovative rules and regulations dealing with long term land guarantees and management responsibilities will be crucial for facilitating the adoption of agroforestry systems such as food forests in urban areas.

Keywords: urban gardening, comunity management, public green spaces, feasibility study, Germany.

References:

1. Clark, K.H., & Nicholas, K.A., 2013. Introducing urban food forestry: a multifunctional approach to

L15_O.03

The ancient urban agroforestry systems of the Conca d'Oro (Palermo, Italy) need protection to defend the city

La Mantia T.[1] (tommaso.lamantia@unipa.it), da Silveira Bueno R.[1], Quatrini P.[2]

[1] *SAAF, University of Palermo, Palermo, Italy*; [2] *STEBICEF, University of Palermo, Palermo, Italy*

The favorable environmental conditions together with the ancient agronomic practices, e.g. the irrigation systems introduced by the Arabs, have made the plain surrounding Palermo, known as Conca d'Oro, the unique agriculture landscape famous worldwide. Several tree and vegetable species have spread throughout in time but the new crops, instead of replacing the others, were often integrated exploiting the different heights of the tree canopies. The result was the creation of complex agroecosystems characterized by orchards with several layers of trees (as walnut, loquat, citrus) and empty spaces where the farmers cultivated vegetables. The grass fed the animals in the stables while manure was returned to the fields. Now the traditional system has changed (simplification, disappearance of animals, abandonment) but new functions, in the meantime, are attributed to these areas: air purification, high quality products, biodiversity conservation, preservation of history, and, recently, training of young farmers. The purpose of this communication is to describe the agroforestry features of today's Conca D'Oro system and that of the recent past and to illustrate its new functions while the city is engulfing its last agricultural areas. It is evident that, without the support and control of the public administration, the green spots left in the Conca D'Oro (one is indicated by the yellow arrow) will disappear and one of the most beautiful landscapes in the world will be lost forever.

Keywords: biodiversity, Citrus orchard, layers of vegetation, agronomic techniques, transmission of culture.

References:

1. Sparacio I., La Mantia T., Colomba M.S. et al., 2017. Biodiversity Journal, 8 (1): 279–310
2. Bellavista M., La Mantia T., Sparacio I., 2015. Acta Horticolturae n. 1092: 283-287.
3. La Mantia T., 2007. Frutti di Demetra, 14: 25-36.

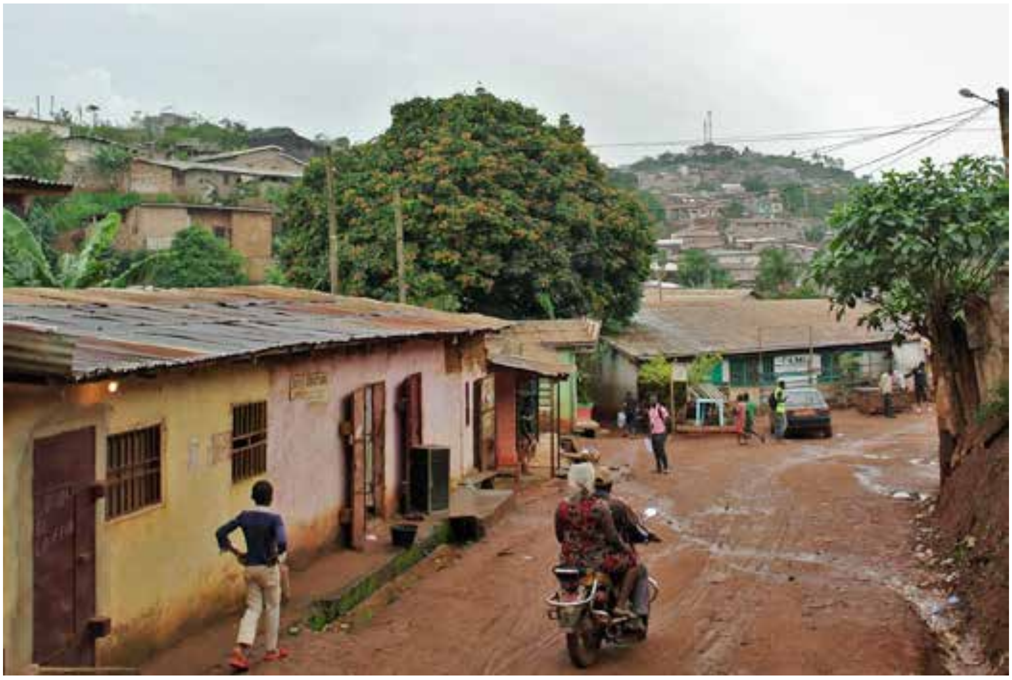
L15_O.04

Genetic diversity of a tropical fruit tree (*Dacryodes edulis*), from Yaoundé home gardens to Cameroonian agroforests

Rimlinger A.[1] (aurore.rimlinger@ird.fr), Marie L.[1], Lemoine T.[1], Meguem F.[2], Avana M.-L.[2], Zekraoui L.[3], Mariac C.[3], Carrière S. M.[4], Duminil J.[3]

[1] *Université de Montpellier, Montpellier, France*; [2] *FASA, Université de Dschang, Dschang, Cameroon*; [3] *UMR DIADE, IRD, Montpellier, France*; [4] *UMR GRED, IRD, Montpellier, France*

Urban agroforestry is largely advocated, as trees in the city provide a number of ecosystem services. In Africa, one of the world's fastest urbanizing regions, they contribute particularly to food production and to maintain the quality of the environment. Nevertheless, little is known on the interplay between management practices and levels of genetic diversity of urban trees. Our model species, *Dacryodes edulis* (G. Don) HJ Lam, is a widespread indigenous fruit tree in Central Africa. In Cameroon, it is commonly found in different agroforestry systems (home gardens, agroforests), from the capital Yaoundé to peri-urban and rural areas. This study characterizes tree management practices along an urbanization gradient and the associated distribution of genetic diversity. Using 13 nuclear microsatellites markers and samples from nine study sites along the gradient (three rural villages, three peri-urban towns and three Yaoundé district), we will compare management practices and their effect on the intraspecific genetic diversity. We hypothesize that the genetic diversity could be higher in Yaoundé, with planting material coming from different regions as people settle. This intraspecific diversity could thus be related to seed sourcing strategies still being the dominant planting strategy for this cross-pollinated species. The results will help understand the distribution of cultivated tree genetic diversity, in the context of ongoing domestication of tropical perennial species.



Urban D. edulis tree bearing young fruits (African plums) in the Messa-Carrière district of Yaoundé

Keywords: ethnoecology, genetic diversity, indigenous fruit tree species, management practices, urban home gardens.

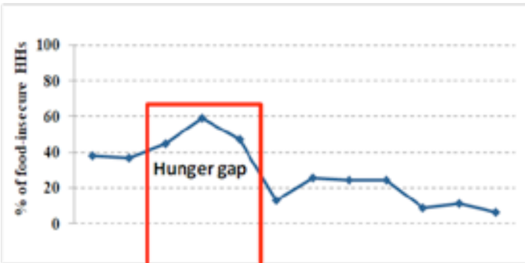
L15_O.05

Filling food harvest and nutrient ‘gaps’ in local diets through site specific food tree and crop portfolios

McMullin S.[1] (s.mcmullin@cgiar.org), Stadlmayr B.[2], Kindt R.[1], Jamnadass R.[1]

[1] *Tree Productivity and Diversity, World Agroforestry Centre, Nairobi, Kenya*; [2] *Centre for Development Research, University of Natural Resources and Life, Vienna, Austria*

Using participatory research, the World Agroforestry Centre (ICRAF) developed the *food tree and crop portfolio* approach to enhance the diversity and seasonal availability of nutritious foods in local food systems. These nutritious food *portfolios* are defined as site-specific combinations of indigenous and exotic food tree species with complementary staple crops, vegetables and pulses that potentially can provide year-round harvest of nutritious foods and, at the same time, fill ‘hunger gaps’ and specific ‘nutrient gaps’. In addition to filling harvest ‘gaps’, certain nutrient ‘gaps’ are addressed by mapping the nutritional value of selected species using food composition data. This data plays a key role in linking agriculture to nutrition, particularly the nutrient composition of indigenous and underutilised species, for which such information is often lacking. To address this data and knowledge gap, ICRAF have collated food composition data to support decision-making in the selection of ecologically suitable and nutritionally valuable species for cultivation. This approach supports the mainstreaming of trees and crops rich in micronutrients which can be overlooked in agriculture - nutrition development planning, projects and policies. The portfolios represent a sustainable food-based approach to address micronutrient deficiencies by promoting nutrient dense foods in the diets of rural and urban consumers. The portfolios have been developed in 15 sites across East Africa.



English name	Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Vit C	Vit A*
Mango	*Mangifera indica*													++	+++
Lemon	*Citrus limon*													+++	
Orange	*Citrus sinensis*													+++	
Passionfruit	*Passiflora edulis*													++	++
Pawpaw	*Carica papaya*													+++	++
Jackfruit	*Artocarpus heterophyllus*													~	
Avocado	*Persea americana*													~	
Guava	*Psidium guajava*													+++	~
Loquat	*Eriobotrya japonica*														+++
Custard apple	*Annona reticulata*													++	
Chocolate berry	*Vitex doniana*													~	
	Available vitamin C and Vitamin A* rich fruit species	4	4	3	4	3	2	1	3	3	1	1	5		

(*expressed as Vitamin A retinol equivalent = retinol + 1/6 beta-carotene + 1/12 alpha-carotene + 1/12 beta-cryptoxanthin)

An example of a fruit tree portfolio* for Siaya/Bondo counties, Western Kenya. Ecologically suitable fruits selected based on their complementary months of harvest and their nutritional contribution for target nutrients, vitamins A and C. Nutritional value ratings of beta carotene (vitamin A) and vitamin C and contents are given as +++ (high source), ++ (source), ~ (present, but low, or moderate), blank, white (no source), blank, grey (no data available). Fruits can also be evaluated for other nutrient values (B vitamins, minerals including zinc etc.). Avocado is included as a source of good fat, minerals and vitamin E. Months of harvest are mapped against food security levels of the surveyed households (HHs) in the counties (n=171) (upper graph). Harvest periods of vitamin-rich fruits are indicated by green-shaded boxes. *This graphic illustrates a fruit tree portfolio, the expanded concept of the food tree and crop portfolio as presented in this abstract is available in further detailed graphics and with additional nutrient mapping of iron and folate.

Keywords: Tree foods, nutrition, diets, local food systems, East Africa.

References:

1. McMullin, S., Stadlmayr, B., Roothaert, R., and Jamnadass, R. 2018. Encyclopedia of Food Security an

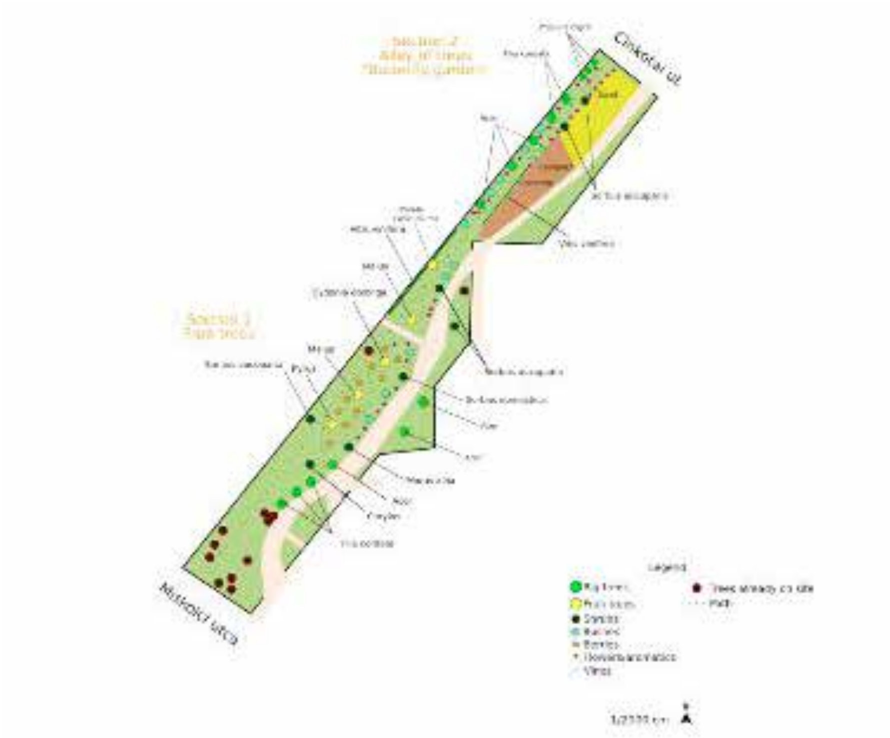
L15_O.06

Planning multipurpose trees in the city

Gonzalez de Linares P. (paloma_de_linares@hotmail.com)

Landscape Architecture and Urbanism, SZIE university of Budapest, 1118 Budapest, Hungary

Urban agroforestry is expanding in the tropical countries due to urban densification and expansion, increasing distance with agricultural lands and farms. Whilst urban agroforestry has been registered in the Adaptation to Climate Change Program of the Tonga Island in 2013, it hasn´t fully been explored in the Temperate Climates. This article is part of a PhD research on urban agroforestry. In the frames of a landscape architectural study, I have planned and designed an experimental public forest garden in partnership with the 14th district of Budapest and an NGO cargonomia. Compared to other urban food systems, urban agroforestry is a complex topic which requires research in both biology and sociology. Therefore, it is important to bring together planners and experts in ecology to plan agroforestry in the urban landscape. Through a Landscape Architectural approach this paper explores why agroforestry systems should be planned in the city and how public spaces can be designed with agroecological principals. Further, this article presents steps in planning a public edible forest garden through the case Budapest, the principals behind the community participation, and the first results from the opening on the 11th of November 2018. The conclusion is that the socio-ecological interactions are the basis to implement a new urban land use policy. Key words : Land use policy, urban agroforestry, landscape architecture, forest gardens



The Edible Climate Forest Plan of Zuglo, Budapest

Keywords: Land use policy, Urban agroforestry, Landscape architecture, Forest gardens.

References:

1. Gonzalez de Linares Paloma, 2018, International Journal on Design and Ecodynamics, 12 pages

L15_O.07

Preparing Potager du Roi of Versailles for the future. A historical kitchen garden in an urbanized setting.

Jacobsohn A.[1] (a.jacobsohn@ecole-paysage.fr), Delbouis F.-X.[1], Lacourt S.[2]

[1] *Potager du Roi, Ecole nationale supérieure de paysage, Versailles, FRANCE*; [2] *Larep, Ecole nationale supérieure de paysage, Versailles, France*

Potager du Roi is a remarkable garden that fits into a unique urban composition. Since its creation starting in 1678, the site has undergone many changes without ever losing its original structure. Gardens must be continually cultivated and maintained. But some architectural and plant structures of large gardens have a life cycle that is approximately centennial. Potager du Roi was created starting in 1678. The first major restoration occured in the 1780's and the second began in the 1880's. Today, Potager du Roi suffers from a thirty year deficit of sustained investment.

This presentation will describe how an agroecological approach, including agroforestry, is being applied to conserve and share the unique and exceptional atmosphere of the garden designed by La Quintinie; to position the site as a living heritage at the heart of contemporary debates and in particular sustainable practices concerning food and health issues in an urban environnement.

Potager du Roi. Historical kitchen garden in an urbanized setting

References:

1. JACOBSOHN, 2014, Carnets de paysage n25, p24-31
2. JACOBSOHN, 2017, Potager du Roi - Dialogues avec La Quintinie, Paris, Artlys.

L15_O.08

Agroforestry and Urban Policy Development: case studies of home gardens in the Cape Flats, South Africa

Llewellyn E. C.F.C.[1] (lizzie.llewellyn@outlook.com), Brook R.M.[2]

[1] *School of Natural Sciences, Bangor University, Cape Town, South Africa*; [2] *School of Natural Sciences, Bangor University, Bangor, United Kingdom*

Despite increasing focus on OLU and trees outside forests, trees in private spaces in cities remain understudied. Urban planners and policy makers need to be able to build resilience and sustainability into all aspects of urban management plans. Home gardens could prove attractive tools for policy development and implementation. They have been shown to support climate change resilience, combat natural resource constraints and address food insecurity however most literature focuses on Asia or rural locations. The present study examined 26 home gardens in the Cape Flats, South Africa in 2017 through semi-structured interviews and direct observation working with three local NGOs. Case studies are presented with data on (1) garden structure and composition and (2) values derived from home gardening, and (3) challenges.

Results showed high species abundance and high variability in garden structure and composition. Garden size had no significant effect on ecological diversity. Gardeners were most motivated by food production (availability, quality, and known provenance) and aesthetics. There was no apparent relationship between economic status and gardening objective. All gardeners acknowledged NGO facilitation through seed provision, skills transfer or, particularly relevant given the drought in Cape Town, water harvesting techniques. Policy makers wishing to encourage these practices would do well to explore ways to collaborate with these organisations.

Figure 1 Large, mature garden with mixed trees and clearly zoned areas

Keywords: urban and peri-urban home gardens, urban greening, urban agroforestry, home-garden policy, home gardening motivations.

References:

1. Battersby, J. & Marshak, M, 2013, Urban Forum, 24(4), pp. 447-461.
2. Cameron, R. W. F. et al., 2012, Urban Forestry & Urban Greening, 11, pp.129-137.
3. Galhena, D. H., Freed, R. & Maredia, K. M., 2013, Agriculture & Food Security, 2, pp.1-13.
4. Shackleton, S. et al., H., 2015, Landscape and Urban Planning, 136, pp.76-86.

L15_O.09

Urban agroforestry: potential for climate change adaptation and mitigation

Mujuru L. (lzzmjr2009@gmail.com), Kapondoro B., Jimu L.

Natural Resources, Bindura University of Science Education, Bindura, Zimbabwe

Agroforestry development in urban and peri-urban areas may respond to food security and environmental concerns by reconnecting urban people with nature. A study was done to determine diversity of trees in urban croplands and contribution of agroforestry to people's livelihoods in Harare, Zimbabwe. Objectives were to i) identify the tree species used in urban agroforestry ii) determine factors influencing adoption of urban agroforestry and iii) identify the challenges of practicing urban agroforestry. Questionnaires and field surveys were used to collect data. In agroforestry plots, *Eucalyptus grandis* (24%) was most abundant species, followed by *Cajunus cajan* (18%), *E. resinifera* (13%), *Faidherbia alibida* (9%), *Leucaena leucocephala* (9%) and *Acacia angustisma* (6%). The other 13 species were below 3% each. Four exotic and four indigenous fruit trees were used in agroforestry plots although their numbers were low due to reasons of fruit insecurity. Fruit trees need to be close to homesteads to ensure their security. About 50% of urban farmers were motivated to engage in agroforestry mainly for food security although soil fertility (20%) and income generation (13%) were also important. The main challenge affecting adoption of agroforestry in urban areas was the small plot sizes and land tenure. There is need for more education and awareness to increase knowledge on the importance of trees in urban agriculture to facilitate ecosystem restoration while achieving economic gains.

Tree component used in urban agroforestry in Dzivarasekwa. Harare. Zimbabwe

SPECIES	FAMILY	STATUS	FREQUENCY (%)
Accacia angustissma	Fabaceae	Exotic	5.90%
Azanza gackeana	Malvaceae	Indigenous	0.30%
Bauhinia petersiana	Fabaceae	Indigenous	1.20%
Brachystegia boehmii	Caesalpiniodeae	Indigenous	2.50%
Brachystegia speciformis	Caesalpinioideae	Indigenous	2.20%
Cajanus cajan	Fabaceae	Exotic	17.80%
Croton megalocarpus	Euphorbiaceae	Exotic	0.90%
Eucalyptus grandis	Myrtaceae	Exotic	23.70%
Eucalyptus resinifera	Myrtaceae	Exotic	13.40%
Faidherbia albida	Fabaceae	Indigenous	9.30%
Leucaena leucocephala	Fabaceae	Exotic	9.30%
Mangifera indica	Anacardiaceae	Exotic	0.60%
Persea americana	Lauraceae	Exotic	0.30%
Piliostigma thonningi	Fabaceae	Indigenous	2.80%
Prunus persica	Rosaceae	Exotic	0.60%
Psidium guajava	Myrtaceae	Exotic	1.20%
Uapaca kirkiana	Phyllanthaceae	Indigenous	1.20%
Ziziphus mauritiana	Rhamnaceae	Indigenous	3.40%
Ziziphus mucronata	Rhamnaceae	Indigenous	3.10%
Total			100%

Keywords: Agroforestry, urban area, tress, soil fertility, agriculture.

References:

1. Kumar Gupta, R. et al. 2017. Int.J.Curr.Microbiol.App.Sci, 6(8), 211–220
2. Mwase, W. et al. 2015. Environment and Natural Resources Research, 5(2), 148–157
3. Rotich, J. et al. 2017. International Scholars Journals, 5(5), 315–325.
4. Naget R. 2000 . Electronic Conference “Urban and peri-urban agriculture on the policy agenda»
5. Crush J. et al. 2010. Urban Food Security Series No. 4. 1-39

L15_O.10

Growing Agroforestry Crops in Peri-urban Areas of New Cities : Ignored or Forgotten?

Lamichhane D. (dhanusara@hotmail.com)

Ministry of Forests and Environment, Kathmandu, Nepal

Increasing trend of rural-urban migration has caused rapid land-use change in peri-urban areas of the capital city of Kathmandu, Nepal. The paper elaborates the need for change in urban authorities and residents for growing trees in peri-urban areas in the future. Five different study sites representing diverse geophysical and socioeconomic strata were sampled out. Methods included literature review, street/transect walk, comparative interviews between younger and elder people, area estimation and recording of trees/plants, and change analysis based on periodic maps. Results show that eighty percent of the households don't think of growing trees while building their houses, and five percent have opinion of need for trees around but have no cropping due to lack of space or appropriate species. Out of total, 20 percent have green space with some flowers and vines. Households having more than 200 square meters area have home yards, and have planted 1-2 tree species (i.e., more than 5 meters height in maturity). People are more interested in planting religiously important trees such as sandalwood (Santalum album), Elaeocarpus sphaericus, and wood apple (Aegle marmelos). Frequency of popularly grown religious tree pairs (Ficus benghalensis & Ficus religiosa) that are now old and hazardous, is rapidly declining mainly due to their large size and root effects. The number of urban trees are positively correlated with household land size and not correlated with size of public land. Governmental and municipal authorities should have programs for awareness, seedling subsidy or other incentives, and mandatory provision in designing, building and granting completion certificate of new buildings or houses. Factors like population pressure, high demand of small size land, fragmentation of landscape, lack of housing standards and collective action between neighbors, and people's habit of sun basking are not to be ignored by authorities and forgotten by residents in the future.

L15.P.01

Greening the Green City: Selection of fruit tree species in Kampala, Uganda, in public and private space

Arponen J. (afp237@bangor.ac.uk), Mollee E., McDonald M. A

School of Natural Sciences, Bangor University, Bangor, United Kingdom

Kampala's municipality plans to 'regreen' its city by planting 500,000 trees. If done well, this can help build climate resiliency and contribute to urban food security. This paper aims to create insights into how trees are valued by local communities in public and private space through scoring and ranking exercises. Fieldwork was conducted in Kampala, Uganda in May-June 2017. Data was collected through 35 semi-structured interviews and one focus group discussion. Preliminary results indicate a higher preference for fruit trees in private space (63%) than in public space (45%) (Fig. 1). A higher number of species was mentioned for public space, 35 versus 19. Aesthetic considerations were the main reason for not wanting more fruit trees in public spaces, followed by the concern that eating fruits from public trees is not permitted. Free seedlings, access to training, and the provision of tools, fertiliser and pesticides are effective incentives for residents to plant more trees in their homegardens. Data on rankings of ecosystem services is currently being analysed and will provide more insight into how the different services are valued by the respondents in public and private space. These results can support urban planners and policy makers when considering urban greening as well as urban food security in both the public and private spaces of Kampala. Since most land in Kampala is privately owned engaging with private land owners is crucial in tackling urban deforestation.

Figure 1. Species ranking scores for preferred fruit and non-fruit species in public and private space in Kampala, Uganda, 2017 (note: only species with ranking minimum of 6 were included in the figure).

Keywords: Urban homegardens, Preference ranking, Urban greening, Tree choice, Urban food security.

References:

1. KCCA (2016) https://www.kcca.go.ug/uDocs/Kampala-Climate-Change-Action.pdf
2. López-Marrero & Hermansen-Báez (2011) Participatory Listing, Ranking, and Scoring of Ecosystem Servi
3. Mollee et al. (2017) Land Use Policy 63: 67–77

L15.P.04

Agroforestry multistrata homegardens: Contribution to food security of Amazonian populations

Rayol B.[1] (bprayol@yahoo.com.br), MIranda I.[2], Avino-Rayol F.[3], Rangel-Vasconcelos L.[4]

[1] *Instituto de Ciências Agrárias, Universidade Federal Rural da Amazônia, Belém, PARÁ, Brasil*; [2] *ISARH, Universidade Federal Rural da Amazônia, Belém, PA'', Brasil*; [3] *Insituto Federal do Pará, Belém, PARÁ, Brasil*; [4] *Instituto de Ciências Agrárias, Universidade Federal Rural da Amazônia, Brasil, Pa, Brasil*

Homegardens are traditional land use systems located near homesteads that bring together different species of plants and animals. The diversity of these systems are significantly associated with subsistence, and may involve a range of indigenous agroforestry practices. In addition, the agrobiodiversity of homegardens is considered to be a useful source of plant germplasm and plant domestication. The aim of this study was to describe the urban? agroforestry multistrata homegardens of Central Amazonia and its social importance and contribution to agrobiodiversity. The study was carried out in 89 agroforestry farms located in the urban areas of Belterra, Curuá, Oriximiná, Porto de Moz and Santarém municipalities. The homegardens were selected by the non-probabilistic sampling technique, due to the difficulties of access and permission. In each garden, a floristic survey was carried out and each owner was interviewed for location, history/chronology of what? and management practices. The urban multistrata homegardens of Central Amazonia have an average size of 664 m2. The age of the gardens? ranged from 01 to 84 years, with a mean age of 23 years. Most gardens are managed with family labor (95%) and the exclusively women managed gardens accounted for 42%. The main management practices used in these systems included pruning, selective cleaning (weeding and thinning) and organic fertilization. The sampled gardens are managed with own internal inputs. Only 15% of the owners raised animals for food, mostly poultry(Gallus gallus domesticus). One hundred and forty five plant species were inventoried, belonging to 63 botanical families. The mean richness of plant species was 11 per garden? and ranged from 2 to 37 species. Asteraceae was the most abundant botanical family (nine species), followed by Lamiaceae and Rutaceae with eight species each. Mangifera indica, Theobroma grandiflorum, Citrus sinensis, Cocos nucifera and Psidium guajava were the most frequent species in these gardens, serving both as a source of food for the family and providing cash income from the sale of surplus production. In the gardens evaluated, most of the production was exclusively for domestic consumption (81%). As for the main uses of plants in the homegardens, food accounted for most (76%), followed by medicinal products (16%), ornamentals (6%), timber (1%) and handicrafts? (1%). Tropical agroforestry multistrata homegardens contribute significantly to food security of most families, especially in places where wage opportunities in formal employment are scarce. Their plant richness shows the potential of these systems to contribute to the conservation of agrobiodiversity as well as to provide better quality of life for the Amazonian urban population.

Keywords: Amazonia, Central Amazonia, multistrata homegarden.

ABSTRACTS

Agroforestry adoption

Adopting the future of land use

- L16 -

Agroforestry mapping

Is that a forest? Is that a park?
No, it's an agroforest! Mapping agroforestry

Landscape level mapping of agroforestry systems and related interventions is an important approach for developmental planning at local, regional and national levels, given that the demand for up-to-date geo-spatial information for informed decision making are increasing exponentially. Mapping agencies must respond to these concerns, and must do so with increasing efficiency and effectiveness. Remote sensing, GPS and GIS techniques have been utilized successfully over the years for addressing these concerns. However, new and revolutionary trends are emerging in data capture and analysis. Invariably, Unmanned Aerial Vehicles (UAV) are one of the newest and most innovative tools offering the advantages of utilizing superior reach and dexterity in data collection. This session will expose participants to results on the theories, science, applications, and technology of remote sensing and GIS studies in agroforestry systems. Our aim is to circulate novel/improved methods/ approaches and / or algorithms of landscape level mapping relating to agro-forestry systems and interventions to drive informed decision support systems. In this session, we will focus on the new trends in acquiring geospatial data through UAV and applications; Remote Sensing and its applications in agro-forestry; Land evaluation in terms of agroforestry land suitability mapping; Modeling and Mapping Agroforestry parameters; and creation of a geospatial information systems to inform effective management of agroforestry systems etc. Special focus and attention will be placed on emerging and revolutionised trends in UAV applications and Lidar and Rader Remote Sensing applications in Agroforestry mapping and monitoring.

L16_O.01

Plant diversity and productivity in Senegalese mango orchards: evidences from UAV photogrammetry

Sarron J.[1] (julien.sarron@cirad.fr), Sané C. A. B.[2], Diatta P.[3], Diatta J.[3], Malézieux É.[1], Faye É.[1]

[1] *UPR HortSys, CIRAD, Montpellier, France*; [2] *Université Cheikh Anta Diop, Dakar, Senegal*; [3] *CDH, ISRA, Dakar, Senegal*

Against the background of global population growth, agricultural productivity must be increased for achieving long-term food and nutrition security in West Africa. Contributing to address this issue, mango is a major fruit crop grown under various cropping systems in the region. The aim of this study was to test how orchard plant diversity, configuration, and practices affect mango yields from large commercial-based monospecific orchards to agroforestry systems. In thirty orchards of different mango cropping systems in Senegal, we mapped orchard land uses by UAV photogrammetry and object-based image analysis (14 classes) and quantified plant diversity (Patch richness, Shannon diversity, Simpson evenness index). Then individual mango tree characteristics (height, cultivars, crown area, and volume) were extracted from drone canopy height models and combined with a load index (taking into account year and management effects) to inform predictive yield models. The mapping procedure reached an average overall accuracy of 0.89 for classification of plant species and mango cultivars. Yield models reached satisfying accuracy with R^2 greater than 0.77 when evaluated with actual yield of 60 validation mango trees. Finally, results showed that orchard mango yield is not only driven by planting density and management practices but also by the tree species diversity, highlighting the efficiency of UAVs to inform stakeholders of complex agroforestry landscapes.

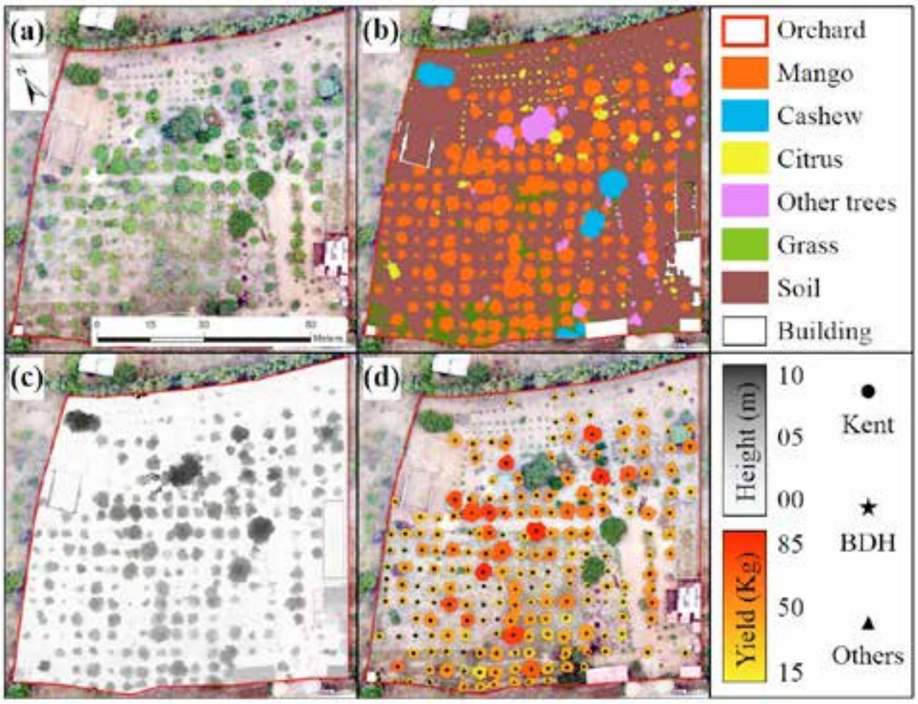


Figure. Mango orchard mapping: (a) UAV-acquired RGB orthomosaic; (b) land use map; (c) Canopy Height Model (in meter); (d) mango cultivar yield map (in kg per tree). UTM coordinates system (zone 28N); Datum WGS84.

Keywords: unmanned aerial vehicle, yield estimation, landscape mapping, GEOBIA.

L16_O.02

Agroforestry map products for the central United States

Meneguzzo D.[1] (dmeneguzzo@fs.fed.us), Kellerman T.[2], Liknes G.[1]

[1] *Forest Service, U.S. Department of Agriculture, Saint Paul, MN, United States*; [2] *National Agroforestry Center, U.S. Department of Agriculture, Lincoln, NE, United States*

Agricultural forests are an important resource in the central United States yet little information describing their extent and location is readily available in formats that are convenient for resource professionals and decision makers. National forest inventory and natural resource monitoring programs seldom account for these non-traditional forests in their official statistics. In addition, most satellite-derived datasets are too coarse to accurately depict small or narrow groupings of trees common in agroforestry systems. Recently, the U.S. Department of Agriculture's (USDA) Strategic Framework included a goal of inventory and monitoring of agroforestry practices. To address this goal, the USDA Forest Service's Forest Inventory and Analysis program and the National Agroforestry Center have developed and implemented a remote sensing-based operational land cover mapping process using 1-meter aerial photography. In a secondary mapping process, tree-covered areas are classified as the most likely agroforestry practice represented, with an emphasis on identifying windbreaks and riparian forest buffers. The resulting high-resolution datasets can be combined with other location-specific information in order to understand relationships between agroforestry systems and soil erodibility, water quality and abundance, habitat suitability, and more. This endeavor is the first of its kind in that datasets are being produced at such fine detail for agricultural landscapes and over such a large portion of the central United States. Maps for Nebraska and Kansas have been completed and additional mapping efforts are currently underway in other areas where agriculture is the dominant land use. The land cover map of Kansas discovered more than 1 million acres of tree cover beyond the national forest inventory estimate of traditional forest land, and the ensuing windbreak map details more than 30,000 miles of windbreaks throughout the state. Descriptions of the mapping methodologies and associated results are presented for multiple states in the central U.S.

L16_O.03

Spatial analysis of area and carbon stock in *Populus deltoides* based agroforestry systems in Punjab state, India

Rizvi R.[1] (rhrizvi@gmail.com), Sridhar K.[2], Rizvi J.[3], Handa A.[4], Dongre G.[5]

[1] *Nrem, Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India*; [2] *Hrd, Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India*; [3] *South Asia Regional Program, World Agroforestry Centre, New Delhi, India*; [4] *Tree Improvement, Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India*; [5] *Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India*

Populus deltoides (Poplar) trees are widely grown on agricultural lands as boundary, block and agrisilviculture systems by farmers in the Indo-gangetic region including Punjab state in India. This species is preferred because of its short rotation and demand of wood for paper, plywood and matchstick industries. These Poplar based agroforestry systems play significant role in sequestration of atmospheric CO2 for a rotation of 6-7 years. In the present study, spatial analysis of *Populus deltoides* based systems for area, biomass and carbon stock has been done in Punjab using field data and remote sensing techniques. Four districts of Punjab state namely Hoshiarpur, Ludhiana, Rupnagar and Shahid Bhagat Singh Nagar were surveyed during Aug. 2018 and data on age, system, spacing, diameter at breast height and GPS points were collected from farmers' fields. Agroforestry plots were also tracked with the help of GPS, which was used for identification and generation of spectral signature for Poplar species.
High resolution LISS IV data (spatial resolution- 5.8m) of selected districts was processed and analyzed for mapping of Poplar based systems and estimation of area. Object oriented image classification technique was applied for identification and mapping of trees on farmlands. For this purpose, Object based image analysis (OBIA) module of ERDAS Imagine software was used (ERDAS 2009).
Stem and aboveground biomass for Poplar trees of different ages were computed using developed biomass equations (Rizvi et al. 2008, Puri et al. 2002). The total biomass was derived by considering 79% of total biomass as aboveground biomass. Carbon stock (CS) was then calculated by formula CS = C x B; where C- carbon content (45.4%) and B – biomass (kg/ tree). In literature carbon content in poplar wood is estimated to 45.4 percent (Negi et al. 2003). Accordingly per tree biomass and carbon was converted into per ha biomass and carbon after multiplying with number of trees per ha.
Results revealed that tree density ranged from 200 to 1905 trees ha-1 in the four districts. Stem and aboveground biomass ranged from 28.36-241.73 t ha-1 and 31.62-286.07 t ha-1, respectively. Estimated carbon stock in stem biomass and total biomass ranged from 5.58-79.80 t ha-1 and 10.93-156.48 t ha-1, respectively. Area under Poplar based systems in Ludhiana, Shahid Bhagat Singh Nagar, Rupnagar and Hoshiarpur districts was estimated to be 3698.7, 534.0, 5465.2, and 10573.1 ha, respectively with more than 85 percent accuracy. Highest area under Poplar based systems was found in Rupnagar district, which is 57.4 percent of total agroforestry area. Study concluded that *Populus deltoides* based systems not only occupy sizeable area in selected districts but also contributing significantly towards carbon sequestration. Object oriented image analysis together with high resolution remote sensing data proved to be better technique for accurate mapping of trees on farmlands.

Keywords: Populus deltoides, Remote sensing, Carbon stock, Mapping, Object based classification.

References:

1. Rizvi RH et al., 2008, Tropical Eclology, 1-8
2. Puri S, 2002, Range Manage Agrofor., 99-104
3. Lehbrass B and Wang JS, 2010, Candian J. Remote Sensing, S287-S297
4. Rizvi et al. 2016, J. Indian Soc. Remote Sens., 657-654

L16_O.04

A remote sensing based approach for optimizing sampling strategies in tree monitoring and agroforestry systems mapping

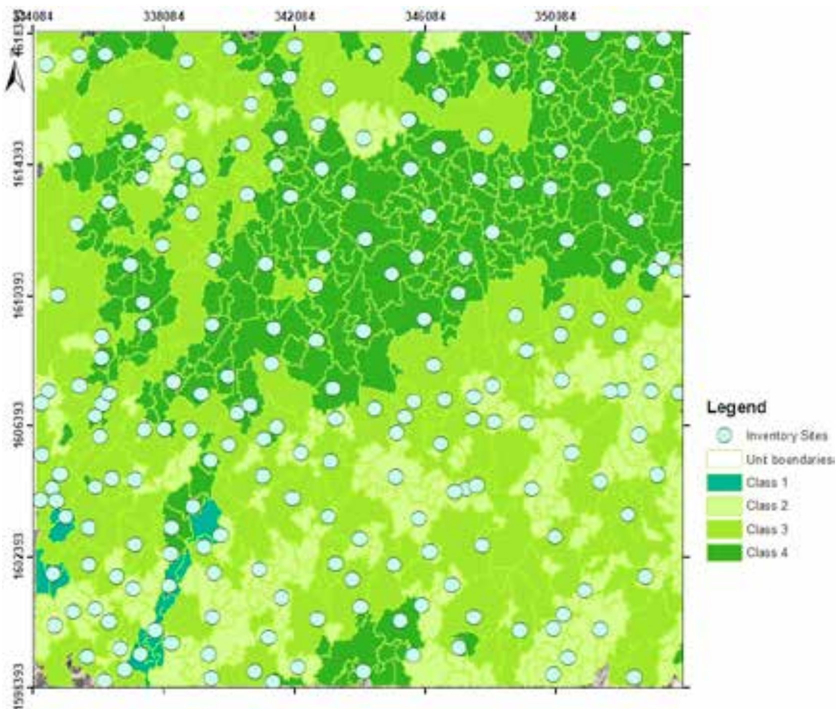
Ndao B.[1] (babacar.ndao@cse.sn), Leroux L.[2], Diouf A. A.[1], Soti V.[2], Sambou B.[3]

[1] *Recherche & Développement, Centre de Suivi Ecologique, Dakar, Senegal*; [2] *UPR AIDA, Cirad, Montpellier, France*; [3] *Institut des Sciences de l'Environnement, Université Cheikh Anta Diop, Dakar, Senegal*

Characterizing agroforestry systems (AFS) at landscape scale is of a great importance for development planning at regional scale in Africa. Therefore, the major constraint to effective AFS mapping with remote sensing is the high diversity within landscapes. To have a robust and representative sample of training data, this study proposes an optimized sampling strategy guided by the AFS functioning and allowing to take into account the landscape diversity. A simple and reproducible approach based on unsupervised classification of remote sensing data and an *a priori* knowledge on the environment functioning is developed. The study is conducted on AFS of the Senegalese Peanut Basin.

Assuming that AFS landscapes with similar trees and crop cover composition will have similar phenological development, a multiresolution segmentation was performed on Sentinel-2 NDVI time series to obtain homogeneous landscape units. Then for each unit, landscape diversity proxies were derived from various geospatial data sources, namely vegetation productivity and its temporal dynamic, actual evapotranspiration, woody cover rates and soil type. Using a hierarchical clustering, four classes of typical unit of the landscape heterogeneity gradient were obtained.

On this basis an optimized sampling plan was produced and used to carry out an inventory campaign of tree biodiversity (figure). The results showed a well-defined landscape diversity gradient, confirmed by the field inventory of tree species.



Landscape heterogeneity gradient divided into four classes and the distribution of tree inventory sites. More than 8000 trees including 41 species have been inventoried covering 213 landscape units distributed accordingly to the weight of each landscape class

Keywords: remote sensing, agroforestry system, sampling strategy, landscape heterogeneity, landscape classification.

L16_O.05

Predicting potential areas across Terai Arc Landscape for the introduction of Poplar based Agroforestry Models

Verma A. K. (amitvermafri@gmail.com), Kaliyathan N. N.

Silviculture and Forest Management, Forest Research Institute, Dehradun, Uttarakhand, India

Terai Arc Landscape (TAL) ecologically important region of the subcontinent is a mosaic of a variety of land use. Increasing population pressure on forests to meet the increasing demand for fuel, fodder, and timber has introduced the concept of multiple uses of land with multipurpose tree species. Agroforestry has drawn the attention of researchers due to its capacity to reduce poverty and land degradation, improve food security and mitigate climate change. In India Poplar is an important Agroforestry species and plays important roles in the livelihood of agriculture-based populations as well as ecological restoration through carbon sequestration. However, the progress in promoting Agroforestry is at a slow pace due to the lack of reliable data sets and appropriate tools and techniques to accurately map the potential areas and to have an adequate decision-making system for Agroforestry models.
The identification of potential areas is important steps to introduce Poplar based Agroforestry models in the region. The present study has been conducted to identify the potential areas for the occurrence of Poplar in Terai Arc Landscape. MaxEnt ecological niche modeling framework was used to predict the potential areas under Poplar across the TAL landscape. A total of 359 GPS coordinates of presence locations was collected from a field survey and the Auto-correlation test was performed using Diva-GIS. A total of 129 independent species occurrence locations was used for model building with 24 predictor variables including climatic, topographical.
The Area under the Receiving Operator Curve (AUC) was used to evaluate models goodness of fit. Model with the highest AUC value was considered as the best performer. A set of ASCII environmental layers and a csv file of presence location of Poplar were used to produce the probability maps that predict the potential distribution of a species. Habitat suitability classes were categorized into high potential (>0.6), good potential (0.4-0.6), moderate potential (0.2-0.4) and least potential (<0.2) (Yang et al., 2013).
The model output shows that the value of Training AUC was 0.9613 and Test AUC was 0.9024 which are close to 1 and the standard deviation was 0.041. It indicates that the model performed better than random. The potential distribution map predicted in this study shows a close resemblance to the ground situation. This research shows the capability of remote sensing in studying Agroforestry practices and in estimating the prominent factors responsible for its optimal productivity. The ongoing Agroforestry projects can be diverted in the areas of high and good suitability potential as an extension. The use of ancillary data from the field survey in the GIS domain can have enormous ability to map the land for the benefit of rural people even up to the village level. Considering the hilly terrain of the Himalayan region, this model can help in identifying high potential areas for future exploration work.

Keywords: Agroforestry, MaxEnt, Poplar, GIS, TAL.

L16_O.06

Fine-scale mapping and dynamics of cyclic agroforestry agriculture using UAV remote sensing in Borneo

Laumonier Y.[1] (yves.laumonier@cirad.fr), Astrono U.[2], Lambrecht F.[2], Narulita S.[2]

[1] *UPR 105 F&S, CIRAD, Montpellier, France*; [2] *CIFOR, Bogor, Indonesia*

The swidden agriculture practice, a cyclic agroforestry system that presents high ecological heterogeneity, still represents the most used farmers' practice in the SE Asian region, experiencing rapid land-use transitions driven by the conversion of biodiversity-rich ecosystems to monoculture plantations. Increased fragmentation creates mosaic of land cover types difficult to map. Challenges persist for evaluating such matrix configuration using satellite remote sensing. The present study explores feasibility, advantage and inconvenience of UAV technology for the acquisition of geospatial data to better understand, fine-scale agroforestry landscape fragmentation, connectivity and the dynamics of the burning and cropping phase.

The study site is a swidden agriculture forest landscape, north of Kapuas Hulu regency in West Kalimantan, Indonesia. The drone system consisted of a customized SkyWalker fixed-wing plane equipped with RGB camera (resolution 7-12 cm). Each flight at 400 m elevation covered around 3000 ha, replicated over 3 years, in the month of October after the burning phase season. Orthophoto mosaics were created using AgiSoft software. Object based image classification (OBIA) was tested with open source software to create a reproducible and automated assessment of landscape, together with an appraisal of the landscape metrics. Ground check and vegetation sampling were performed for each mapped classes.

The results showed that: (1) Up to 25 vegetation classes can be easily interpreted visually, but the low spectral resolution of RGB bands restricted the number of classes used for OBIA; (2) The area of swidden agriculture on forest increased only by 2%; (3) Over 80% of swidden fields were transformed from fern savannahs, the rest mainly taken on young fallows; (4) From 2016 to 2019, the frequency of swidden fields in the district remained constant; (5) The proportion of very short burning cycle (1 to 3 years) was around 50%, revealing that swidden cycles in this particular area were shortened; (6) Overall, connectivity of old fallows and forest patches was maintained.

This particular study represents promising preliminary steps in fully mapping the agroforestry landscape for future monitoring. Local people involvement was critical in mapping their landscape. Integrating ground-based surveys with UAV remote sensing appeared as promising tool essential for achieving cost-efficient wide-scale surveys of agroforestry resources and to monitor changes and long-term sustainability of the system. The ecosystem recovery time following initial slash-and-burn practices may be longer in our study area. Soil impoverishment related to reduction in rotation length may become a serious threat likely to jeopardize the production of goods and services in the long-term. In our study site, the long-term persistence of the swidden agriculture system maybe at stake, if enhanced management of fallows and agroforestry plots (enrichment planting) is not performed.

Keywords: swidden agroforestry, UAV, land use land cover change, communities, Borneo.

L16_O.08

A systematic map of the impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being

Brown S.[1] (saraheb3@illinois.edu), Miller D.[1], Ordonez P.[2], Baylis K.[2]

[1] *Nat. Resources & Env. Sciences, University of Illinois, Urbana, Illinois, United States*; [2] *Agricultural & Consumer Economics, University of Illinois, Urbana, Illinois, United States*

Agroforestry bridges the gap that often separates agriculture and forestry by creating integrated systems that address both environmental and social-economic objectives. Agroforestry research spans many disciplines and addresses a broad range of outcomes, thus creating an opportunity and need to synthesize the evidence for easier exchange of knowledge and ideas. Existing research suggests that integrating trees on farms can reduce environmental degradation, diversify agricultural production, increase carbon sequestration, reduce pollution, control runoff, and enhance soil fertility while providing stable incomes and other benefits to human welfare[1]. Although these claims are becoming more widely accepted as the body of agroforestry research increases, systematic understanding of the evidence supporting them remains lacking. To address this research need, we develop a systematic map of the evidence on the impacts of agroforestry practices and interventions on agricultural productivity, ecosystem services, and human well-being published between 2000-2018[2].
Our map is global in scope, combining the results from parallel efforts to systematically map available evidence in low- and middle-income countries (L&MICs) and in high-income countries. The systematic map allows users to easily navigate and access available evidence, and it provides an intuitive visualization tool that highlights areas that have been relatively well studied together with research gaps. We provide an overview of the systematic mapping process and results, and show heatmaps, charted with agroforestry practices and interventions on one axis and outcomes on the other, reflecting the number of available studies for each intersection. We also map the distribution of studies conducted within each country geographically. Finally, we present descriptive statistics on the growth rate of evidence over time, research and publication trends, study type distribution, top publication sources, and author institutional affiliations. The results from our L&MICs evidence gap map showed that there is a notable lack of impact evaluation work on agroforestry interventions as well as a lack of studies evaluating social and human well-being impacts of agroforestry. Agroforestry research in L&MICs has focused primarily on productivity, biodiversity, and soil health in tree-crop agrisilvicultural systems. These results are compared with our results for high-income countries.
Our dataset will be made available online on an open-access, interactive map server. Users will be able to visualize our results, filter the dataset per our data coding criteria, and automatically interact with the most updated version. The map is intended to serve as a tool for informing policy decisions and developing strategies for future research initiatives, with special relevance in the context of the UN Sustainable Development Goals.

Keywords: Evidence Synthesis, Impact Evaluation, Systematic Map, Agroforestry.

References:

1. Jose, et al., 2012, Agroforestry - The Future of Global Land Use, pp 217-245.
2. Brown, et al., 2018, Environmental Evidence, pp 1-24

L16_O.09

Shelterbelts in Canada: century-old agroforestry systems for climate adaptation

Van Rees K. (ken.vanrees@usask.ca), Amichev B., Ha T., Laroque C.

Soil Science, University of Saskatchewan, Saskatoon, SK, Canada

Shelterbelt agroforestry systems are an integral part of the Canadian landscape. From 1888 to 2014, over 600 million trees were distributed to farmers across the Canadian Prairie Provinces through the Prairie Shelterbelt Program (PSP) of the Government of Canada. While there are records of trees shipped and their destinations, until now, there has not been an accurate inventory of where, and how many, shelterbelts are still growing, or how many are being removed by farmers for various reasons. The Saskatchewan Shelterbelt Inventory was created by locating and identifying shelterbelts visible on digital airphotos (ca .2008) obtained from the Saskatchewan Geospatial Imagery Collaborative. As the shelterbelts were digitized, a number of characteristics were recorded – type, width, species composition, and condition. Recently, a new method was developed to map removal of planted shelterbelts using object-based classification techniques and a combination of 2016 Sentinel MSI and SAR radar satellite imagery. This method was useful in differentiating very narrow shelterbelts from the surrounding bare soil and crops, aiding in the production of land cover maps across a vast agricultural landscape with an accuracy of 80%. A land-cover change detection analysis from these two successive shelterbelt inventories (2008 digitized and 2016 satellite-based) was used to produce a map of planted shelterbelt removal occurring in the period 2008-2016. Carbon stocks of existing and removed shelterbelts in farm yards or crop fields were estimated using the map-derived shelterbelt lengths, approximate shelterbelt age, and estimated species-specific C sequestration rates. The results showed that shelterbelt tree species could sequester from 1.78 to 6.54 Mg C km-1 yr-1, and that soil C storage in shelterbelts was 2 Mg C ha-1 higher than surrounding crop production fields. The current cumulative shelterbelt length across five soil zones in Saskatchewan is 62,832 km (single-row estimate) with majority, 79%, planted in 1-row, 19% in 2-3 row, and 2% in >3-row design. The cumulative carbon stocks in these shelterbelts is 5.79 Tg C (1 Tg = 1 million Mg), 72% sequestered in deciduous, 19% in shrub, and 9% in coniferous shelterbelts. Approximately 4% of all shelterbelts were removed during the 2008-2016 period, equivalent to 2,491 km and 0.19 Tg C removal, the majority of which were planted in 1-row design (97%), 30-50 years-old, and comprised of shrub (56%) or deciduous (41%) species. In light of a future carbon tax implementation across Canada, shelterbelt retention or removal has grown in importance for balancing carbon emissions in the agricultural sectors. A more focused understanding of shelterbelt removals in Saskatchewan can lead to new socio-economic policies aimed at addressing shelterbelt removal, and promoting future shelterbelt planting and retention.

Keywords: shelter belt inventory, carbon stocks, retention, removal, mapping.

L16_O.10

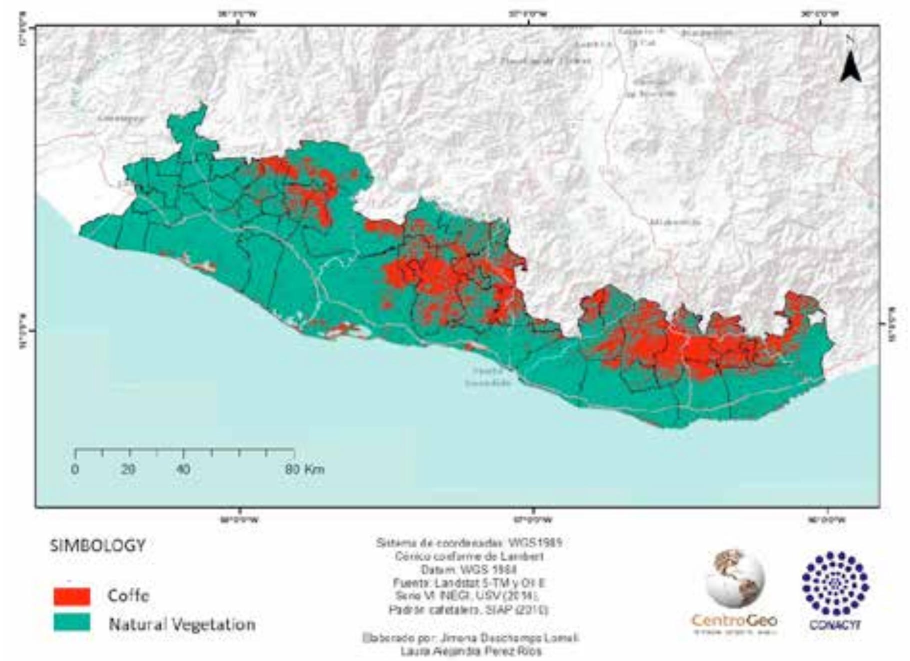
New method to mapping coffee cover plantations in the region of Costa de Oaxaca, Mexico

Deschamps J. (jimedescha@gmail.com)

Socio-ecological studies, CentroGeo A.C., Mexico, Mexico, Mexico

The use of remote sensing (RP) analysis techniques, with a parametric approach on Geographical Information Systems (GIS) and interpretive classification represent an alternative to obtain thematic maps of the distribution of productive systems at different spatial and temporal scales. Oaxaca is the third largest coffee-growing state in Mexico , occupying the coffee-growing zone of the coast of Oaxaca almost half of the state surface of coffee. Despite the practice of coffee management, this can be confused with forest or jungle ecosystems, whether under shade or even without tree cover.

The present study intends to use a new method to differentiate the vegetation cover between zones of coffee plantations and natural vegetation in the coastal region of Oaxaca, Mexico, using a sub-pixel classification method. LANDSAT 5TM and 8 OLI satellite images were used for three time periods, 2011, 2014 and 2017, from which the fraction of photosynthetic vegetation was obtained using CLASLITE v. 3.3. Subsequently, the Random Forest Land Cover classification tool was applied, which allows the generation of a prospective classification model. The fraction of photosynthetic vegetation was higher in the coffee plantations than in the rest of the natural vegetation in the, with an average difference of around 20%. The Overall accuracy was 79.3% and the Kaapa Index 0.56. The method turn to be viable for coffee classification.



Keywords: photosynthetic vegetation.

References:

1. Servicio de información agro-alimentaria y pesquera, 2017, Gobierno de la ciudad de México https://w
2. Bautista- Calderón et al., 2018, Terra Latinoamericana, 261-273
3. Aranda y Beltran, 2017, Grupo Autónomo para la Investigación Ambiental (GAIA), 10-20
4. Escamilla et al, 2006, Manejo integral de plagas agroecologicas, 5-16
5. INEGI, 2010, http://www.inegi.org.mx/

L16.P.01

Carbon mapping in Portugal forest and agroforest systems using direct remote sensing and combine assign approaches

Ameray A.[1] (ameray.iav@gmail.com), Castro M.[1], Bouhaloua M.[2], Castro J.[1]

[1] *Mountain Research Centre (CIMO), Polytechnic Institut of Bragança, Bragança, Portugal*; [2] *Environment and Natural Resources, IAV Institute Hassan II, Rabat, Morocco*

Reducing Emissions from Deforestation and Forest Degradation (REDD and REDD+) recommend specific approaches for quantifying and spatializing ecosystem services (ES). In the context of climate change, REDD recommends the mapping of carbon stocks and its sequestration by vegetation cover to implement more appropriate environmental management practices and policies against global warming. Forest carbon mapping is a current and important environmental tool for a better land management as successful implementation of climate change mitigation (Saatchi et al., 2011). This study presents the mapping of carbon sequestration using two different approaches. Firstly, the direct Remote Sensing (DRS) approach using MODIS images (product MOD17) (Running & Zhao, 2015). Secondly, the indirect approach named Combine and Assign (CA) Approach (Goetz et al., 2009). MODIS images allow the accounting of Net Primary Productivity (NPP) which presents the quantity of carbon absorbed by vegetation cover during a period as a key indicator of ecosystem performance. The CA Approach combines remote sensing and field data in GIS environment to assess the yearly carbon sequestration for each ecozone and the carbon losses by fires in 2010, using the atmospheric flow proposed by Intergovernmental Panel on Climate Change (IPCC). Both CA and DRS mapping approaches show that the forest stands, generally, *Pinus pinaster* and *Eucalyptus* stands, in central and coastal areas have the higher CO2 sequestration potential. However, these two species contribute significantly to CO2 emissions comparing to all other species. The comparison between IPCC methodology and the MODIS product (MOD17) used to follow the carbon dynamic in terrestrial ecosystems has demonstrate that IPCC method can be used as a perfect method to validate MOD17 product.

Keywords: Climate Change, IPCC, Carbon dioxide, Geoprocessing, MODIS.

References:

1. Goetz et al, 2009, Carbon Balance and Management, 7 pp
2. Running & Zhao, M. ,2015, MODIS Land Team, 28pp
3. Saatchi et al, 2011, Proceedings of the National Academy of Sciences, 6pp

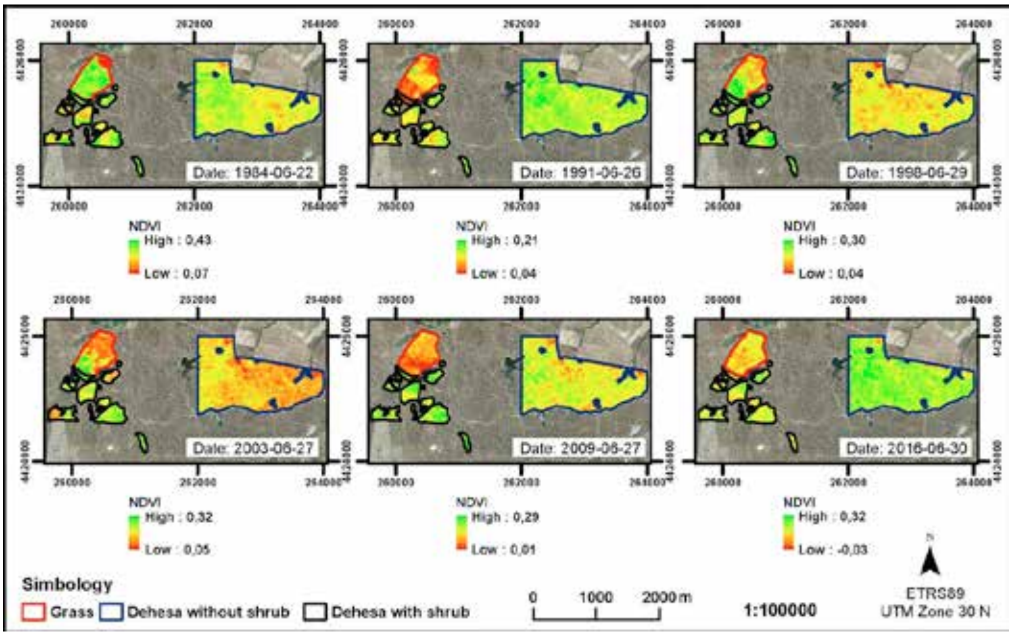
L16.P.02

A large-scale method to assess the role of tree cover in climate change effects in a mediterranean silvopastoral systems

Arenas-Corraliza I.[1] (isabelarenascorraliza@unex.es), Nieto A.[1], Moreno G.[2]

[1] *INTERRA, University of Extremadura, Cáceres, Cáceres, Spain*; [2] *INDEHESA, University of Extremadura, Plasencia, Cáceres, Spain*

The Iberian Dehesa, one of the most widespread silvopastoral systems in Europe (den Herder et al, 2017), have been identified as example of adaptation useful to face the effects of the climate change on Mediterranean grasslands. Although it is known that trees in Mediterranean wood pastures can favor grass growth (López-Carrasco and Gómez, 2009), studies at large spatial and temporal scale are needed since the relationship of competition and facilitation between trees and grass depends on the edaphoclimatic conditions (Rivest et al, 2013). The aim of this study is to evaluate, through the examination of long series of satellite images, the buffering capacity of the trees for the pasture yield variability in Western Spain. This study uses temporal series of Landsat-5 and Landsat-8 data to map different spectral vegetation indices such as Normalized Difference Vegetation Index, Soil-Adjusted Vegetation Index and Enhanced Vegetation Index. The phenology of the grass has been evaluated in dehesas that follow a gradient of structural complexity (tree and shrub cover), which was determined by the combination of Object-Based Image Analysis and Digital Surface Model applied to infrared orthophotographs and LiDAR data. The results show that trees does not reduce grass yield compared to pure grassland areas, but extend the vegetative period and stabilizes the grass yield across years. Using this methodology, we try to determine optimal tree density for different edaphoclimatic regions.



NDVI value in three systems (grass, dehesa without shrub and dehesa with shrub) in six different years.

Keywords: dehesa, canopy cover percentage, spectral vegetation index, Landsat, pasture yield.

References:

1. den Herder et al., 2017, Agric. Ecosyst. Environ, 121-132. DOI: 10.1016/j.agee.2017.03.005
2. López-Carrasco in: La Multifuncionalidad de los pastos: producción ganadera sostenible y gestión de
3. Rivest et al, 2013, Agric. Ecosyst. Environ, 74–79. DOI: 10.1016/j.agee.2012.12.010

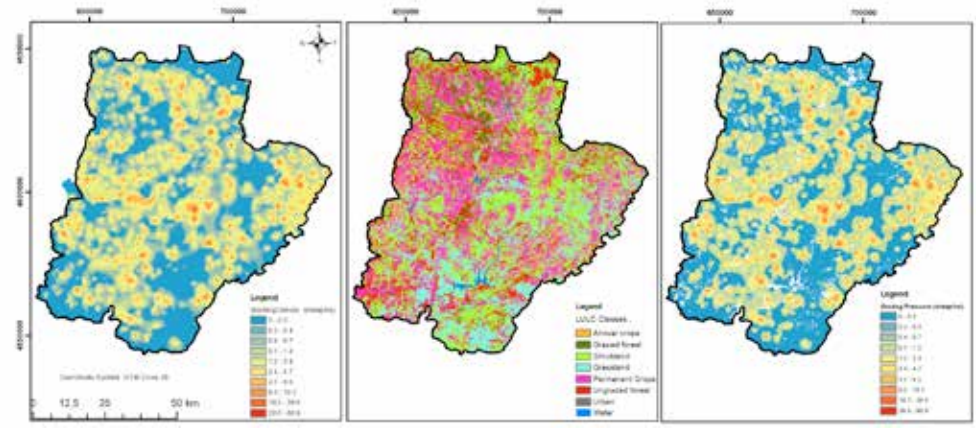
L16.P.03

A new approach to quantify grazing pressure under Mediterranean pastoral systems

Castro M. (marina.castro@ipb.pt), Ameray A., Castro J.

Mountain Research Centre (CIMO), Polytechnic Institut of Bragança, Bragança, Portugal

Pastoral systems based on grazing itineraries, very common along the Mediterranean region, provides an opportunity to search feeding resources at landscape scale under a silvopastoral system called by San Miguel (2004) as "Mosaic of different land uses within one management unit". However daily and seasonal movements of flocks bring on different Grazing Pressure (GP) over the landscape. This study presents an approach to modeling sheep GP under a Mediterranean pastoral system in Northeast of Portugal. The pressure of grazing in a given location depends on Distance from the stable to the border of the parish, Distance to the stable, Stocking Density (SD) (sheep/ha) and preferences for land use and land cover (LULC) (Castro et al., 2004). Geoprocessing integrates several geodatabases, a) land use (COS2015), b) parishes boundaries (DGT, 2017), c) stables location (0108_OTSA_2_E), and d) Sentinel-2 data. SD was performed by Multiple Ring Buffer tool and Ordinary kriging. Homogeneous LULC units (Permanent Crops; Annual crops; Forest; Shrubland; Grassland; Waterland) were obtained by Supervised classification algorithms. The COS2015 was used to establish a mask of the urban area and ungrazed forests. The best performing preferences classifier was Random Forest (kappa=89,3%; global accuracy= 91%). Integrating the LULC grazing and the SD (Weighted Overlay tool) allows to calculate and to map the GP (figure 1). The most common GP in grazing classes is about 4.7 sheep/ha.



Grazing pressure and the LULC classes in Northeast of Portugal

Keywords: LULC classification, silvopastoral system, geoprocessing.

References:

1. SanMiguel-Ayanz A, 2004, International Congress on Silvopastoralism, pp. 36-40
2. 0108_OTSA_2_E: http://esa.ipb.pt/projecto.php?d=1&id=75
3. Castro et al, (2004),venir des systèmes extensifs face aux changements de la société,pp(249–254)
4. Direção-Geral do Território (DGT), 2017, (CAOP2017 e COS2015) http://www.dgterritorio.pt/

L16.P.04

Remote sensing, GIS and GPS: Geospatial techniques for detecting TOF in Italian traditional Agroforestry systems

Chiocchini F. (francesca.chiocchini@cnr.it), Ciolfi M., Sarti M., Lauteri M., Leonardi L., Cherubini M., Paris P.

CNR - IRET, Porano, TR, Italy

Background

Agroforestry, being grounded in traditional land use practices, has developed as an autonomous science to increase productivity and profitability for the farmers, while ensuring the land use sustainability. Agroforestry systems are widespread in many countries, supporting the coexistence of tree, crop and livestock components. Such complex ecological systems offer a wide range of economic, social and environmental benefits, occurring over a range of spatial and temporal scales. The integrated use of GIS, Remote Sensing and GPS technologies is particularly suited for assessing, mapping and quantifying the intrinsic spatial complexity of these systems.

One of the major geospatial issues in Agroforestry is detecting, mapping and estimating the forest component of the systems: scattered trees or linear forest formations located either inside the field or along the field boundaries, also known as Trees Outside Forest (TOF) (FAO 1998, 2001). Data on TOF are scarce and the information available is fragmented at regional and national levels (Schnell et al., 2015). Beckschäfer et al. (2017) give an overview of inventory approaches suitable for the science-based assessment of TOF, specifically on agricultural lands. However, up to now there are no guidelines for TOF inventory in agroforestry systems.

Aims

Traditional tree-based agriculture systems involving different multipurpose trees such as chestnuts (*Castanea* spp.), oaks (*Quercus* spp.), and olive (*Olea europa*), (Eichhorn et al., 2006) are common in Italy and other Mediterranean countries. We investigated the integration of geospatial techniques for TOF inventory in traditional silvoarable systems located in Umbria region (central Italy), where oaks tree hedgerows (THRs) coexist with herbaceous crops.

Methods

We tested a procedure for the GIS inventory of THRs, through the semiautomatic photo interpretation of high-resolution multispectral Sentinel-2 satellite images and NDVI. Results were compared with GPS field measurements of THRs as control points to assess the ground truth. We also compared THRs picked up by remote sensing products with different spatial resolution (Google Digital Globe, Sentinel-2 and Landsat 8) using the same combination of spectral bands.

Results and conclusion

The THRs length detected, corresponding to the 14% of the total perimeter of the cultivated fields, fits accurately with the GPS field survey. The THRs' crowns cover the 3% of the total cultivated area, with an incidence of 67 m of linear tree rows for each hectare of cultivated land. We also observed that the THRs' spatial distribution improves the connection between forested patches in the study area, enhancing landscape connectivity.

Further development is needed in order to include diverse landscape patterns: the high-resolution Sentinel-2 imagery appear especially suitable for the detection of most TOFs at landscape level.

Keywords: NDVI, Sentinel-2, Tree Hedgerow, TOF Inventory, Ecological Connectivity.

References:

1. Beckschäfer P. et al., 2017, In: Dagar J., Tewari V. (eds) Agroforestry , 137-161
2. Eichhorn, M.P. et al., 2006, Agroforest Syst, 67: 29-50
3. FAO, 1998, FRA 2000 – terms and definitions. Forest Resources Assessment Programme
4. FAO, 2001, Global forest resources assessment 2000.
5. Schnell S et al., 2015, Environmental Monitoring and Assessment, 187:600

L16.P.05

Hedgerow networks mapping and monitoring in metropolitan France

Commagnac L.[1] (loic.commagnac@ign.fr), Sinoquet A.[2], Morin-Pinaud S.[2], Benest F.[1]

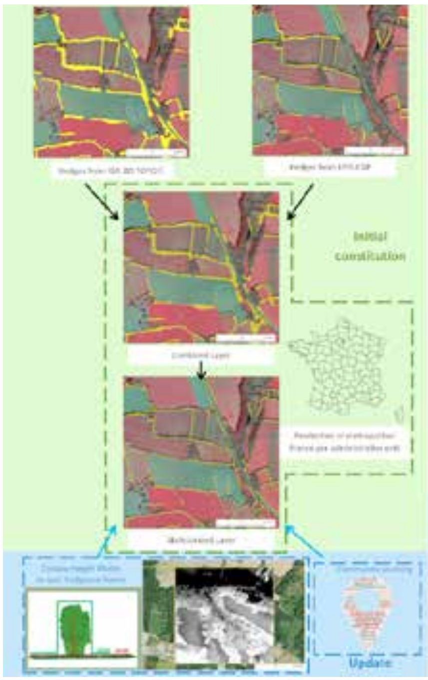
[1] *Forest ecology unit, IGN, Saint-Médard-en-Jalles, France*; [2] *Bocage and wildlife unit, ONCFS, Villiers-en-Bois, France*

"Bocage" is a typical Western European landscape consisting in a network of hedgerows surrounding agricultural parcels. Hedgerows have decreased globally in France since the 1950s, in parallel a decline of agricultural wildlife has been demonstrated by the scientific community. ONCFS and IGN are preparing a national survey program on bocages to evaluate and monitor their quantity and their quality (ecosystem approach). This project is divided into three phases:
- Create a first geographic layer with French hedgerows,
- Edit a new map of bocages in France,
- Define and set up a field monitoring on bocages.

Current phase, phase I, assumes the mapping of French metropolitan hedgerow network, it will be achieved by combining two pre-existent data sets featuring surface hedgerows:
- BD TOPO® from the IGN : VHR aerial imagery with semiautomatic segmentation,
- Data from Land Parcel Identification System (LPIS) of the CAP.

The resulting layer will then be skeletonized. This geographic information layer will be updated using several innovative methods which will be discussed:
- Digital Canopy Height Model (using photogrammetry obtained DSM) to spot hedgerow losses,
- Participatory mapping via a web GIS application,
- Other resources possibly available.

The first project partners are French Ministry for Agriculture and Food and the French Ministry for an Ecological and Solidary Transition. Indeed, the program could help to lead and evaluate both national agroforestry and biodiversity plans.



Principle of hedgerow networks mapping and update in metropolitan France

Keywords: Hedgerows, Mapping, Monitoring, Bocages.

References:

1. UICN, MNHN in partnership with SFEPM and ONCFS, 2017. Press release. Online : https://goo.gl/DGu2NL
2. Burel, F. et al. 1990. Landscape Ecol 4: 197. https://doi.org/10.1007/BF00129828
3. Ewelina et al. 2017. Open Geospatial Data, Software and Standards 2:14. https://doi.org/10.1186/s409

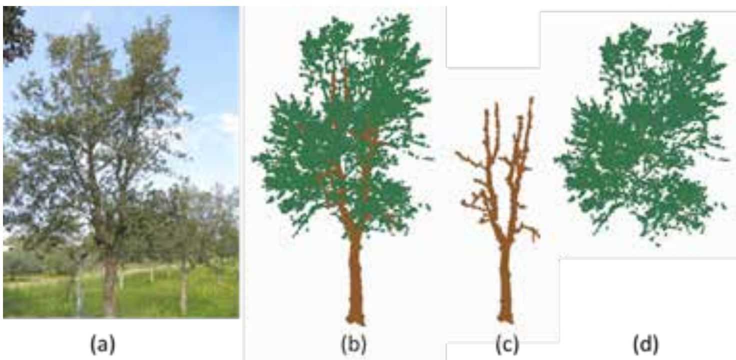
L16.P.06

Application of terrestrial laser scanning to estimate tree attributes in *Quercus suber* L. trees in Sardinia (Italy)

Duce P.[1] (p.duce@ibimet.cnr.it), Arca B.[1], Ferrara R.[1], Ghisu T.[2], Salis M.[1], Ventura A.[1], Pellizzaro G.[1]

[1] *Institute of Biometeorology, National Research Council, Sassari, Italy*; [2] *Mech., Chemistry & Materials Engineering, University of Cagliari, Cagliari, Italy*

Information on forest canopy structure is required at a wide range of spatial scales for several environmental applications.
Recently, ground based Lidar has been used on a sample plot basis to provide local data with high resolution and to capture more detailed information at the individual tree level (Liang et al., 2016). Detailed canopy variable estimations must be accompanied by a reliable and accurate tree reconstruction. The estimation of wood volume and above-ground woody biomass as well as of the tree canopy characteristics often requires separation of leaves and wood.
The main objective of this research was to test the applicability of Terrestrial Laser Scanner (TLS) techniques for canopy characterization of broadleaf evergreen forests and to improve the estimate of crown and woody material volumes in *Quercus suber* trees by developing a method for separating wood points from leaf points.
In this study a simple approach was developed and tested using a TLS data set collected in field by multiple scanning on seven cork oak trees. To handle the large number of points, clouds were partitioned in cubic volumes (voxels) that were used as basic volume elements for processing TLS measurement. A density-based clustering algorithm was used for separating wood/non-wood voxels in the point clouds. Clustering process led to the identification of wood and leaf voxels. Points belonging to each voxel were then classified and quantified as wood and foliage.



Overall accuracy	0.95
Matthews correlation coefficient	0.8
Bias score	1.1
Completeness	0.88
Correctness	0.78
Cohen's K	0.80

Qualitative final segmentation results and relative accuracy values: (a) cork oak tree, (b) whole plant voxels, (c) wood voxels, (d) non-wood voxels.

Keywords: TLS, Lidar, Tree structure, wood-leaves segmentation, tree volume.

References:

1. Liang et al, 2016 ISPRS J Photogramm Remote Sens 115:63-77

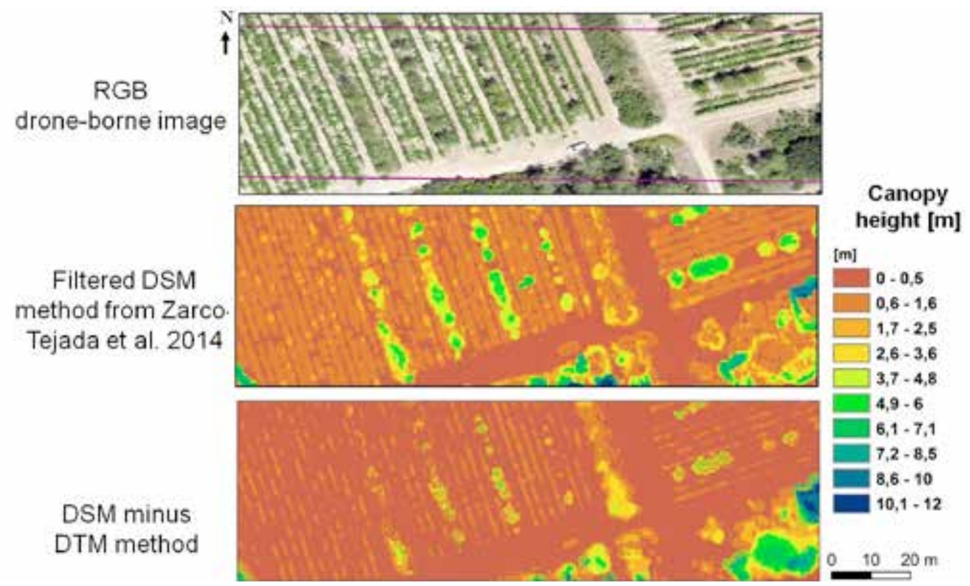
L16.P.07

Mapping the height of heterogeneous vegetation from UAV-borne visible images and DSM

Grimaldi J.[1] (juliette.grimaldi@inra.fr), Helen F.[2], Pelletier C.[3], Bustillo V.[4], Houet T.[5]

[1] *INRA UMR System, Montpellier, France*; [2] *Faculty of Engineering, Airbus, Toulouse, France*; [3] *Faculty of Information Technology, Monash University, Melbourne, Australia*; [4] *CESBIO, Toulouse, France*; [5] *LETG-Rennes Costel -CNRS, Renes, France*

Assessing vegetation structure is essential for studying light distribution and air flow regime within agroforestry plots. Canopy heights and foliage density notably stand as key variables and should be described at both the internal and at the landscape scale of the vegetation. Based on this knowledge, a two-step generic methodology is proposed for describing vegetation structure of agroforestry plots using very high resolution stereoscopic RGB images acquired through UAV flights. It consists first in mapping the land cover and second in mapping the height of vegetation canopy. Both steps were tested using images of three different agroforestry vineyards located in Southern-France. For the first step, using a Random Forest [1] supervised classification approach showed important confusion between grapevine and tree classes unless post-processing masks were applied. For the second step, the 'filtered DSM' method proposed by Zarco-Tejada et al. [2] was compared with a 'DSM minus DTM' approach.
For most of the tree species standing as individual trees at the study sites, this new method showed a higher overall accuracy for estimating their heights based on laser-meter measures of reference. In the particular case of very small leaved canopies, no conclusion could be drawn due to experimental bias. The 'DSM minus DTM' method also revealed several promising methodological advantages: it preserves vegetation borderlines and it allows pixel at pixel applications.



RGB image and top canopy heights of the agroforestry vineyards at Domaine of Restinclières, France

Keywords: UAV, Digital Surface Model, Digital terrain Model, supervised classification, top canopy height.

References:

1. Breiman L (2001) Machine learning 45:5–32
2. Zarco-Tejada PJ, Diaz-Varela R, Angileri V, Loudjani P (2014) European Journal of Agronomy 55:89–99

L16.P.08

Using remote sensing to monitor biodiversity and ecological changes in tropical agroforestry landscapes

Harrison S.[1] (sam.harrison@ed.ac.uk), Ryan C.[1], Harrison R.[2]

[1] *School of Geosciences, University of Edinburgh, Edinburgh, United Kingdom*; [2] *World Agroforestry Centre, Lusaka, Zambia*

Trees on farms will play an increasingly important role in national contributions to meet global objectives like Aichi target 7 and SDG 2 that ensures sustainably managed agriculture for biodiversity conservation. Meeting these targets relies on accurate and timely monitoring of these systems to measure progress and inform decision making. Currently, measuring contributions to these targets is not straightforward, with indicators such as 'area under sustainable agriculture' leaving out the crucial question of what actually constitutes sustainable agricultural. New satellites from the ESA's Copernicus programme and advances in radar remote sensing have proved useful in estimating biophysical parameters across landscapes, but to date there has been limited application in agroforestry systems. This offers a great opportunity to employ these new technologies to enhance our understanding of these agricultural mosaic landscapes. Using a combination of freely available optical and radar imagery and data on trees, birds, pollinators, natural enemies, soil organisms and land health, this research aims to explore the best approaches for monitoring biodiversity and ecological changes in trees on farms with remote sensing. The ICRAF Sentinel landscape network provides an ideal setting for developing these approaches, with a good dataset on biophysical and socioeconomic metrics in rural landscapes across the tropics. This dataset will allow us to develop models that are scalable across the tropics to accurately predict indicators of agricultural sustainability, including farmland's contribution to habitat connectivity, support for forest and farmland dependent species, and land health. These methods will measure biodiversity in trees on farms, but also monitor ongoing changes such as the spread of agroforestry, growth rates and tree harvesting. This research will provide new approaches for monitoring agroforestry to deliver information to land managers and decision makers to take appropriate action towards more sustainable agricultural production.

Keywords: remote sensing, biodiversity, trees on farms, sustainability.

L16.P.09

Detection of wasteland by remote sensing at high spatial resolution

Herblot A. (claire.marais-sicre@cesbio.cnes.fr), Marais Sicre C., Demarez V.

CESBIO, Toulouse, France

Wasteland is defined as an agricultural area with a cultural past (Derioz, 1991), where natural and uncontrolled vegetation have gradually established (MAPAQ). Wastelands, which are islands of biodiversity, have the capacity to support diversified fauna and flora. They allow to maintain ecological continuity and fight against soil erosion. Characterized by three stages of ecological succession (herbaceous, shrubby and tree-lined) these environments may close if they are not maintained which may lead to endemic species disappearance.
Our study site is located in the Pyrénées-Orientales near Perpignan, where the premiums for grubbing-up vines have affected the agricultural economy (Chakir et al., 2006). This region had been severely impacted with 70% of the plots uprooted (Arnal et al., 2013) and wastelands occupied 30% of the agricultural land in 2016 (Association des AFP et GP des Pyrénées-Orientales, 2016). Many problems arise from these wastelands and rehabilitation projects aim to make this land available to agricultural projects and thus meet local food demand. These projects could limit the closure of areas, conserve an agricultural belt, manage these areas and thus limit urban sprawl (UrbaLyon, 2017). In this context, our study aims to detect wastelands using satellite images with high spatial and temporal resolution.
Many studies report the use of multispectral and multi-temporal remote sensing images to map crops, grasslands and even forested areas, but areas with mixed vegetation are still difficult to identify (Genet, 2010 ; Latour, 2017). However, the availability of high spatial (HRS) and temporal resolution satellite images offers new opportunities for detecting these areas.
We implemented a method for mapping wasteland, using a time series of Sentinel-2 images and in situ data for calibration and validation. The methodology is applied in two processing phases. A supervised classification based on a Random Forest algorithm is first used to separate crops, grasslands and woodlands (OA, 0.83; Kappa, 0.87). Then, in a second step, we apply texture parameters on the previously identified pixels as grassland or wooded area, in order to take into account the heterogeneity of the various kinds of wasteland plots.
Taking texture into account allows the detection of different types of wastelands (herbaceous, shrubby and tree-lined) and increases the detection of grasslands. We obtain an F score of 0.80 for herbaceous wastelands and 0.73 for tree-lined wastelands.

Keywords: remote sensing, wasteland, classification, haralick.

References:

1. Arnal, C. et al., 2013, Revue géographique des pays méditerranéens, n° 120, pp 49-58.
2. Chakir, R., & Madignier, A.-C., 2006, Économie rurale, n° 296, pp 59-68.
3. Derioz, P., 1991, Revue de Géographie de Lyon, vol. 66, n°1, pp 47-54.
4. Genet, B., 2010, Mémoire master : Ecole Nationale Supérieur Agronomique de Toulouse, 47p.
5. Latour, F., 2017, Mémoire master : Université lumière Lyon 2, 78p.

L16.P.10

Mapping silvopastoral systems: From plot to farm and regional scale

Iñamagua J. P.[1] (juan.inamagua@abdn.ac.uk), Green D. R[2], Fitton N.[1], Hillier J.[3], Torres J.[4], Sangoluisa P.[4], Merino J.[4], Smith P.[1]

[1] *School of Biological Sciences, University of Aberdeen, Aberdeen, United Kingdom*; [2] *School of Geosciences, University of Aberdeen, Aberdeen, United Kingdom*; [3] *Global Academy of Agriculture and Food S, The Royal School of Veterinary Studies, Edinburgh, United Kingdom*; [4] *Climate-smart livestock project, FAO-Ecuador, Quito, Ecuador*

Silvopastoral systems (SPS) have been recommended as one of the strategies to mitigate the effects that livestock production systems have on the climate through greenhouse gas emissions. To determine the extent and characteristics of SPS, most research has been focused on tree sampling in pasture areas, using circular plots, transects or a combination of both and subsequently these results are extrapolated to farm and regional level. Although these approaches allow to understand the characteristics of the woody component on the SPS, they usually **a)** assume homogeneity of the tree characteristics and abundance from plot to farm and regional level, and **b)** the spatial arrangement of the trees is neglected in the study, which can be considered as key information in order to determine farmer's preferences for tree arrangements. This study aims to fill the gaps identified above by proposing a novel approach that combines field level techniques (plots measurements) with remote sensing information (UAV photographs and satellite imagery). Forty-three farms from the Climate Smart Livestock project executed by FAO, located in the Ecuadorian Amazon region, were used to study SPS. In each farm, two square plots of 1ha were marked in the pasture areas suggested by the farmers as representative of the total pasture area. Inside the square plots, a circular plot of radius=17.84m was installed. Species information, total height (Th), commercial height and two crown diameter (Cd) were measured for each tree with diameter at breast height > 5cm. From May to July 2018, a drone survey was performed on the square plot, using a DJI Mavic Pro. Th and Cd were calculated from the point cloud using the Web Open Drone Map software. Above ground biomass was up-scaled using two different approaches: results from the tree inventory at the plot level followed the following assumptions to upscale the results: *plot ha farm (area reported by farmers as pasture areas) parish (pasture area within a region).* For the information gathered from the drone surveys, the workflow proposed was as follows: *1ha plot percentage of biomass under different tree spatial arrangements farm level (area identified as pastures by the use of satellite imagery) region (pasture area within a region).*

Keywords: silvopastoral, UAV, remote sensing, biomass, Ecuador.

L16.P.11

Survey of olive agroforestry systems in Chalkidiki, northern Greece

Mantzanas K. (konman@for.auth.gr), Papadimitriou M., Sidiropoulou A., Sklavou P., Chouvardas D.

Forestry and Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece

One of the most important evergreen tree species is olive (*Olea europea* L.), found in many regions of Greece. Olive trees are planted mainly to produce table olives and olive oil. The understory could be either natural vegetation grazed by livestock or agricultural cultivation. In the region of Chalkidiki these systems are threatened by abandonment or conversion to intensive monocultures. The aim of the study was to identify olive agroforestry systems in the area and study their characteristics. For this purpose, the European ICT tool of land/use types Corine Land Cover 2012 (CLC – 2012) was used followed by onsite visits (Fig. 1). The following systems were distinguished: a) silvoarable systems with trees in rows intercropped with cereals, b) silvoarable systems with scattered trees intercropped with cereals, and c) silvopastoral systems with scattered trees with natural vegetation and grazing. These systems were mainly found in the land cover type 223 (olive groves) of CLC-2012 in the Kassandra and Sithonia peninsulas. The occupation of local population with tourism contributed to the preservation of agroforestry systems, which could be better exploited in the future by adoption of new CAP agri-environmental measures by farmers.

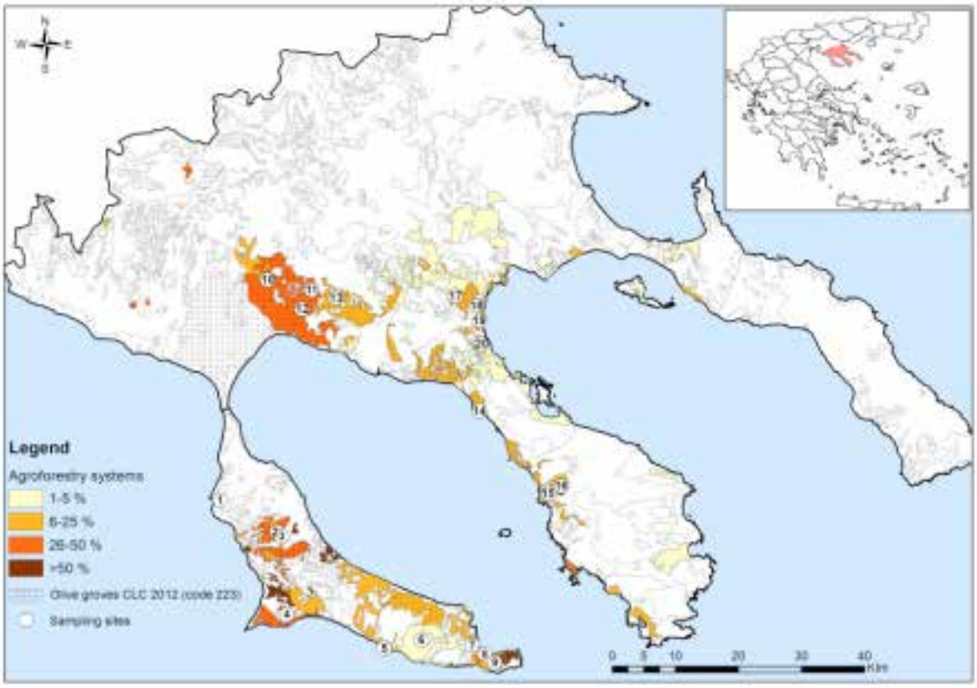


Figure 1: Cover of olive agroforestry systems according to Corine Land Cover 2012 land use types.

Keywords: Corine Land Cover 2012, silvoarable, silvopastoral systems, tree arrangement, understory.

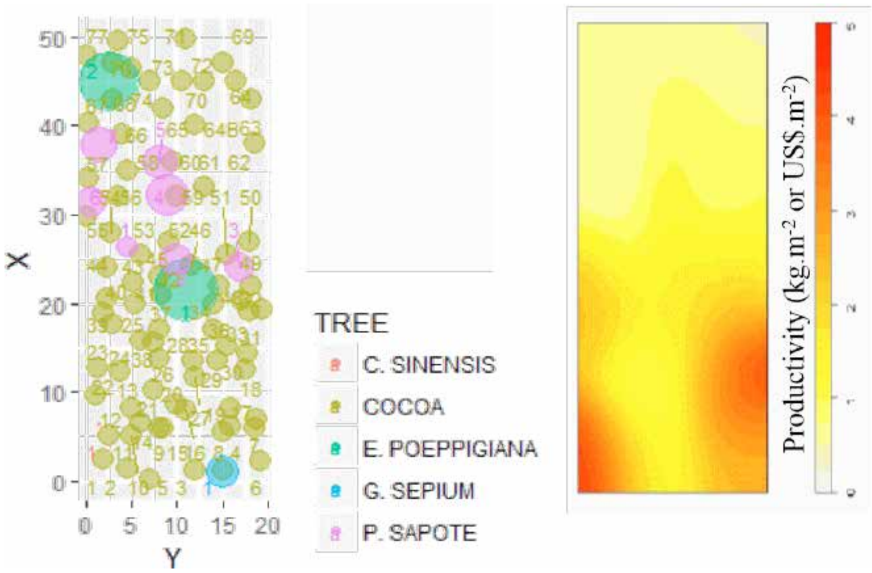
L16.P.12

Mapping plant diversity in cocoa-based agroforestry systems to improve overall productivity

Notaro M.[1] (martin.notaro@cirad.fr), Gary C.[2], Deheuvels O.[3]

[1] *CIRAD, Villa Altagracia, Dominican Republic*; [2] *INRA, Montpellier, France*; [3] *CIRAD, Lima, Peru*

In cocoa-based agroforestry systems (CAFS), the cocoa trees are associated with other cultivated plant species at variable densities. There, the spatial distribution of the cultivated plants can be regular, random or aggregated, and their age may vary even in the same species. Variables of (i) density, (ii) spatial distribution and (iii) age can thus influence the overall productivity of CAFS and its distribution in space. We studied the relationships between these 3 variables and CAFS productivity based on data collected in 34 experimental yield tracking plots placed in agroforestry fields of producers in the Dominican Republic. A mapping of the cultivated plants was carried out on each plot at their installation and harvests of the ripe products of each individual plant were carried out every two weeks over a period of one year. The first results of this study indicate that optimal CAFS productivity can be maintained along a decreasing density gradient of crops, associated with cocoa tree ageing. In addition, regular and random spatial distribution of all plant species may increase overall productivity. The analysis of the variability of cocoa, fruit, tuber and timber yields allows us to provide recommendations on the most suitable species and the optimal distance between plants to improve overall productivity and therefore the producer's income.



On the left, example of a schematic map of a 1000m² plot showing the position of each tree.
On the right, the illustration shows the productivity (agronomic or economic) and its distribution in the experimental set-up.

Keywords: Cocoa-based agroforestry systems, Planting density, Spatial distribution, Age, Productivity.

L16.P.13

When policy requires technical innovation: considerations about mapping Agroforestry Concessions in the Peruvian Amazon

Reyes M. (martin.reyes@cgiar.org)

ICRAF, Lima, Peru

The Agroforestry Concessions mechanism in Peru´s Forest Law seeks to formalize tenure of smallholder farms that illegally encroached State forest land. This 40-years lease is conditional to the engagement in conservation of on-farm tree cover and adoption of agroforestry systems through the signing of a contract. Circa 1.2M ha of mosaic forest landscapes of more than 120,000 smallholder farms in the Peruvian Amazon might be of interest of this mechanism with major positive impact on deforestation reduction and restoration of ecosystem services on agricultural land. Strategic to the identification of the interventions to be promoted and of the monitoring of compliance in the long term and at a large scale, is the capacity to map agroforestry and monitor fine-grained land-use changes typical of heterogeneous smallholder land-use mosaics. That requires to address issues related to the recognition of agroforestry mosaics including their intrinsic temporal sequences (i.e fallow rotations) at an adequate spatial and temporal scale, and accuracy level.

This study assesses different mapping approaches and techniques; and provides conceptual and technical recommendations to address key challenges in the mapping and large-scale monitoring of agroforestry concessions. A literature review of different experiences in mapping tropical land-use mosaics such as Unmanned Aerial Vehicle (UAV) technology, remote sensing and mixed mapping systems together with farm registry and cadaster systems constitutes the basis for a discussion with users, including land administration officers and remote sensing/GIS experts. This will consider implications regarding feasibility and costs for large-scale implementation of agroforestry concessions. We evaluate trade-offs between approaches and identify mixed methods to compliment remote sensing classification with UAV-based validation and expert knowledge.

To properly capture local agroforestry practices, a classification system that takes into account differences in spatial arrangements, vertical structure and temporal sequences of land-use mosaics components is needed. Depending of the sensor used, satellite imagery may not provide enough detail to differentiate the mosaic through remote sensing techniques, leading to misclassification errors. To overcome spatial resolution issues, UAV technology has proven to have optimal potential for fine-grained mapping as it provides enough detail to distinguish land-uses at the farm level. However, the large-scale adoption of such technology in terms of costs and logistics, might be prohibitive for local authorities to adopt it and for repeating monitoring activities.

This study brings elements to support decision-making in order to appropriately map agroforestry mosaics, and therefore, support the future implementation and facilitation of high-impact policies.

Keywords: mapping, approaches, agroforestry, concessions, smallholder.

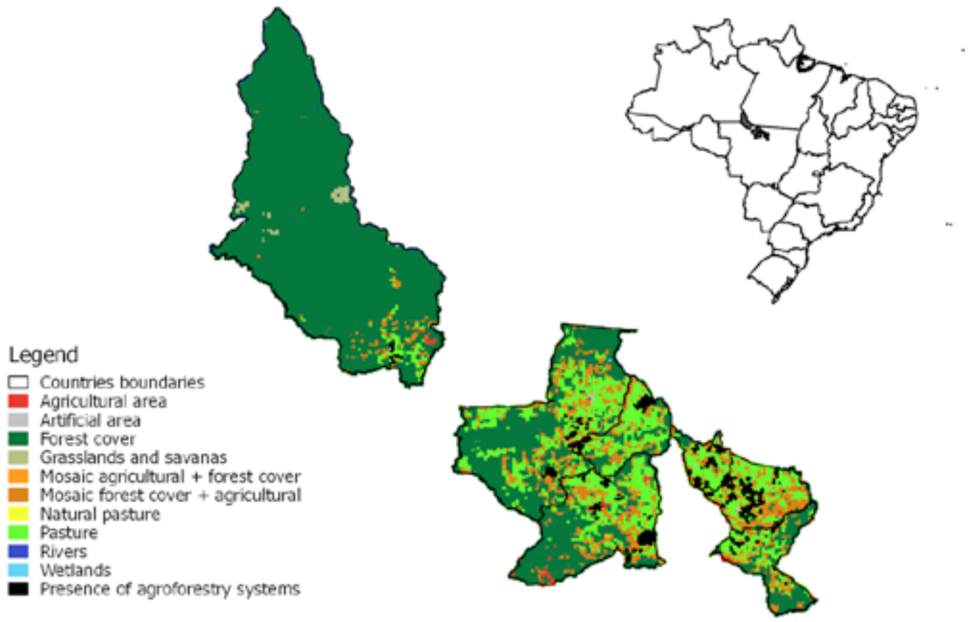
L16.P.14

Mapping agroforestry systems for landscape planning in Amazonia (Mato Grosso, Brazil): from local to regional scales

Sais A.[1] (adrianacs@ufscar.br), Oliveira R.[1], de Paula R.[2], Fernandes E.[3], Olival A.[4]

[1] *Rural Development, Universidade Federal de São Carlos, Araras, SP, Brazil*; [2] *PPGADR, Universidade Federal de São Carlos, Araras, SP, Brazil*; [3] *Agroecology Graduate Course, Universidade Federal de São Carlos, Araras, SP, Brazil*; [4] *Campus Alta Floresta, Universidade do Estado do Mato Grosso, Alta Floresta, MT, Brazil*

Mapping of agroforestry systems (AFS) is an important approach for landscape analysis and planning at different scales. As these systems are interesting tools for forest landscape restoration, improving resilience and sustainability in rural areas, the NGO Ouro Verde Institute has encouraged their adoption in “Portal da Amazonia” Territory (MT, Brazil), with BNDES (National Development Bank)/Amazonia Fund support. We have mapped AFS implemented from 2010 to 2017 in 751 properties, organizing their location and size in a geographic information system, which was overlaid with official data provided by the Brazilian Institute of Geography and Statistics (IBGE), in maps with the predominant land use in cells of 1 km² (100 ha). Using the most recent available data, dated 2014, we have detected the presence and absence of AFS in these cells. Our results show that in an area of 44.759 km2 there was decrease of forest cover (8,93%) and increase of pasture (7,47%) and agriculture (1,46%). Deforestation summed 3.998 km² in fourteen years. Although they are still incipient as land use systems (AFS are 1.7% of the total area), 759 of the 44,759 cells have at least one AFS. There are 2,284 AFS, with a total area of 9.16 km² and wide distribution in the landscape. This methodology can support planning and monitoring of new areas in multiple scales, aiming forest restoration and more sustainable agricultural production as it associates official data with practical implementation of AFS.



Predominant land use and spatial distribution of cells (1 km²) with AFS

Keywords: Deforestation, Mapping methods, Landscape analysis, Multiple scales, Amazonia.

L16.P.15

Tree biomass estimation by SfM method in highlands of Northern Ethiopia

Sakai T.[1] (torus@affrc.go.jp), Takenaka K.[2], Abebe B.[3], Gebre-Meskel D.[3]

[1] *Social Sciences Division, JIRCAS, Tsukuba, Japan*; [2] *Rural Development Division, JIRCAS, Tsukuba, Japan*; [3] *College of Dryland Agriculture & Nature, Mekelle University, Mekelle, Ethiopia*

In Ethiopia, forested areas are decreasing because of increases in cultivation and grazing pressure by livestock. In addition, the illegal logging for firewood also contributes to the forest degradation. However, the combination of agriculture and forestry benefits for increase in biodiversity and decrease in erosion. Therefore, sustainable use of the land should be considered in trees, crop and livestock. From a viewpoint of agroforestry, it is important to map forest areas and quantify tree biomass. Satellite remote sensing is powerful tool for large scale mapping of forests. However, trees with canopy size of a few meters are sparsely distributed in highlands of Northern Ethiopia. It is not easy to detect single trees and estimate tree biomass even by using high spatial resolution satellite images. The objective of this study is to establish a method to estimate trees biomass by structure from motion (SfM) method. Pseudo aerial photographs were taken from a 3-m tripod to estimate and the 3D structure of tree was built (Figure 1). There were good correlations between measured and estimated plant parameters, such as tree height and canopy area. The R^2 values for tree height and canopy area were 0.82 and 0.93, respectively. Tree biomass was estimated by using an allometry equation with tree height and canopy area as parameters. Tree biomass was approximately 4.5 ton ha^{-1}. The SfM method would be useful for biomass management.

Figure 1. 3D structure of Acacia etbaica Schweinf. by SfM method.

Keywords: 3D model, Canopy structure, Forest management, GIS, SfM.

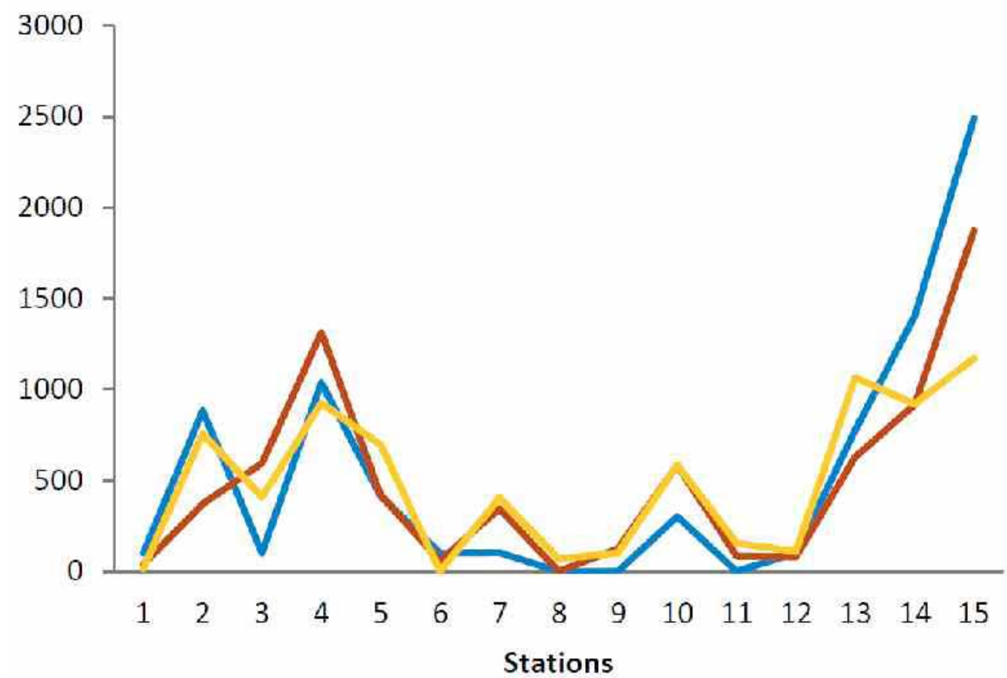
L16.P.16

Comparing methods for detecting and mapping tree parkland dynamics on large areas in Burkina Faso

Serpantié G.[1] (georges.serpantie@ird.fr), Girres J.-F.[2], Coupin T.[1], Abidi I.[3], Ali Mahad M.[3], Sawadogo W. E.[3]

[1] *UMR GRED, IRD, Montpellier, France*; [2] *UMR GRED, Université Paul Valery Montpellier, Montellier, France*; [3] *Master Géomatique de Montpellier, Université Paul Valery Montpellier, Montpellier, France*

Parklands are a widespread agroforestry practice in West Africa, subject to the risk of aging and threatened by increasing mechanized agricultural practices. Their diagnosis is based on a landscape analysis and a systematic quantitative characterization over large areas. It involves identifying the description variables of parklands at different scales, and comparing results by taking into account the associated uncertainty. The pilot approach of characterization of a sudanian park is carried out at a local scale (village of Lofing, Commune Dano, Province Ioba, Burkina Faso) by comparing 4 methods: field transect, photo-interpretation of archive and on-line imagery, and satellite image processing. The dry season inventory by transect carried out by trained local people provides basic information and serves as ground truth. The photo-interpretation of archive aerial images is limited by their resolution, but remains irreplaceable in terms of temporal depth. The photo-interpretation of online images from Google Earth or Bing Maps allows to estimate the number of tree elements and to identify certain recognizable species to study issues related to aging and elimination over a few years. Finally, Sentinel 2 image processing is used to assess the park's covering ratio with an acceptable uncertainty for the characterization of spatial variations of park density (fig 1).



Comparison of tree crown area (in sq. m.) on 15 stations (defined by circles of 50 m. radius) by remote sensing (blue), photo-interpretation (orange) and field survey (red).

Keywords: mapping, parkland, remote sensing, degradation, Burkina Faso.

ABSTRACTS

Specific agroforestry systems

Let's drill down: the amazing varieties of agroforestry

- L17 -

Challenges, opportunities and trade-offs of agroforestry with perennial crops

Coffee, cocoa, rubber, vineyards and orchards: perennial crops the agroforestry way

The benefits of adopting agroforestry practices have been widely promoted for perennial crops, particularly tropical ones with respect to sustainability, income diversification and climate change. However, they are not universal and dependent on local ecological conditions (i.e. climate, soil), companion tree species, and institutional and socio-economic context. Therefore, this session welcomes presentations (oral and poster) documenting challenges, opportunities and trade-offs of temperature and tropical agroforestry systems (AFS) with perennial crops, particularly dealing with the following issues :

- ecological intensification in perennial AFS,
- reforestation and deforestation linked to expansion and intensification of tree crops,
- trade-offs between production and delivery of ecosystem services (soil fertility, biodiversity conservation, carbon sequestration, pests and diseases control, buffering of climate extremes),
- climate-smart practices for adaptation of perennial AFS to climate change
- eco-certification, value chains and perennial AFS,
- cost/benefit analysis and revenue diversification of perennial AFS,
- local agroforestry knowledge and co-innovation,
- timber production in tree crop based agroforestry systems: productivity, risk and vulnerability management, enabling frameworks (legal, political, financial, cultural).

L17.1_O.01

The research and policy pathway to climate-smart cocoa and REDD+ in Ghana

Asare R. (rebeccaashleyasare@yahoo.com), Mason J.

Nature Conservation Research Centre, Accra, Ghana

Research has played a crucial part in the development of climate-smart cocoa (CSC) in Ghana, and in supporting the design and implementation of REDD+. However, we argue that research alone is unlikely to have significant impacts on any sector unless it is purposely linked into an intentional decision process focused on the development of policies and practices. This paper tells the story of how research has played a major role in shaping CSC in Ghana and the pathway that was followed to where it is firmly embedded in policy, in private sector investment, and in practice.

Ghana's cocoa production landscape (5.9 million ha) has one of the highest deforestation rates in Africa, at 3.2% per annum and being driven by cocoa expansion, other agriculture, and extractive industries. Efforts to address this situation date back to 2005, when local and international researchers launched a study to to measure the impacts of cocoa intensification on yields, biodiversity and ecosystem services in a cocoa landscape in Ghana. The results were clear and worrying. As management intensity increased, biodiversity and ecosystem services decreased. The results also showed some interesting outliers; farms that had maintained high shade, high carbon stocks and still had high yields—the first indication that there does not have to be an extreme trade-off between increasing yields and maintaining shade to support biodiversity and carbon storage[1].

Though Ghana was one of Africa's leaders on REDD+, neither the Cocoa Board nor the Forestry Commission was speaking to each other and there was no interest to explore the research implications. In 2011, the Nature Conservation Research Centre, established a CSC working group to reach consensus on the cocoa sector's business-as-usual (BAU) trajectory, and if unsustainable to envision a future "desired state" and set a critical pathway to achieve that state.

This paper tells the story of how research played a crucial role in informing the BAU assessment and designing the pathway to a sustainable, CSC system. It outlines how intentional actions were taken to create understanding and commitment between the Cocoa Board and the Forestry Commission. It highlights how the two agencies came to realize the opportunity of climate finance and the potential to create a CSC emission reductions (ER) program. It outlines how research directly informed the concept of CSC. It shows how Ghana entered the World Bank Carbon Fund pipeline in 2014 and moved to sign a performance-based ER contract in 2019, while also receiving significant private sector investment thru the industry's Cocoa & Forest Initiative to support implementation of a no-deforestation supply chain. In summary, this case study shows the potential for astounding impact if research and results are firmly rooted in the real-life dialogues and pathways that actually influence policy and practice at scales.

Keywords: cocoa, climate smart agriculture, carbon, REDD+, policy.

References:

1. Wade et al., 2010, Agriculture, Ecosystems and Environment, 138:324-334.

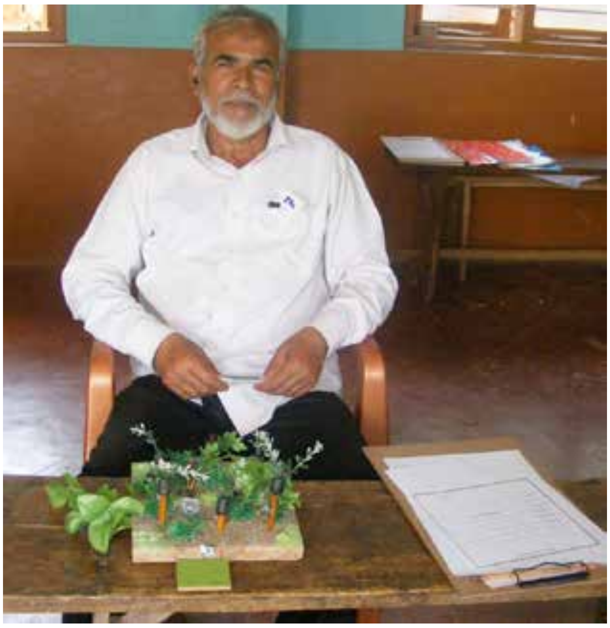
L17.1_O.02

Understanding coffee farmers: using games to explore future coffee agroforestry landscapes in the Western Ghats (India)

Garcia C. A.[1] (claude.garcia@usys.ethz.ch), Vende J.[2], Nanaya K.[3], Nay M.[4], Kalla J.[5], Dray A.[6], Delay M.[6], Waeber P.[6], Stoudmann N.[6], Bose A.[6], Le Page C.[7], Raghuramulu Y.[8], Bagchi R.[9], Ghazoul J.[10], Kushalappa C.[3], Vaast P.[11]

[1] *ForDev, CIRAD / ETHZ, Zurich, Zürich, Switzerland*; [2] *AgroParisTech, Montpellier, France*; [3] *Ponnampet College of Forestry, UHAS Shimoga, Shimoga, India*; [4] *USYS, ETH Zurich, Zurich, Switzerland*; [5] *French Institute of Pondicherry, Pondicherry, India*; [6] *ForDev, ETH Zurich, Zurich, Switzerland*; [7] *ES, CIRAD, Montpellier, France*; [8] *Central Coffee Board, Bangalore, India*; [9] *Ecology and Evolutionary Biology, University of Connecticut, Stors, United States*; [10] *Ecosystem Management, ETH Zurich, Zurich, Switzerland*; [11] *Persyst, CIRAD, Montpellier, France*

Deforestation and biodiversity loss in agroecosystems are the result of rational choices, not of a lack of awareness. Despite both scientific evidence and traditional knowledge that supports the value of diverse production systems for ecosystem services and resilience, a trend of intensification is apparent across tropical regions. These transitions happen in spite of policies that prohibit such transformations.
We present a participatory modelling study run (1) to understand the drivers of landscape transition and (2) to explore the livelihood and environmental impacts of tenure changes in the coffee agroforestry systems of Kodagu (India). The components of the system, actors and resources, and their interactions were defined with stakeholders, following the companion modelling (ComMod) approach. The underlying processes driving the system were validated through expert knowledge and scientific literature. The conceptual model was transformed into a Role Playing Game and validated by 8 workshops with 57 participants. Two scenarios were explored, a No Policy Change as baseline, and a Restitution of Rights where rights to cut the native trees are handed over to farmers. Our results suggest the landscape transition is likely to continue unabated unless there is a change to the current policy framework. However, the Restitution of tree Rights risks speeding up the process rather than reversing it, as slow variables such the differential growth rates between species kick in.



A coffee planter from Kodagu presents his coffee estate after one morning of play.

Keywords: Companion modelling, shade-grown coffee, tree rights, games.

References:

1. Garcia, C.A. et al., 2018. AgriXiv. https://doi.org/10.31220/osf.io/9374a

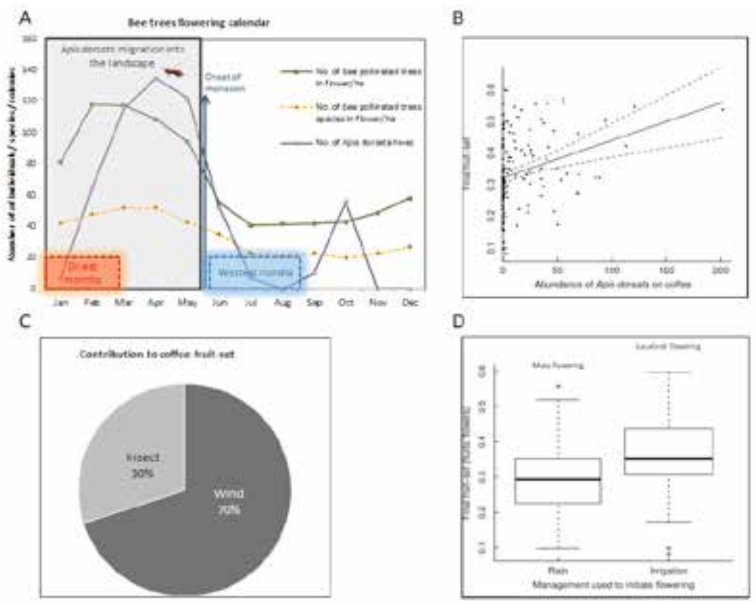
L17.1_O.03

Ecological and agricultural intensification and the associated trade-offs on coffee pollination and fruit-set

Krishnan S.[1] (smithakrishnan@gmail.com), Cheppudira K.[2], Ghazoul J.[3]

[1] *Insect Lab, ATREE, Bangalore, Karnataka, India*; [2] *Forestry and Environment Science, College of Forestry, UAHS, Ponnampet, Kodagu, Karnataka, India*; [3] *Environmental Systems Science, ETH Zurich, Zurich, Switzerland*

We explore the role of forest fragments and the trade-offs of ecological and agricultural intensification on coffee pollination and fruit-set in a landscape with a high density of remnant forests dispersed within a paddy and coffee-agroforestry matrix.
Pollination by insects improved pollination success and enhanced fruit-set by 50% in *Coffea canephora*. Social bees accounted for 95% of all visitors and *Apis dorsata* (AD), the forest nesting wild migratory bee was the main visitor. AD migrate into coffee landscape to benefit from the forage provided by shade trees. Coffee flowering overlaps with that of shade trees and thus benefits from the pollination services of AD.
Flowering in coffee is initiated annually by either irrigation or rain. With intensification and change in rainfall patterns in recent years, many farmers have resorted to irrigation to initiate flowering. Irrigation which, stimulated flowering of individual agro-forests, resulted in a dramatic increase in pollinator visits and fruit-set as opposed to fewer pollinator visits and low fruit-set when coffee mass-flowered following rain. Size of the adjoining forest and availability of alternative floral resources influenced pollinator visitation and pollination success, and the extent of coffee flowering within the landscape determined the direction of the effects. This study demonstrates the implications of ecological and agricultural intensification and the associated trade-offs on coffee pollination and fruit-set.



A. Flowering calendar of bee pollinated shade trees and abundance of Apis dorsata colonies. B. Influence of Apis dorsata visits on coffee fruit-set. C. Contribution of bees and wind to coffee fruit-set. D. Effect of mass and localized flowering on coffee fruit-set.

Keywords: Alternative floral resources, Apis dorsata, Coffea canephora, Fruit-set, Pollination.

References:

1. Krishnan, in: Agroforestry: Anecdotal to Modern Science. 2018. Dagar and Tewari: 771-795
2. Boreux et al. 2013. Agriculture Ecosystems & Envt: 42-48. https://doi.org/10.1016/j.agee.2012.05.003
3. Krishnan et al. 2012. Basic and Applied Ecology: 277-285. https://doi.org/10.1016/j.baae.2012.03.007
4. Krishnan et al. 2012. Indian Coffee: 10-12.

L17.1_O.04

Agroforestry: Lifeline of world cocoa production. Utopia or credible alternative?

Jagoret P.[1] (patrick.jagoret@cirad.fr), Malézieux E.[2], Lauri P.-E.[3], Saj S.[1]

[1] *UMR System, Cirad, Montpellier, France*; [2] *UR HortSys, Cirad, Montpellier, France*; [3] *UMR System, Inra, Montpellier, France*

A large part of the world cocoa production is provided by multifunctional agroforestry systems (AFS). Despite their ability to provide a large range of ecosystem services (ES), eg. biodiversity, carbon sequestration, crop production, these systems were however long considered inefficient in terms of cocoa yield and, thus, neglected by agronomists. Our studies are carried out in Cameroon on farmers' cocoa plantations. They are based on 100-year chronosequences and/or a large array of situations, ranging from simple systems to very complex ones. We show that cocoa AFS can reach yields of over 1000 kg ha-1 of marketable cocoa which is in many cases comparable or even better than yields of conventional systems. We found that very long-term sustainability of cocoa AFS could be achieved if the basal area (BA) share of the cacao stand does not exceed 40% of the total BA of the cocoa AFS. Moreover, farmer's management of the different species associated with cocoa trees provides not only continuous cocoa production on the very long-term but also permits interesting combinations of valued products and/or ES. For instance, the combination of expert knowledge and Pareto front algorithms enabled us to shed light on some of the tradeoffs occurring in these systems and to identify clusters of increasing ES provision. Significant differences in associated tree communities and management strategies were identified across these clusters. Furthermore, by combining field observations and historical survey data, we reconstructed the impacts of changes over time on management practices, agroforestry structures and cocoa yields. The long-term trajectories we identified explain the current agroforests structures, with low or high cocoa tree densities, mean basal area per cocoa tree (from 29.4 cm2 to 92.7 cm2), and finally cocoa yields which varied from 542 to 1275kg ha−1. We show that farmer's management of cocoa AFS allows a system balance that can be temporarily broken or redesigned, suggesting the resilient and flexible nature of these complex cocoa agroforests. Despite such results and the increasing recognition of their multifunctionality, cocoa AFS were recently questioned about their putative unsuitability to climate change adaptation. This question appears legitimate and we support that, when necessary, adaptation to climate change in cocoa AFS shall be overcomed by choosing adequate associated species and planting densities. Yet, in order to prevent the possible misuse of this ongoing discussion within the cocoa supply chain, we urge the scientific community to support and keep demonstrating that complex cocoa AFS are valuable, ecofriendly and climate-smart systems. Finally, we argue that these systems should be used to promote the building and establishment of cocoa cropping models that fully include associated flora diversity in order to provide the farmers, the cocoa supply chain and the consumers with sustainable revenue, goods and services.

References:

1. Andreotti et al., 2018. Ecological Indicators, 94: 257–265, doi.org/10.1016/j.ecolind.2018.06.048
2. Jagoret et al., 2018. European Journal of Agronomy, 101: 183–192, doi.org/10.1016/j.eja.2018.09.007
3. Jagoret et al., 2017, Agronomy for sustainable Development, 37: 60, doi.org/10.1007/s13593-017-0468-
4. Saj et al., 2017. Agricultural Systems, 156: 95-104, doi.org/10.1016/j.agsy.2017.06.002

L17.1_O.05

Accounting for biogenic carbon sequestration in product carbon footprints: analysing trade-offs in a coffee agroforestry

Birkenberg A. (a.birkenberg@uni-hohenheim.de), Kumeh E. M.

University of Hohenheim, Stuttgart, Germany

Product carbon footprints are increasingly used to determine and reduce greenhouse gas (GHG) emissions from the agri-food sector and to produce carbon neutral agro-commodities. However, contrary to what is often assumed and desired by consumers, biogenic carbon sequestration in perennial systems, e.g. agroforestry systems, is not accounted for in product carbon footprints, e.g. of shaded coffee (Brandão *et al.*, 2013; Plassmann and Norton, 2017). The lack of a precise and harmonized method to undertake the accounting is not compatible with life-cycle assessment principles (Bessou *et al.*, 2013). Notwithstanding, there are valuable reasons why biogenic carbon accounting is worth considering. Accounting for biogenic carbon sequestration in product carbon footprints could reduce offsetting costs, and enable small-scale farmers to participate in carbon neutral value chains too (Birkenberg and Birner, 2018). Further, it could incentivize the integration of shade trees into production systems, which would result in positive environmental effects (Kumar and Nair, 2011). However, before promoting biogenic carbon accounting in product carbon footprints it is of fundamental importance to understand potential risks and trade-offs. This study addresses the knowledge gap regarding trade-offs between farm gross margins and carbon sequestration footprints based on a case study from shaded coffee farms in the highlands of Costa Rica.

Based on a carbon inventory, a biogenic carbon accounting model was used to estimate the development of carbon sequestration footprints in selected coffee farms over a 20-year period. Farmers production costs and revenues were obtained through household surveys of 190 coffee farmers in the study area. A regression model is used to identify the relationship between carbon sequestration footprints and farm gross margins. Furthermore, a sensitivity analysis is used to identify the magnitude of influence of the different variables, i.e. GHG emission ha-1, carbon sequestration ha-1 and yield or gross margins ha-1.

The preliminary results suggest that carbon sequestration footprints of shade grown coffee in Costa Rica are negatively correlated with farm gross margins. Thereby, the magnitude of carbon sequestration is the most influential factor to reduce product carbon footprints. It is expected that further results of this study contribute to a better understanding of potential trade-offs that farmers would face when participating in product carbon footprint schemes which would account for biogenic carbon sequestration of perennials. Further, this study might provide insights on conditions under which coffee agroforestry systems in Costa Rica could bridge the trade-offs and rather create synergies.

Finally, implications on how smallholder coffee farmers could participate in increasingly demanded carbon neutral value chains might be generated.

Keywords: product carbon footprints, coffee agroforestry, economic-environmental trade-offs, climate change mitigation, carbon neutral value chains.

References:

1. Bessou et al., 2013, Int. J. Life Cycle Assess., 340–361, doi: 10.1007/s11367-012-0502-z
2. Birkenberg and Birner, 2018, J. Clean. Prod., 485-501, doi: 10.1016/j.jclepro.2018.03.226
3. Brandão et al., 2013, Int. J. Life Cycle Assess., 230–240, doi: 10.1007/s11367-012-0451-6
4. Carbon Sequestration Potential of Agroforestry Systems, 2011, Kumar and Nair
5. Plassmann and Norton, 2017, Carbon Management, 343–349, doi: 10.1080/17583004.2017.1362947

L17.1_O.06

Nitrogen Fixing Shade Trees in Coffee Agroforestry: Quantification of Nitrogen Transfer to the Coffee Plant.

Van den Meersche K.[1] (karel.van_den_meersche@cirad.fr), Harmand J.-M.[2], Zeller B.[3], Blanchart E.[4]

[1] *Eco&Sols, CIRAD, Montpellier, France*; [2] *Eco&Sols, CIRAD, ICRAF, Yaoundé, Cameroon*; [3] *BEF, INRA, Nancy, France*; [4] *Eco&Sols, IRD, Montpellier, France*

Nitrogen-fixing shade trees in coffee agroforestry systems are assumed to provide an alternative nitrogen source for the coffee crop when fertilizer applications are low, but the transfer of nitrogen from shade trees to the coffee crop has not yet been quantified directly. We present a case study for coffee agroforestry systems with *Erythrina poeppigiana* as a shade tree. The transfer of nitrogen from the N2 fixing tree to coffee plants was measured through a stable isotope pulse and chase experiment.

Shade trees that had been labelled with a 15N-enriched nitrate solution, were pruned, and the prunings were subsequently laid out below coffee crops under conventional or organic management. Significant fractions of nitrogen ended up in the coffee plants 5 months after the deposition of 15N labelled prunings on the plantation floor (figure 1). More nitrogen from prunings was found in the soil under organic management than under conventional management. This finding was associated with higher macrofauna abundance, particularly earthworms, in the organic system.

Coppicing of the shade tree and subsequent decomposition of the pruned material was the dominant mechanism for nitrogen transfer to the coffee plant, while other mechanisms only affected coffee plants directly neighbouring the tree.

In conclusion, the pruning of shade trees in coffee agroforestry systems is an important pathway for the transfer of fixed N to the coffee plants and seems to be essential in organic systems.

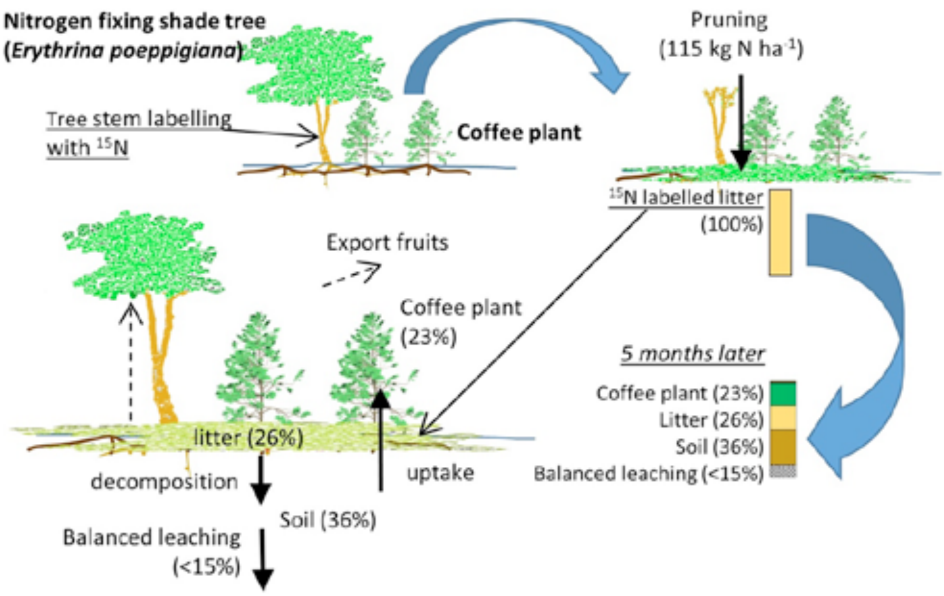


Figure: Fate of nitrogen from 15N labelled tree prunings: N transfer (% of initial N litter) to the soil and the coffee plant, 5 months after pruning. Data for the organic management.

Keywords: nutrient transfer, facilitation, litter decomposition, nitrogen budget.

L17.1_O.07

Local knowledge on the role of trees in coffee agroforestry systems of Northwest Vietnam

Mai Phuong N.[1] (n.maiphuong@cgiar.org), Vaast P.[2], Pagella T.[3], Nguyen L.[1], Sinclair F.[4]

[1] *ICRAF Vietnam, Ha Noi, Vietnam*; [2] *ICRAF/CIRAD, Ha Noi, Vietnam*; [3] *Bangor University, Bangor, Gwynedd, Wales, United Kingdom*; [4] *ICRAF/Bangor University, Nairobi, Kenya*

Over the past decades in Northwestern Vietnam, Arabica coffee systems have been moving towards intensified, full sun monocultures that are not long-term sustainable and have negative environmental impacts. As most of the farming systems in this area are on sloping land (approximately 75% of the total farmed area), these systems are associated with very high levels of soil erosion, loss of biodiversity. This, in turn has contributed to declines in agricultural productivity. There is now a need reverse these trends and better integration of agroforestry is one potential option. Indigenous coffee systems often use trees for shade. A survey of 124 farmers from three indigenous groups was conducted in Northwest Vietnam to document the characteristics of these shaded coffee agroforestry systems. This included systematic acquisition of the local knowledge of the ecosystem services and disservices that rural communities associate with the different tree species used within these systems.
Our results show that tree species richness in shaded coffee agroforestry plots was much higher compared to other farming systems in the area (including maize, orchards, and timber plantations). Farmers had in-depth knowledge of environmental benefits of different trees in their systems including their capacity to reduce soil erosion, improve soil fertility, enhance biodiversity and reduce damage from wind and frost. Interestingly farmers had limited knowledge on both how trees affected coffee quality and yield as well as their role in light and nutrient dynamics. The leguminous shade tree species (*Leucaena leucocephala*) was the highest ranked tree in terms of providing most ecosystem benefits. Nonetheless, farmers' selection of tree species in their shaded coffee systems was more heavily influenced by economic value associated with the intercropped trees. Our survey shows that there were fewer native species in the areas with better road accessibility (in these systems the road is synonymous with the market) despite the recognition of their value to coffee systems. Consequently, *Leucaena leucocephala* was only maintained in areas away from roads. This study highlights areas where we can target learning to improve the uptake of trees with high environmental value and highlights challenges associated with tree selection as Vietnam attempts to move towards more climate smart agricultural systems.

Keywords: local knowledge, ecosystem service, coffee agroforestry, tree diversity, tree selection.

L17.1_O.08

Young shade trees rapidly improve soil fertility in coffee-agroforestry systems

Rigal C.[1] (clement.rigal@netcourrier.com), Xu J.[1], Vaast P.[2]

[1] *Kunming Institute of Botany / ICRAF, Kunming, China*; [2] *CIRAD UMR Eco&Sols / ICRAF, Hanoi, Vietnam*

Background and aim
Highly productive monoculture coffee (*Coffea arabica* L.) farms have rapidly expanded since the 1990s in Yunnan Province, China. In 2013, in order to initiate a large-scale transition towards more sustainable coffee growing practices, local government in southern Yunnan started distributing free shade tree seedlings to all coffee farmers in their jurisdictions. This study highlights the impact of three of these promoted shade tree species (*Cinnamomum camphora*, *Bishofia javanica* and *Jacaranda mimosifolia*) on soil fertility and coffee production only four years after their distribution to coffee farmers.
Materials and methods
Soil samples in the 0-20 cm soil layer were tested for chemical composition (soil organic matter, pH, total N, available P, exchangeable K, Ca and Mg), soil communities (free-living nematodes and microbial communities) and soil enzyme activities (β-glucosidase, N-acetyl-glucosaminidase and acid phosphatase) under shade trees (6 replicates per tree species) and in open areas (15 replicates), both in coffee rows and inter-rows, once during the rainy and once during the dry season. Additionally, we characterized root systems and soil water profiles to a depth of 1.2m, monitored litterfall for one year, as well as coffee production for two years.
Major results
We detected a clear positive impact of all three shade tree species on soil chemical, biological and biochemical fertility, despite the marked effect of 20 years of high mineral fertilizer inputs. In particular, we measured higher pH and soil organic matter; similar or higher soil enzyme activities throughout the year; more abundant fungi communities throughout the year; and more abundant microbial communities during the dry season below shade trees than in open areas. Furthermore, coffee trees shaded by *B. javanica* and *J. mimosifolia* yielded as much as open coffee trees. On the other hand, coffee trees shaded by *C. camphora* yielded less than open coffee trees, most likely as a result of high root competition from this shade tree species. Lastly, shade trees had no visible impact on coffee organoleptic quality.
Conclusion
These results demonstrate that carefully selected shade trees can rapidly contribute to preserving and/or restoring soil fertility in intensive coffee systems, while maintaining high coffee yield.

Keywords: Arabica coffee, China, PLFA, Soil enzyme, Soil fertility.

L17.1_O.09

Traditional Mexican tropical smallholder agroforestry systems: it is possible to intercrop two ancestral crops?

Cerdán C. R.[1] (ccerdan@uv.mx), del Amo S.[2], Hipólito E.[2], Ramos-Prado J. M.[2], Ricaño J.[2]

[1] *Faculty of Agricultural Sciences, Universidad Veracruzana, Xalapa, Veracruz, Mexico*; [2] *Eco-dialogue Centre, Universidad Veracruzana, Xalapa, Veracruz, Mexico*

The history of the origins of cultivated vanilla suggests that almost the entire stock of cultivated vanilla outside of Mexico is a single genetic individual (clone)[1]. Vanilla is therefore suspected to be a highly susceptible monoculture, and new sources of germplasm (either from wild vanilla or from closely related species) should be introduced through breeding. Although vanilla can be found cultivated through the Tropics, natural populations in southern Mexico –the most critical sources of novel genetic diversity– are on the verge of disappearing.
Traditionally, Mexican vanilla plantations have been managed in highly diversified agroforests, with some indigenous groups being related to its domestication and cultivation by centuries, especially in Southern states (by Totonacas, Mazatecos, Chinantecos and Mayans among others). Profitability of these traditional multistrata agroforestry systems relies on the diversity of incomes obtained through a set of different timber and non-timber species (vanilla representing less than the 7% of the total income).
However, three challenges are currently faced by these smallholder vanilla production systems: a) Land Use Change to more profitable alternatives (decades ago to orange monocultures, currently to pastures), b) vanilla trade is monopolized by one company, c) and more recently, abortion in blooming likely due to rainy changes. Because of that, vanilla area has been reduced to less than 700 hectares in the whole Mexico.
Simultaneously, cacao is growing there on agroforestry systems since it was introduced more than 2000 years ago. It is well known that original inhabitants were the first to use cacao for human enjoyment (from xocolātl to chocolate)[2]. However, Mexico has lost nearly half of its cacao areas during the last decade, resulting in deforestation and the loss of valuable traditional knowledge. There is a need to improve the profitability either cacao and vanilla plantations.
Vanilla and cacao can be grown in humid tropics, both from sea level up to an altitude of 1200 m and optimum range is 20-30º C, as well as a minimum of 1800 mm of rain. However, intercropping of these two crops is not a common practice[3]. It is argued a possible competition, either for nutrients and space; by the other side, there are some reports about the existence of agroforestry systems by indigenous groups in the past, which are however currently unknown. Even its common origin and requirements, intercropping of vanilla and cacao has not studied enough.
Plots intercropping cacao and vanilla has been stablished 4 years ago in three different states of Southern Mexico in order to study: a) competition between crops, b) adaptation of them in different agro ecological conditions, c) differences in local management practices, c) phenology of tree species used as shade, and d) use of microorganisms to promote plant growth. Preliminary results shown that intercropping is not affecting farm profitability.

Keywords: Conservation, Local knowledge, Co-innovation, Diversification, Performance.

References:

1. Lubinsky et al, 2008, Economic Botany, 127-138
2. Motamayor et al, 2002, Heredity, 380-386
3. Sujatha and Bhat, 2010, Agricultural Water Management, 988-994

L17.1_O.10

Afforestation of savannah with cocoa agroforestry: a climate-smart sustainable agricultural practice

Harmand J.-M.[1] (jean-michel.harmand@cirad.fr), Nijmeijer A.[2], Lauri P.-E.[3], Jagoret P.[4], Freschet G.[5], Essobo Nieboukaho J.-D.[6], Enock S.[6], Fonkeng E. E.[6], Sauvadet M.[7], Gond V.[8], Saj S.[4]

[1] *UMR Eco&Sols, CIRAD, ICRAF, Yaounde, Cameroon*; [2] *UMR System, CIRAD, Montpellier SupAgro, Univ Montpellier, Montpellier, France*; [3] *UMR System, INRA, Montpellier, France*; [4] *UMR System, CIRAD, Montpellier, France*; [5] *UMR CEFE, CNRS, Montpellier, France*; [6] *World Agroforestry Centre (ICRAF), Yaounde, Cameroon*; [7] *UMR AGHYLE, UniLaSalle, Mont Saint-Aignan, France*; [8] *UPR Forêts et Sociétés, CIRAD, Montpellier, France*

Recent studies based on remote sensing showed a gradual expansion of tree cover over savannah and agricultural land in the forest-savannah transition zone of Cameroon[1], part of this expansion is actually due to shaded cocoa. Despite unfavourable conditions in herbaceous savannah (low soil fertility, weed competition and risk of bush fire), farmers have proven that afforestation is achievable using cocoa and specific technics to build up an associated tree canopy[2]. Full-grown cocoa agroforestry systems created on savannah (S-cAFS) and in forest (F-cAFS) seem to exhibit comparable multi-strata structure. Nevertheless, previous land uses and related canopy structures may have contrasted impacts on production and other ecosystem services over time.

We selected 1 to 70 year-old S-cAFS and F-cAFS, and we used forest and savannah patches as controls[3]. By combining measurements of cocoa production, litter fall and cycling, soil quality, carbon storage and tree species diversity along this age gradient, we showed that those variables in S- and F-cAFS generally tended to comparable levels after several decades. Results also emphasized the ability of S-cAFS to increase most of the ecosystem services (ES) although the time needed to reach levels found in F-cAFS varied strongly amongst variables (Fig 1). Results also showed the positive contribution of associated plants to ES, particularly C storage and nutrient cycling contributing to REDD+ [4] and sustainability of the cropping system.

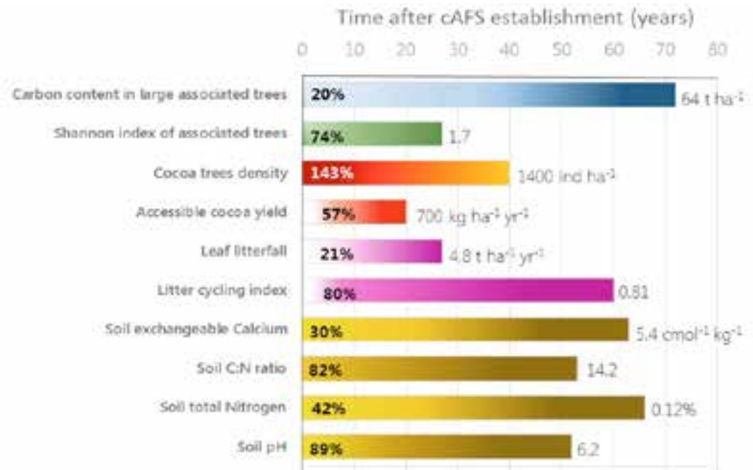


Figure 1: Time (years) needed for cocoa agroforests set up after savannah (S-cAFS) to reach the same values as cocoa agroforests set up after forest (F-cAFS) in term of carbon storage, tree species diversity, cocoa production, litterfall, litter cycling and soil features. These values, displayed on the right side of each bar correspond to a convergence point of each variable for both systems along the age gradient. The initial values for S-cAFS at 0 or 5 years according to the variable, are expressed in % of this convergent reference.

Keywords: Ecosystem services, Soil fertility, Cocoa sustainability, Land restoration.

References:

1. Gillet B. et al., 2001, J. Trop. Ecol. 809–832 http://journals.cambridge.org/abstract_S02664674010
2. Jagoret P. et al., 2012. Agrofor. Syst., 493-504 https://doi.org/10.1007/s10457-012-9513-9
3. Nijmeijer A. et al., 2018. Agrofor. Syst., 12p. https://doi.org/10.1007/s10457-017-0182-6
4. REDD+: Reducing emissions from deforestation and forest degradation ...

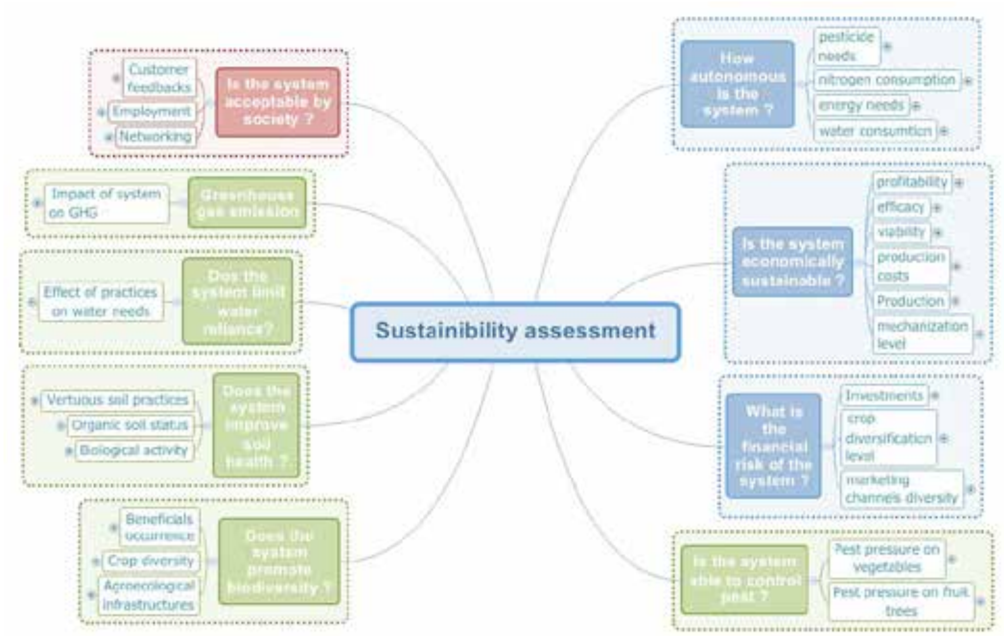
L17.2_O.01

Fruit agroforestry as a suitable candidate for new resilient food systems ? A french case

Warlop F.[1] (francois.warlop@grab.fr), Castel L.[2], Gaspari C.[1], Fourrié L.[3], Plessix S.[2]

[1] *GRAB, Avignon, France*; [2] *Chambre d'Agriculture de la Drôme, Etoile s/Rhône, France*; [3] *ITAB, St Marcel les Valence, France*

Because of negative externalities of specialized agricultural systems, diversification has been shown as a relevant tool to improve their resilience. Agroforestry in traditional peasant models is a case-study of a diversification. In 2012, French partners worked on *de novo* designs of two modern fruit agroforestry systems in southeastern France, with a specific objective of reduction of plant protection inputs, through higher wild/cultivated biodiversity occurrence. One system ('TAB') is oriented on long marketing channels with arable crops, the second ('Durette') is dedicated to short channels with highly diversified vegetables and directly managed by farmers. This long-term research project (funded by French Agricultural Ministry -Ecophyto- from 2012 to 2018, to be continued) has led to useful deliverables. A co-design methodology for innovative agroforestry systems has been thought to involve farmers in design choices, considering scientific objectives together with pragmatism. A multi-criteria assessment tool has been initiated to assess *ex ante* performance, and has been adapted for *ex post* assessment. A common methodology has been developed for on-farm performance assessment, based on classical sustainability indicators (picture). Preliminary results have been produced on biodiversity or economic performance and will be further detailed. The following years will be useful to further investigate natural pest control mechanisms, and complete performance assessment.



Overview of sustainibility indicators used

Keywords: agroecology, agroforestry, fruit growing, alley cropping.

L17.2_O.02

Agroforestry system enhances interspecific facilitation in a rainfed jujube orchard in the semi-arid Loess plateau

Ling Q. (lingybh@163.com), Gao X., Zhao X., Wu P., Sun W.

Northwest A&F University, Yangling, Shaanxi, China

Background
The increasing frequency of extreme and variable climate patterns in the future will threaten agricultural productivity in many areas, especially in dryland regions. In rainfed agriculture, to investigate the capability of the agroforestry system under global climate change is essential to achieve sustainable agriculture.
Aims
This study examines whether intercropping a rain-fed jujube orchard in the Loess Plateau, China with either *Brassica napus* (JB) or *Hemerocallis fulva* (JH) is a viable agroforestry system.
Materials and methods
A portable Time Domain Reflectometry (TDR) system was used to take long-term volumetric measurements. A cryogenic vacuum distillation system was used to extract water from xylem and soil samples. The thermal dissipation method was monitored the tree sap flux.
Main results
Soil water data collected over four years show that the JB and JH treatments increased soil water during the jujube growth (May-to-October) and dormant (March-to-April) relative to the control. The JB and JH treatments were characterized by a significant increase in soil water at a depth of 0-60 cm, along with a significant increase in average relative extractable water (REW) of 14.68% and 21.18% over four years, respectively. At the inter-row, the *B. napus* and *H. fulva* significantly increased the soil water at the depth of 0-60 cm in 2015-2017 and provided average REW gains 11.5% and 3.48%, respectively. The two economic crops significantly decreased soil water at the depth 60-180 cm and resulted in average REW losses 17% and 47.7%, respectively. The agroforestry altered the jujube trees' water sources but its impact depended on soil wetness: compared to monocultures, jujube trees in agroforestry systems generally shifted to deeper water under dry conditions but to shallower water under wet conditions. Complementary water use between jujube trees and crops was observed on most sampling dates, but there was clear evidence of water competition in the shallow layer under relatively wet conditions. The jujube transpiration was higher in the two agroforestry systems than the CC treatment, especially at the jujube critical water requirement stage (June to September). In addition, jujube yields in agroforestry systems were clearly higher than in monoculture.
Conclusion
The two tested agroforestry systems were directly related to soil water improvements in the jujube orchard. These findings demonstrate that agroforestry is a climate-smart agricultural system and can increase the resilience of semiarid jujube plantations to extreme real-world drought. The presented research demonstrates that agroforestry systems provide an economically feasible way to protect trees during both drought and normal years, and should be seriously considered by farmers who face water limitations.

Keywords: agroforestry, soil water, transpiration, stable isotopes, the Loess Plateau.

L17.2_O.03

Agroforestry with oil palm: ecological and economic trade-offs

Zemp D. C.[1] (dzemp@gwdg.de), Hölscher D.[2], Irawan B.[3], Sundawati L.[4], Wollni M.[5], Kreft H.[1]

[1] *Biodiversity, Macroecology, Biogeography, University of Goettingen, Göttingen, Germany*; [2] *Tropical Silviculture & Forest Ecology, University of Goettingen, Göttingen, Germany*; [3] *Forestry faculty, University of Jambi, Jambi, Indonesia*; [4] *Forest Management, Bogor Agricultural University, Bogor, Indonesia*; [5] *Agricultural Economics, University of Goettingen, Göttingen, Germany*

The transformation of rainforest into monocultural oil palm plantations has led to dramatic losses in biodiversity and in ecological functioning. To alleviate the negative ecological impacts in existing plantations, designer plantation landscapes have been proposed, in which agroforestry zones are considered to have a positive impact on biodiversity. In 2013, we established a biodiversity enrichment experiment in Indonesia (EFForTS-BEE) with multiple tree species planted in an oil palm monoculture, forming agroforestry plots of varying tree species diversity, composition, and plot size. Two main questions are investigated: is mixed-species tree planting a suitable measure for biodiversity enrichment in oil palm plantations? What are the socio-economic and ecological trade-offs? As the experiment is now well established, we study the experimental response of (a) the environment (soil, micro-climate), (b) plants (tree performance, plant water relations, natural succession, structural complexity), (c) animals (bird, bat and invertebrate communities), (d) micro-organisms (prokaryotes and fungi) and (d) socio-economics (oil-palm yields, benefits from the planted trees, incentive for enrichment planting). Here, we present initial findings resulting from the integration of comprehensive ecological and socio-economic studies from the past five years. These preliminary results contribute to the development of ecologically improved management concepts in oil palm landscapes.

Oil palm plantation enriched with six native tree species used for fruit, wood and latex (EFFoRTS-BEE 2016).

Keywords: oil palm, Indonesia, biodiversity, experiment, tree planting.

References:

1. Gérard et al., 2017, Agriculture, Ecosystems and Environment, 253-260
2. Teuscher et al., 2016, Frontiers in Plant Science, 1538

L17.2_O.04

Agroforestry: a pathway to enhance livelihoods of smallholders in the northern Laos

Pachas A. N. A.[1] (a.pachas@uq.edu.au), Sakanphet S.[2], Newby J. C[3], Soukkhy O.[4], Dieters M.[1]

[1] *School of Agriculture and Food Sciences, The Universtity of Queensland, Brisbane, QLD, Australia*; [2] *Upland Agriculture Research Center, Houay Khot, Luang Prabang, Laos*; [3] *International Center for Tropical Agricu, Vientiane, Laos*; [4] *Northern Agriculture Forestry College, Luang Prabang, Laos*

Smallholder households in the rural uplands of northern Laos PDR are characterised by high rates of poverty; however, well-managed teak (*Tectona grandis*) can provide a pathway out of poverty for these households (Newby *et al*. 2012). The benefits of alley cropping systems have long been recognised in Lao PDR (Hansen and Sodarak 2004), yet examples of their successful adoption are rare. Midgley et al. (2007) identify that one factor hindering adoption is lack of the information on the initial tree density, suitable companion crops, and appropriate management techniques. The Australian Centre for International Agriculture Research (ACIAR) has supported collaborative research on teak-based agroforestry systems in northern Laos since 2008. A total of 88 agroforestry trials were established in 2014 and 2015 across six districts of Luang Prabang province: Ngoy, Pakxieng, Pak-ou, Phonxay, Xieng Nguen and Viengkham. The trials were established using a paired-row configuration, with 2.1m between rows within a pair, and 1.8m between trees along the rows. The distance between adjacent paired-rows was set at 8, 10, 12 and 15 m giving planting densities of 1100, 918, 788 and 650 trees/ha respectively. In each of the 88 trials, two of these spacings were tested, providing a balanced set of comparisons across all trials within a district. The height and diameter at breast height (DBH) of all surviving trees were measured annually. A total 56 of the agroforestry trial sites were regarded as having been ‘successful’ (20 sites classified as good, 24 average and 12 poor performance). The remaining 32 trials were deemed to be unsuccessful, primarily due to a lack of weed control after the first growing season, which adversely impacted on survival and growth of the teak. The poorest growth and survival of the teak was associated with farmers who did not grow companion crops after the first year, and/or where the trials had been burnt. The most successful companion crops involved the growth of perennial crops (particularly banana, but also fodder crops). Factors impacting on the success or failure of these agroforestry trials are complex, and require further analysis. Nevertheless, some important factors are: farmers did not understand the concept of alley cropping as they had never seen this before, and only understood companion cropping only in terms of the *Taungya* system; the location in relation to the village (plots further away were less likely to be managed); availability of household labour (often related to the age of the farmers); and geographic location (high elevation sites were unsuccessful). In summary, our experience demonstrates that alley cropping systems involving teak in northern Lao PDR are applicable where farmers have limited land, but sufficient labour; sites are located in proximity to village or other upland fields (to minimise travel and maximise return on labour), and sites are below 800m above sea level.

Keywords: mixed-plantation, Tectona grandis, Non- Timber Forest Products, intercropping, fodder.

References:

1. Hansen P and Sodarak H (2004). Improving Livelihoods in Lao PDR A Sourcebook. NAFRI, Vientiane, Lao
2. Midgley S, Blyth M, Mounlamai K, Midgley D, Brown A (2007)ACIAR technical reports 64, 45 pp
3. Newby JC, Cramb RA, Sakanphet S (2012) Small-scale Forestry 11: 27–46 https://doi.org/10.1007/s11842

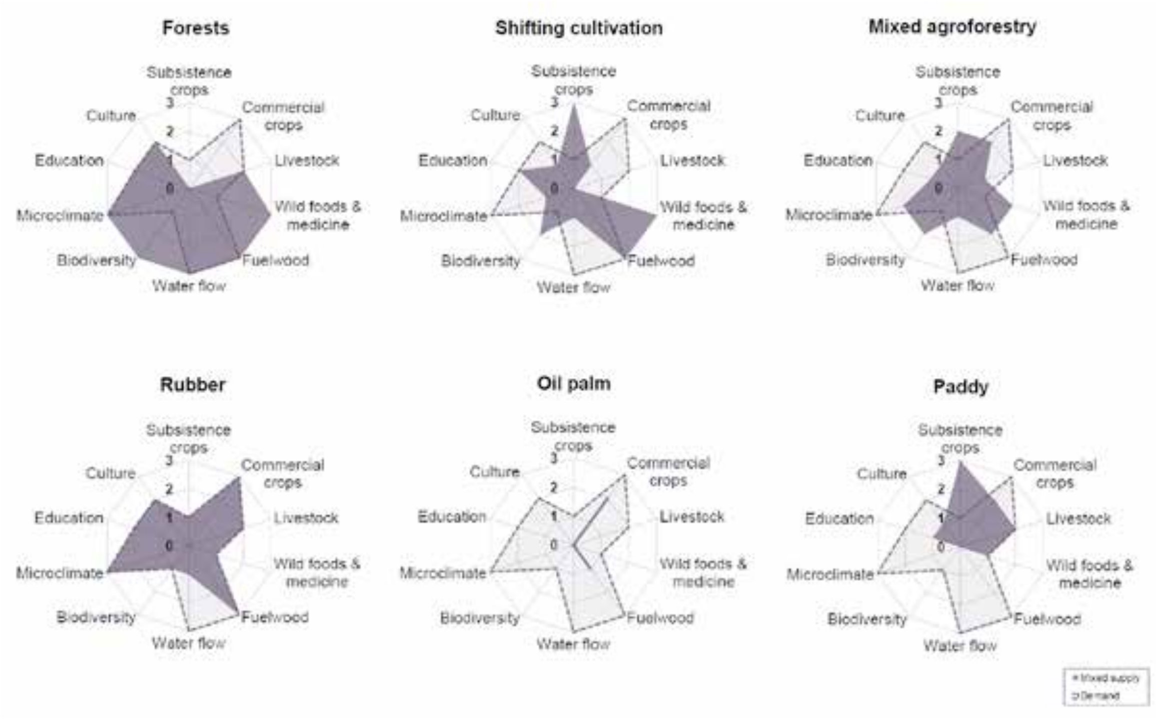
L17.2_O.05

Ecosystem services trade-offs from tree crop expansion in Myanmar's forest frontier landscapes

Feurer M.[1] (melanie.feurer@bfh.ch), Heinimann A.[2], Zähringer J. G.[2]

[1] *Agriculture, Forest and Food Sciences, Bern University of Applied Sciences, Zollikofen, Switzerland*;
[2] *Centre for Development and Environment, Bern, Switzerland*

Myanmar's Tanintharyi Region is a forest frontier landscape facing rapid rubber and oil palm expansion. In the past two decades, subsistence use of forests, shifting cultivation and traditional mixed betelnut/cashew agroforestry have been largely replaced by more intensive land uses, strongly impacting the supply of ecosystem services (ES) and human well-being. We investigated the bundles of ES provided by former and current land uses and analyzed the trade-offs for ten ES from the perspective of local land users. Using participatory action research, we conducted four transect walks, 16 focus groups and 27 semi-structured key informant interviews in three villages. Based on a qualitative content analysis, we developed a scoring system from 0 (no supply) to 3 (high supply) and applied it to each land use. We found the highest trade-offs for the conversion of forests to oil palm due to environmental pollution and limited access of local communities to concession areas and potential benefits. On the other hand, the booming rubber expansion offers income from commercial crops as well as fuelwood, climate regulation and even new cultural values. With the additional opportunity to include poultry production, rubber agroforestry provides most of the locally demanded ES. Nevertheless, disturbed water flows might cause future problems. We conclude that both remaining forests and new rubber agroforestry can contribute to a sustainable landscape development and human well-being.



Supply of ecosystem service bundles by different land uses in a forest frontier landscape in Myanmar

Keywords: Ecosystem services, Trade-offs, Frontier landscape, Tree crop, Myanmar.

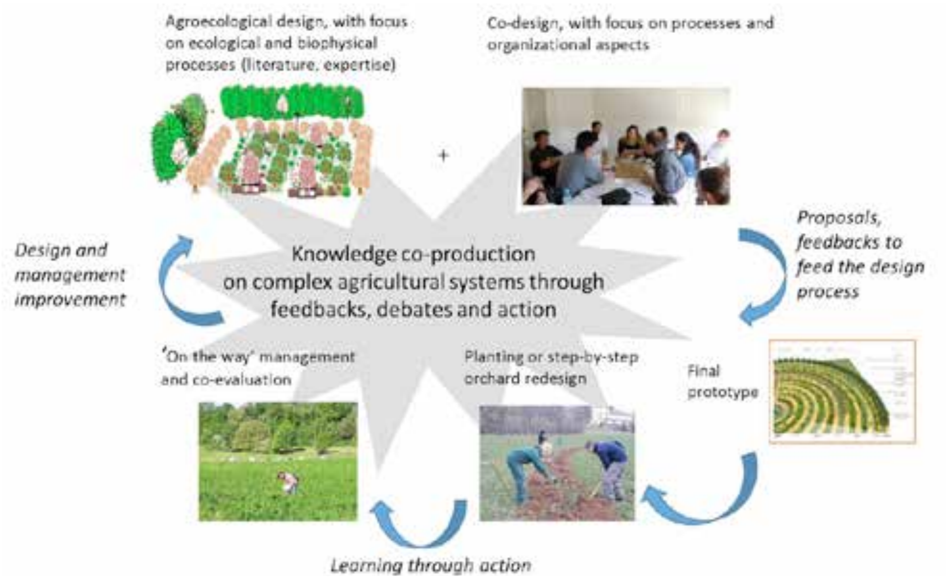
L17.2_O.07

Methodology to co-design temperate fruit tree-based agroforestry systems: three case studies in Southern France

Simon S.[1] (sylvaine.simon@inra.fr), Alaphilippe A.[1], Borne S.[1], Penvern S.[2], Dufils A.[2], Ricard J.-M.[3], Lauri P.-É.[4]

[1] *Unité Expérimentale Gotheron, INRA, Saint Marcel lès Valence, France*; [2] *Ecodéveloppement, INRA, Avignon, France*; [3] *Ctifl Balandran, Bellegarde, France*; [4] *UMR System, INRA, Montpellier, France*

Diversification of fruit tree species, cultivars, crops and companion plants is a way to reinforce ecosystem services towards productive and 'pest suppressive' fruit-tree based agroforestry systems (FT-AFS). We analyzed the approach and the outputs of three design processes that shared the same objectives of ecological intensification and diversification in FT-AFS.
The approach targeted 'pest suppressive' processes but also resource use optimization within time and space between productive and associated plants. Basic and applied knowledge on ecological and biophysical processes, feedbacks and experiences of various stakeholders in the fruitchain permitted to make tradeoff between agronomic, ecological and organizational aspects. For genericity purpose, the functions of each plant species or assemblage (e.g. barrier, trap, production) were identified taking into account growth dynamics over time.
The set-up of those FT-AFS prototypes implies changes in technics due to the spatial design (e.g. machinery adaptation, ergonomics) and changes in management of the agroecosystem, made 'on the way' considering the objectives and design principles as dynamic guidelines. The trajectory and performances of those systems are now assessed through multicriteria evaluation including organizational aspects and products' valorization. All steps include an interdisciplinary and participative approach fostering exchanges, knowledge sharing and building, and providing innovative avenues in FT-AFS.



Overall co-design process

Keywords: temperate agroforestry, fruit, co-design process, ecosystem service, pest suppression.

References:

1. Lauri PÉ et al., 2016, Acta Hort 1137, 255-265, http://dx.doi.org/10.17660/ActaHortic.2016.1137.37
2. Penvern S et al., 2018, Proc. 13th European IFSA Symposium (IFSA 2018), Greece. http://www.ifsa2018.
3. Simon S et al., 2017, Eur. J Agron 82,320–330, http://dx.doi.org/10.1016/j.eja.2016.09.004

L17.2_O.08

Traditional practices in shea tree (*Vitellaria paradoxa*) conservation in Uganda: Reflections and lessons from the past

Gwali S.[1] (gwalis@yahoo.co.uk), Eilu G.[2], Okullo J. B. L.[2]

[1] *Tree Improvement and Germplasm Research, National Forestry Resources Research Ins, Kampala, Uganda*; [2] *School of Forestry, Environment and Geog, Makerere University, Kampala, Uganda*

In Africa, the personal self is greatly influenced by and is in close interaction with both the human and natural environment. In the past, conservation in Africa was greatly influenced by its close interaction with both the belief and knowledge systems. There was always a linguistic expression, a category of knowledge, a practical use, a religious meaning or a role in ritual, which gave vitality to the conservation and protection of natural resources. Local community conservation of the shea trees, was therefore governed by a complex mix of traditions, customs, taboos, rituals and legends handed down from generation to generation and are neither found in written form, nor organized and structured in ways accessible to science. However, despite the value of traditional and cultural practices, their inclusion in national conservation policies has not been pragmatic. This paper aims to show the value of past traditional and cultural practices in the conservation of shea trees in Uganda. Data were collected through 15 focus group discussions, 41 key informant interviews and 300 semi-structured interviews across three farming systems of the shea tree parklands of Uganda. The results indicated that pre-current shea tree conservation can be traced back to the value system and traditional practices which can be broken down into seven broad levels: (i) the use of taboos, (ii) folklore and legends, (iii) local bye-laws, (iv) the sanctity of the elders, (v) the authority of traditional chiefs, (vi) traditional songs, and (vii) depth of integration into tradition, culture and custom. These have, however, been eroded over time, threatening the conservation of shea trees in Uganda. Given the diversity of traditional conservation practices, it is imperative that the people need to be active participants in conservation decisions, and traditional knowledge has to be accepted and/or regularised as a component of conservation. Conservation does not need to undermine the traditional wisdom base; rather traditional knowledge can offer lessons and complement contemporary methods to produce an acceptable and working conservation framework.

Keywords: shea tree, Vitellaria paradoxa, conservation, traditional practices, traditional knowledge.

References:

1. Dudley N. et al. (2005). WWF, Gland. Pp. 144.
2. Somjee S. H. (2000). Research in African Literatures 31 (4): 97 – 103
3. Eskell-Blokland L.M. (2009). Journal of Health Management 11 (2): 355 – 373
4. Alemna A.A. (1992). Journal of Documentation 48 (4): 422 - 429
5. Snively G. and Corsiglia J. (2000). Science Education 85 (1): 6 - 34

L17.2_O.09

Benefits and tradeoffs of integrated sheep vineyard systems in California

Gaudin A.[1] (agaudin@ucdavis.edu), Brewer K.[1], Patzec L.[2], Tiffany S.[3], Ryschawy J.[4]

[1] *Plant Sciences, University of California, Davis, Davis, CA, United States*; [2] *Napa RCD, Napa, CA, United States*; [3] *CAFF, Davis, CA, United States*; [4] *INPT ENSAT INRA UMR AGIR, Castanet Tolosan, France*

California hosts one of the most valuable, diverse and intensive cropping systems in the world. Several rounds of intensification and chronic irrigation water shortages have incentivized highly specialized crop and livestock enterprises and scientific research and technological development tailored to simplified systems. The broader aim of our work is to study ecosystem services provided by livestock reintegration into perennial cropping systems and their potential to offset external inputs, mitigate climate change and provide an effective adaptive strategy to impending shifts in resource availability in California. We propose to take the specific example of Integrated Sheep Vineyard Systems in Northern California (ISVS), a growing agroforestry system. Although this practice is gaining popularity among growers, no impact assessments have been conducted and benefits and tradeoffs associated with sheep integration remain unclear. We will present preliminary results of an interdisciplinary project assessing how and to what extent sheep integration impacts multiple ecosystem services and in turn the economic and environmental sustainability of vineyard production systems. We will also present leverages available for wider adoption of such systems in California.

L17.2_O.10

Too good to be true? Permanent Rubber Agroforestry Systems. Reality and challenges in Thailand

Thaler P.[1] (thaler@cirad.fr), Chambon B.[1], Tongkaemkaew U.[2], Penot E.[3], Brauman A.[4], Sajjaphan K.[5], Suvannang N.[6], Panklang P.[7], Thoumazeau A.[1], Béral A.[8], Theriez M.[9], Stroesser L.[9]

[1] *PERSYST, CIRAD, Montpellier, France*; [2] *Fac of technology & community developmen, Thaksin University, Phatthalung, Thailand*; [3] *ES, CIRAD, Montpellier, France*; [4] *UMR ECO&SOLS, IRD, Montpellier, France*; [5] *Soil Science, Kasetsart University, Bangkok, Thailand*; [6] *Land Development Department, Bangkok, Thailand*; [7] *Plant Science, Prince of Songkla University, Songkhla,, Thailand*; [8] *AgroParisTech, Paris, France*; [9] *IRC/Supagro, Montpellier, France*

Many of the socio-economic and environmental issues of rubber plantations are linked to their monocrop nature. Agroforestry systems (AFS) associating permanently crops or other trees to rubber are widely believed to offer a favourable alternative, not only able to diversify the source of income for farmers but also to limit the negative environmental impacts of plantations.
However, despite such good reputation, in Thailand, the first rubber producing country, rubber AFS are estimated to cover less than 5% of the surface area, mainly in the south zone. Within Heveadapt, a multidisciplinary project on the adaptation of rubber smallholders to global changes, we assessed the existing systems in a representative zone (Phattalung Province) of the main rubber producing area (South) and evaluated their actual impact on the farms economy and on soil quality.
Only few rubber farmers had permanent AFS and none of them in all their rubber plots. The 3 main systems in southern Thailand were fruit trees/rubber, vegetable/rubber, timber trees/rubber. Complex systems mixing several associated species also exist. The density of rubber trees was always the same as in the monocrop, safeguarding the latex yield. The fruit tree/rubber association provided the best trade-off between return to land and to labour. Timber provided a labour-saving alternative with high but late income. Simulations showed that, thanks to their flexibility and a higher gross margin, the AFS actually provided a higher resilience of the farms when the price of rubber fall.
The effects of AFS on soil biological and physico-chemical properties were not that clear. Actually, agricultural practices (weeding, fertilization) tended to vary more between farms than between the AFS and monocrop plots. Therefore, the heterogeneity was high within each system. The age of the plantation also had a greater effect than the kind of system. However, differences between systems increased with age and traits linked to carbon transformation indicated more active processes in fruit tree/rubber than in monocrop. Nevertheless, the actual vegetation soil cover was the most important factor influencing soil quality and weeds sometimes covered more the soil in monocrop plots than in AFS.
We showed that current AFS originated from individual pioneer initiatives that spread in a second step through farmers-to-farmers networks. Social motivations and family consumption prevailed at the beginning, but diversification of the source of income is now the main reason to adopt AFS. The change in the attitude of official institutions, mainly the Rubber Authority of Thailand, now promoting AFS, was also important. Such basis, with existing networks, knowledgeable leaders and institutional support, paves the way for the development of regional innovation platforms offering channels (meetings, social medias, trainings) to share the available information necessary to scale-up the rubber AFS from a marginal to a widespread system.

Keywords: Hevea, Sustainability, Diversification, Soil quality, Innovation.

L17.P.01

Farmer's perceptions of the effects of some preserved trees in cocoa and coffee agroforests in Togo (West Africa)

Adden A. K.[1] (ayiadden@gmail.com), Fontondji K. J.[2], Fare Y.[3]

[1] *Institut de Conseil et d'Appui Technique, Unité Technique Café Cacao, Kpalime, Région des Platraux, Togo*; [2] *Université de Lomé, Laboratoire de Recherche Forestière, Lomé, Togo*; [3] *Kinome SAS, Campus du Jardin Trooical, Paris, France*

A survey conducted in the forest zone in Togo nearby 317 cocoa and coffee producers, allowed to identify appreciated and unappreciated trees by them in the cocoa and coffee agroforests, then the main raisons for this discrimination. In coffee agroforests, the first trees species appreciated and able to be conserved by farmers remain Erythrophleum suaveolens (76,2%), Khaya grandifoliola (76,1%), Albizia adianthifolia (72,3%), Milicia excelsa (68,4%), Albizia zygia (56,1%), Terminalia ivoiriensis (40,1%) and Terminalia superba (40,1%). In cocoa agroforests, farmers prefer Milicia excelsa (65,2%), Albizia adianthifolia (56,5%), Terminalia ivoiriensis (52,2%), Terminalia superba (52,2%) and Khaya grandifoliola (39,1%). The main raisons evocated by the producers were linked to the trees shade quality (95%), the soil fertility and conservation improvment (93%) and the timber tree quality provided (92%). The unappreciated trees in coffee agroforests were Cola chlamydantha (89%), Cola nitida (89%), Ceiba pentadra (88%), Milicia excelsa (86%),Bombax costatum (79%) and Mangifera indica (77%) while in the cocoa agroforests it remained Bombax costatum (93%), Cola nitida (91%), Anogeisus leicarpus (88%), Cola chlamydantha (87%) and Glyricidia sepium (80%), because these trees in the orchards, depleted and hardened the soil (89%), provised bad tree shade (78%) and invaded the agroforests (75%). More informations is capitalised for the best orientation of the phytogenetic ressources conservation and dissemination strategies in the production area for enhancing sustainable cocoa and coffee production in Togo.

Keywords: Farmer's perception, Cocoa and coffee agroforests, Preserved trees, Togo.

References:

1. Adden et al, 2016, International Journal of Development Research 06 (04), 7269-7274
2. Koglo et al, 2018, Soil Syst 2(49), 1-11, doi:10.3390

L17.P.03

Co-design agricultural systems combining gaming and backcasting methods in smallholder coffee agroforestry systems

Andreotti F.[1] (federico.andreotti@outlook.com), Speelman E. N.[1], Van den Meersche K.[2], Allinne C.[3]

[1] *Farming Systems Ecology, Wageningen University & Research, Wageningen, Netherlands*; [2] *UMR Eco&Sols, CIRAD, Montpellier, France*; [3] *UMR System, CIRAD, Montpellier, France*

In Central America, smallholder coffee farmers rely on low input agroforestry systems (AFS) while experiencing increased pressure from climate change and social inequality. In order to increase the sustainability of these systems and to guide farmers along agroecological transition pathways, participatory approaches are needed. However, methods for the co-design process of such complex AFS are still scarce. Here, we present a practical approach based on game sessions and backcasting for the development of sustainable farming systems, together with the smallholder communities. We organized five game sessions and one backcasting workshop with farmer communities, technicians, researchers and municipality officials in La Dalia, Nicaragua. Through the game sessions we managed to highlight the key factors that allow or impede successful coordination among farmers to diversify their systems and develop organic and/or low input agriculture. Furthermore, using backcasting, we shared the outcomes from the game sessions among the communities and co-designed new farming systems highlighting major economic, social and environmental benefits and barriers. Through combining game and backcasting sessions, we were able to describe the current system and co-construct a desirable future vision towards agrological transition. We envision a wide range of relevant applications of this method in agriculture and beyond to facilitate stakeholders to collaboratively initiate processes of change.

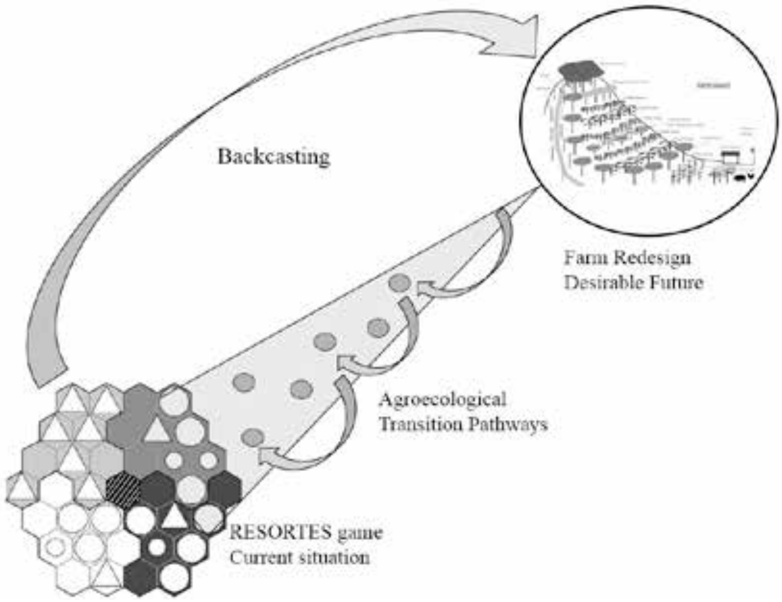


Illustration that combine RESORTES game sessions describing current situation and backcasting approach, showing how targets are chosen and pathways are then subsequently developed for achieving those targets.

Keywords: Agroecology, Action research, Land-use change, Nicaragua, Coffea Arabica.

References:

1. Andreotti F., Mao Z., Jagoret P., Speelman E.N., Gary C., Saj S. 2018. Ecol. Indic. 94,1: 257-265
2. Speelman, E.N., García-Barrios, L.E., Groot, J.C.J., Tittonell, P., 2014. Agric. Syst. 126, 62–75.
3. Duru, M., and Therond, O. 2015. Agron Sustain Dev. 35,4: 0.
4. Le Page, C. L., and A. Perrotton. 2017. Computer Science: 31–44.
5. Jacobi, J., S.-L. Mathez-Stiefel, H. Gambon, S. Rist, M. Altieri. 2016. Environ. Manage. 59:464–476

L17.P.04

Successfully establishing a large-scale mechanized dynamic cocoa agroforestry at a marginal site in central Ivory Coast

Andres C.[1] (christian.andres@fibl.org), Wiens S.[1], Degonda K.[1], Milz J.[2], Schneider M.[3], Hiestand F.[4], Six J.[1]

[1] *Sustainable Agroecosystems, ETH Zurich, Zurich, Switzerland*; [2] *Ecotop Consult, La Paz, Bolivia*; [3] *International Cooperation, FiBL, Frick, Switzerland*; [4] *Fredy's Plantation, Tiassalé, Côte d'Ivoire*

One third of the world's cocoa (*Theobroma cacao* L.) grows in monocultures in Ivory Coast, which are threatened by degraded soils and vulnerability to climate change. Cocoa agroforestry systems have the potential to provide various ecological benefits. However, making them economically feasible at larger scales remains a challenge. In this study, we assessed critical success factors for the establishment (in 2014) of Fredy's Plantation, a unique large-scale mechanized dynamic agroforestry system under organic management located at a marginal site for cocoa production in central Ivory Coast. Major parts of the site had previously been under 30 years of intensive pineapple production. Using a pairwise comparison of six plots each in high- and low-tree vigour areas, we assessed physicochemical soil properties and meteorological stand parameters, as well as growth and survival rate of cocoa trees. We observed a decrease of the daily temperature amplitude (difference Tmax – Tmin) in high-tree vigour areas (denser shade canopy), which correlated with enhanced cocoa tree growth and survival rate. Furthermore, survival of cocoa trees correlated with increased soil fertility (higher organic C and N), lower bulk density and higher water holding capacity (Figure 1). Applying large amounts of biomass through regular pruning may be a key factor for the regeneration of impaired soil health on marginal lands in order to increase the productivity of cocoa-based dynamic agroforestry systems.

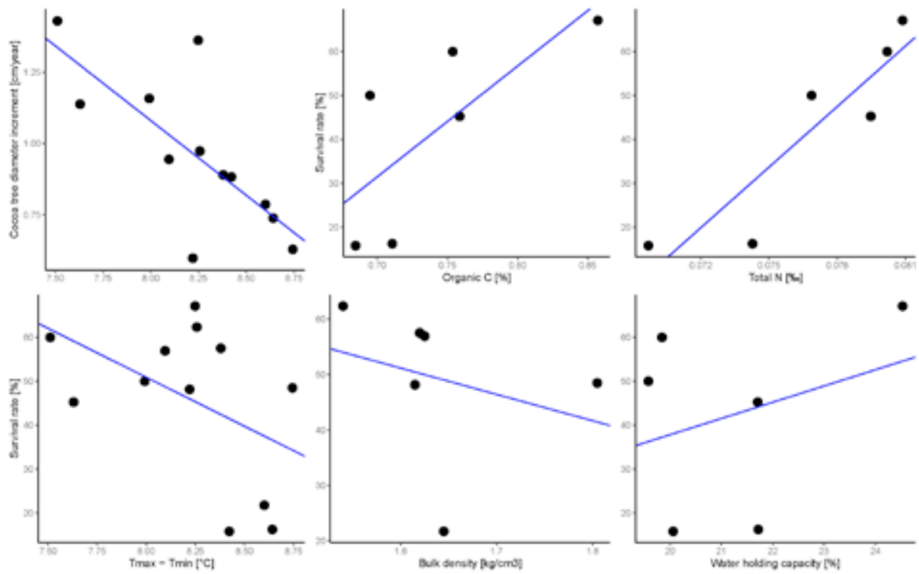


Figure 1: Correlations between temperature amplitude (difference Tmax – Tmin) during the day and growth rate (upper left panel) and survival rate (lower left panel) of cocoa trees, as well as between organic C (upper middle panel), total N (upper right panel), bulk density (lower middle panel) and water holding capacity (lower right panel) and survival rate of cocoa trees.

Keywords: sustainable organic cocoa production systems, Climate-smart practices/buffering of climate extremes, soil fertility, carbon sequestration, reforestation/timber production.

References:

1. Ruf, 2011, Hum. Ecol. 39, 373-388; doi: [10.1007/s10745-011-9392-0]
2. Tondoh et al., 2015, Glob. Ecol. Conserv. 3, 575-595; doi: [10.1016/j.gecco.2015.02.007]
3. Wessel and Quist-Wessel, 2015, NJAS 74-75, 1-7; doi: [10.1016/j.njas.2015.09.001]
4. Schroth et al., 2016, Sci. Total Environ. 556, 231-241; doi: [10.1016/j.scitotenv.2016.03.024]
5. Jose, 2009 Agrofor. Syst. 76, 1-10; doi: [10.1007/s10457-009-9229-7]

L17.P.05

The role of the herbaceous community in ecosystem service provisioning in coffee agroforestry systems

Archibald S.[1] (sarah.archibald@mail.utoronto.ca), Isaac M. E[2]

[1] *Geography, University of Toronto, Toronto, Ontario, Canada*; [2] *Geography, Environmental Science, University of Toronto Scarborough, Toron, Canada*

The effects of diversifying shade-tree composition in coffee agroforestry systems has been explored in depth, showing many benefits to overall land productivity, farmer livelihoods, and biodiversity conservation (Tscharntke et al. 2011). However, the role of the herbaceous community (HC) in contributing to agroecosystem processes and ecosystem services in coffee agroforestry systems are poorly understood. My research aims to provide key insights on the function of HC on ecosystem services using social and ecological research approaches.
I implemented a functional trait-based approach to measure plant functional diversity - functional richness, evenness and divergence - of the HC on 15 organic coffee agroforestry farms (Figure 1). This was paired with in-depth producer interviews to document the management and the perception of the HC using a cognitive mapping approach (see Isaac et al. 2009).
My research found that both soil carbon and nitrogen increased with higher HC functional richness. Cognitive maps were diverse in their number of variables, indicating that there are many pathways to promote HC as a way to increase ecosystem services while reducing farmer labour in coffee agroforestry systems.
This research aims to contribute to the growing field of agroecology, functional-trait ecology, and HC research. I aim to provide timely and essential information to support farmers interested in transitioning to low/no-chemical coffee agroforestry systems.

Figure 1. Herbaceous community sampling plot in an organic coffee agroforestry systems in the Turrialba Valley of Costa Rica.

Keywords: coffee agroforestry systems, ecosystem services, herbaceous communities, functional traits, biodiversity.

References:

1. Isaac, M. E., Dawoe, E., & Sieciechowicz, K. 2009. Envir. Mgmt. 1321–1329. https://doi.org/10.1007/s
2. Tscharntke, T. et al. 2011, J.Appl.Ecol. 619-629. doi.org/10.1111/j.1365-2664.2010.01939.x

L17.P.06

Innovation and Transition in Agriculture: How dairy farming is emerging in the coffee agroforestry systems of Kenya

Asayehegn K.[1] (kinfe85@gmail.com), Temple L.[2], Iglesias A.[3]

[1] *Dr., Hawassa, SNNPR, Ethiopia*; [2] *UMR Innovation, CIRAD, Montpellier, France*; [3] *UPM, Madrid, Spain*

Emerging challenges to farming drives farming systems to have three strategies; intensification options optimizing resources and technological innovations, firm diversification orchestrating interdependencies among sectoral boundaries, and transition to new system and trajectories. The intensification in the coffee system is the process to specialize in coffee using new varieties and practices while the second option is diversification to complementary enterprises to adapt challenges. The trajectory shift emphasis on how new sectoral systems (dairy sector) emerges, and its link with the previous system (coffee) in terms of impact pathway. In the multi-level perspective however, there is no simple cause effect relationship drives transitions rather systems change is enacted by various types of actors. This paper, therefore, presents (1) how the transition from coffee to dairy based farming system is taking place? (2) How the different actors in the innovation system of transition contribute to the learning and innovation process? (3) What contributes the transition from intensified coffee based to dairy based farming system on household food security? Our data collection consists of household survey (120) for household specific data, focus group discussions (9 FGDs) and stakeholders' interview. The results revealed, coffee production declined by 65% in the last 30 years, and the trend is straight. The dairy on contrary is in opposite visualizing sharp increase in volume of production and price. In line to this, innovation process and actors' interaction to adapt to climate change differs for the coffee and dairy. Actors in the coffee are limited, the system is highly centralized with limited options to farmers to process and market their product while the dairy sector is informally controlled by demand based business, comparatively numerous actors with limited government intervention, various options to marketing. The strong correlation between farm performance and socio-institutional variables, stakeholder interaction suggests the need for the establishment and strengthening of local institutions that have capacity to break the farmers' capital constraint to invest in climate smart agriculture which is beneficial to sustain systems.

Keywords: Climate Change, Coffee agroforestry, Climate Smart Agriculture, Innovation, Transition.

References:

1. CHHETRI, N., CHAUDHARY, P., TIWARI, P. R., YADAW, R. B. (2012), Institutional and Technological Inno
2. EDQUIST, C., CHAMINADE, C. (2006), Industrial Policy from a Systems-Of-Innovation Perspective, EIB P
3. HALLEGATTE, S. (2009), Strategies to Adapt to an Uncertain Climate Change, Global Environmental Chan
4. JARAMILLO, J., SETAMOU, M., MUCHUGU, E., OLAYE, A. C., JARAMILLO, A., MUKABANA, J., GATHARA, S. (201
5. KLERKX, L., NETTLE, R. (2013), Achievements and Challenges of Innovation Co-Production Support Initi

L17.P.07

Forest coffee in Ethiopia: understanding and developing a specific agroforestry system. Case study at Anfilo, Wallaga

Ayerbe D. (delphineayerbe@hotmail.com)

Belco, Palaiseau, France

The Anfilo Coffee Forest in western Ethiopia is an ancient heritage forest where coffee has been cultivated for centuries. Coffee is grown under various ancient species of trees originating from primary forests. This specific type of production gives local harvests a more complex range of aromas of interest to consumers. However, the system is now under threat from recent developments, in particular a growing population, land pressure and the development of cash crops.

In our lecture, we will analyze the specific features of this type of land use to understand how it works and how it might be developed in such a way as to make it sustainable. To do this, we propose describing the coffee forests of Anfilo, which employ a specific type of highly localized farming technique. We will then explore our case study in relation to global trends in favor of promoting and defending agroforestry coffee. Finally, we will consider ways of developing such production, which despite low yields is of a remarkable quality, in order to prevent this culture system specific to the coffee-growing regions of western Ethiopia from disappearing and to make it more beneficial for local farmers.

Keywords: Coffee, Forest, Ethiopia.

L17.P.08

Agroforestry systems in the Sudanian zone of Côte d'Ivoire and resilience of family farms to climate shocks

Barima Y. S. S. (byssabas@yahoo.fr), Timité N.

UFR Environnement, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire

In West Africa, most of farmers regard trees as an integral part of the cultivated system. They maintain traditional farming systems in which trees spared during clearing are scattered over the fields. Agroforestry has been practiced for several centuries and provides wood and non-wood products, from which households derive an essential part for their food security (Kouakou *et al*., 2017). In these fragmented agricultural landscapes, these agroforestry systems (AFS) maintain connectivity between different habitats and provide excellent refuge for biodiversity (Asare *et al.,*2014; Smith Dumont *et al*., 2014). Moreover, socially, trees are precious land markers and constitute an important part of family heritage (Camara *et al*., 2009). Furthermore, several studies have shown that AFS sequester more or less carbon depending on their level of complexity and contribute to the mitigation of climate change (Somarriba *et al*., 2013). Since two decades, there has been a diversification of crops in the Ivorian Sudanian zone and a large increase of cashew trees (*Anacardium occidentale*)in this area. This crop has become the main perennial one of the Ivorian savanna zone. Côte d'Ivoire is also the main African producer of cashew nuts with around 50% of African production. However, this extension of cultivated areas in cashew trees is to the detriment of existing traditional AFS dedicated either to food crops or to the conservation of local biodiversity. The expansion of orchards also leads to a reorganization of social relations, particularly through renegotiation of land rights. The increase in cashew orchards is therefore a threat of traditional AFS making some agroforestry parks, sources of greenhouse gases. Despite the extend of human pressures and constraints to biodiversity conservation, a lack of data and information on the spatial-temporal dynamics of land use, the potential of ecosystem services of traditional AFS compared to cashew trees and the impact of climate change on the evolution of these systems remains. Moreover, the factors of the establishment of these traditional AFS, and their suppression or maintenance by the farmers are still poorly known in the Ivorian Sudanian zone. In view of the need of scientific data on the Ivorian Sudanian zone, it is important to adopt a multidisciplinary and integrative approach that allows, on the one hand, a better understanding of the dynamics of the vegetation cover of the zone, to predict their future evolution in a context of climate change and, the other hand, to establish alternative models of management of these AFS.

Keywords: Sudanian zone, traditional agroforestry systems, cashew trees, fragmented agricultural landscapes, family farming.

References:

1. Asare et al., Agroforest Syst, 88,1143-1156.
2. Camara et al., 2009, Cahiers agricultures, 18, 425 - 432.
3. Kouakou et al., 2017, Tropicultura 35, 121-136.
4. Smith Dumont et al., Agroforest Syst, 88, 1047.
5. Somarriba et al. 2013, Ecosystems and Environment, 173, 46 - 57.

L17.P.09

Climate-smart, sustainable agriculture in low-to-intermediate shade agroforests

Blaser W. J.[1] (wilma.blaser@usys.ethz.ch), Oppong J.[2], Hart S. P.[1], Landolt J.[1], Yeboah E.[2], Six J.[1]

[1] *ETH Zurich, Zürich, Switzerland*; [2] *CSIR - Soil Research Institute Ghana, Kumasi, Ghana*

Meeting demands for agricultural production while maintaining ecosystem services, mitigating and adapting to climate change, and conserving biodiversity will be a defining challenge of this century. Crop production in agroforests is being widely implemented with the expectation that it can simultaneously meet each of these goals. But trade-offs are inherent to agroforestry and so unless implemented with levels of canopy-cover that optimise these trade-offs, this effort in climate-smart, sustainable intensification may simply compromise both production and ecosystem services. By combining simultaneous measurements of production, soil fertility, disease, climate variables, carbon storage, and species diversity along a shade-tree cover gradient, here we show that low-to-intermediate shade cocoa agroforests in West Africa do not compromise production, while creating benefits for climate adaptation, climate mitigation, and biodiversity (Fig 1). As shade-tree cover increases above approximately 30%, agroforests become increasingly less likely to generate win-win scenarios. Our results demonstrate that agroforests cannot simultaneously maximise production, climate, and sustainability goals but might optimise the trade-off between these goals at low-to-intermediate levels of cover.

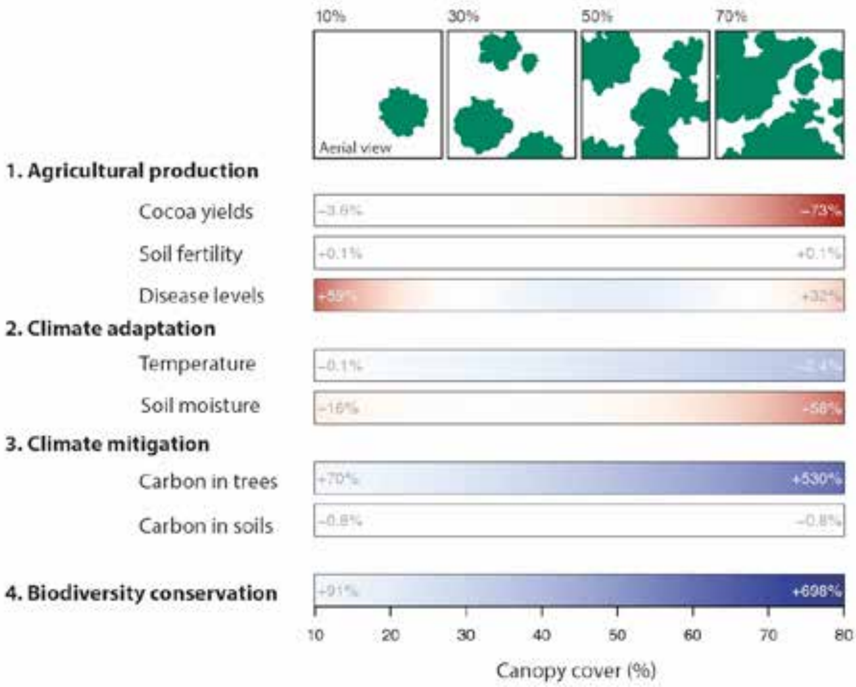


Figure 1 Optimizing shade levels in agroforests. Agroforests with ~30% cover are ideal for optimizing the trade-off between the costs (red) and benefits (blue) for yield and the provisioning of ecosystem services such as climate adaptation, climate mitigation and biodiversity along a gradient of shade-tree cover, relative to paired monocultures. Blaser et al., Nature Sustainability (2018).

Keywords: agricultural production, climate adaptation and mitigation, biodiversity conservation, shade-tree cover, trade-offs.

L17.P.10

Trade-offs among ecosystem services and productivity in coffee-based agroforestry systems in Nicaragua

Cerdán C. R.[1] (ccerdan@uv.mx), Bucardo E. M[2], Cartier M.[3], Soto G.[4], Fallot A.[5], Rapidel B.[6]

[1] *Faculty of Agricultural Sciences, Universidad Veracruzana, Xalapa, Veracruz, Mexico*; [2] *Bioversity International, Jinotega, Nicaragua*; [3] *ISTOM, Cergy, France*; [4] *Committee on Sustainability Assessment, San José, Costa Rica*; [5] *UPR GREEN, CIRAD, Montpellier, France*; [6] *Persyst Department, CIRAD, Montpellier, France*

Many studies have measured biodiversity loss across the coffee intensification gradient; some studies have shown, with contradictory results, the trade-offs between biodiversity loss and coffee production increments. Plot assessments of tree diversity, soil conservation, carbon sequestration and coffee production are lacking. We characterized the structure, productivity, diversity, soil conservation and carbon sequestration of 40 coffee agroforestry systems in two different areas in Northern Nicaragua. Coffee management, environmental conditions and soils properties were also characterized to better understand the trade-offs among services within the plots and their dependence on the local environment. These agroforestry systems were chosen to maximize contrasts in terms of biophysical context, botanical composition and management practices. Results (preliminary) showed significant differences in the vegetation structure that enabled us to identify main clusters: CAFS with dense and diverse overstorey canopy, CAFS with high *Musa* density and CAFS with low density of overstorey canopy. Changes in vegetation structure reflected differences in farmers' strategies but did not affect the overall coffee yield or the conservation of soils. Coffee yields had strong variations among the plots, and this was mainly related to the amount of fertilizer applied. Neither carbon sequestered, soil conserved nor tree diversity have a significant negative relationship with coffee productivity. However, coffee yields were low comparing with other coffee areas in the region. These results open new perspectives to improve coffee agroforestry systems' structural complexity and their relative ecosystem services without affecting their overall productivity. Further investigations and a more stratified sampling to get a good grasp of the whole range of variability (in highly productive areas with less shade canopy) are needed to fully understand the mechanisms involved in trade-offs.

Keywords: Performance, Management, Multivariate analysis, Ecological intensification.

L17.P.11

Restoration of abandoned tea plantations in Western Ghats landscape of south India: Do shade trees help?

Chetan H C[1] (chetan.hcc@gmail.com), Ganesh T[2]

[1] *CCNR, Trans-Disciplinary University (TDU), Bengaluru, Karnataka, India*; [2] *Conservation Science, ATREE, Royal Enclave, Srirampur Jakkur, Bengaluru, Karnataka, India*

For centuries, millions of hectares of tropical forests have been cleared and replaced by commercial plantations of tea, coffee and cardamom in biodiversity rich Western Ghats of India. Many of these plantations have been already abandoned or are in the verge of abandonment due to various socio-economic and legal issues including dwindling profits and market factors and change in legal and policy frameworks. Such abandoned areas provide opportunities for restoring diverse economically important local forest species which support the community needs and livelihoods.

We studied tea plantations in Agasthyamalai region in south India where about 55% of plantations are under various levels of abandonment. Our aim was to understand the factors associated with the establishment of native plant species in abandoned plantations, especially how shade trees in plantations can enhance local biodiversity in context of birds/mammals and seed inputs from neighbouring forests. Seven permanently marked, 10 × 10-m plots were laid along a linear transect from forests to tea plantations in both managed and abandoned conditions to assess the seasonal seed inputs. Transact plots were laid at distance from 0 m (forest edge), and towards forest edge to interior of the plantation transact at distance of 25 m, 60 m and 95 m, respectively. Nested 1x1 m subplots were laid at four corners to assess the soil seed bank and dispersal syndrome. The species richness and seed density in the plantations were assessed using seed banks.

We found out that forest proximity to tea plantations is critical for native species to colonise the plantations. Nearly 92% of the seeds are animal-dispersed, even then seeds do not move more than 60–95 m from the forest edge, which significantly restricts species' colonisation inside the plantations. Most of the species that reach the tea plantation are early successional species dispersed by small birds while large-seeded species dispersed by hornbills and pigeons are not established in the plantations. Further, in managed plantations restoration can be facilitated by retaining shade trees in the tea landscape. Presence of shade trees is increased native species richness by 3 times and seed density by 3–30 times compared with plantations without shade trees. Further, distance to forests influenced seed arrival in plantation without shade trees and plot 95m from the forest did not have any seeds in them. No such effect was seen in the plantations with shade trees. In general density of shade trees have strong influences on seed arrival which can negate the forest proximity effect and enhance natural forest colonisation. Results of the study have direct relevance in strategizing ecological restoration of degraded areas in this globally important landscape.

Keywords: Tea plantation, Abandonment, Shade tree, Seed input, Restoraiton.

References:

1. Ray-Benayas, et al.. 2008. Creating woodland islets to reconcile ..Front. in Eco. and the Env. 6:329
2. Holl, K.D 1998. Do bird perching structures elevate seed rain and seedling., Rest Eco 6:253–261.
3. Guevara et al 2004. Rain forest regeneration beneath the canopy., Mexico. Biotropica36:99–108.
4. Gorchov et al 1993. The role of seed dispersal in the natural.. Vegetatio 107/108;339–349

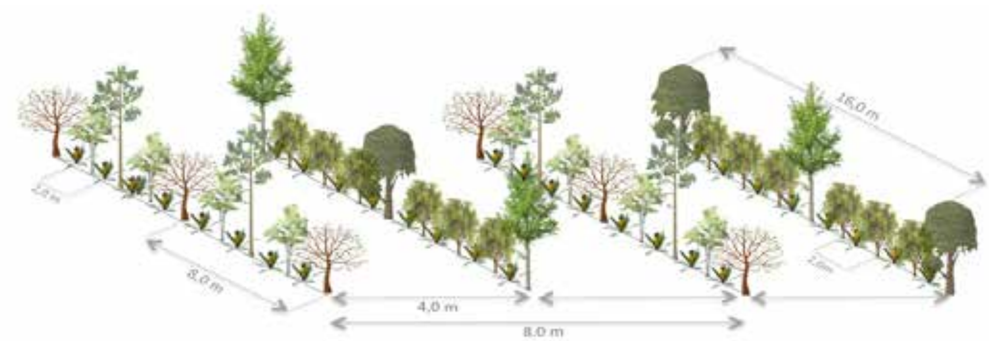
L17.P.12

Diversifying revenue with successional perennial crops: a large-scale agroforestry design in Southern Brazil

Costa P.[1] (paula.costa.agroforestry@gmail.com), Ziantoni V.[2]

[1] *Agroforestry, PRETATERRA, São Paulo, SP, Brazil*; [2] *Agroforestry, PRETATERRA, Timburi, SP, Brazil*

Agroforestry planning and design is fundamental for investment safety, especially for neo-rural entrepreneurs. An ecologic and economically sustainable regenerative agroforestry system was designed in Mar-Apr, 2018. Species were selected considering succession, stratification, and cash flow. Arrangement considered treetop architecture, permeability and area, as well as shade tolerance, lifecycle, root depth, nutrition and water need. Baseline ROI considered monocultural correlated systems. The final design is shown in figure 1. Composition of the system is: (a) pecan walnut, olive and yerba-mate (perennial); (b) *C. citriodora* and *T. ciliata* (timber), (c) pineapple (annual crop), (d) *G. sepium* and *I. vera* (service nitrogen fixing). For economical modelling, variables were systematized, encompassing costs of inputs, labor and equipment, schedules and complete life-cycle management operations. Overall CapEx and OpEx were obtained through benchmarking campaigns within the region. Crop expected yields were outlined proportionally considering integrated system ratios with realistic revenues. Results shown a ROI of 25.6%, NPV of U$ 26,288 and US$ 8,976 cost per ha. Payback in 6 years and cost-benefit ratio of 13.74. Prototype 20 first hectares were implemented in July, 2018. Integrated systems are more ecologically and economically resilient, presenting revenue diversification while maximizing cash flow. Scaling up adoption will depend on proper designed agroforestry systems.



Species	Legend	Arrangement (m)	Treetop area (m²)	Harvest years	Plant/ha	Expected Yield (per year)	
						m³/ha (MAI)	Kg/ha
Ananas comosus		4.0 x 2.0	0.25	1-3	1250	-	800
Carya illinoensis		8.0 x 16.0	64	8-22	78	-	3051
Ilex paraguariensis		8.0 x 2.7	30	4-22	469	-	4196
Olea europaea		8.0 x 8.0	45	6-22	156	-	2210
Corymbia citriodora		8.0 x 8.0	60	22	156	6.58	-
Toona ciliata		8.0 x 16.0	55	16	78	15.91	-
Gliricidia sepium / Inga vera		8.0 x 4.0	40	2-4-6	312	-	-

Agroforestry system composition, arrangement, and density, as well as harvest years and expected yield per species.

Keywords: agroforestry design, large-scale agroforestry planning, yerba mate, olive, pecan walnut.

References:

1. Jose et al., In: Toward agroforestry design, 2008, Springer, 3-12.
2. Alavalapati et al., 2004, Agroforestry systems, 299-310.
3. McAdam et al., In: Agroforestry in Europe. Current status and future prospects, 2009, Springer, 3-20
4. Eibi et al., 2000, Agroforestry systems, 1-8. DOI: 10.1023/A:1006299920574

L17.P.13

The effect of organic matter additions on soil properties and cocoa production

Fungenzi T. (thomas.fungenzi@gmail.com), Sakrabani R., Burgess P.

Environment and Agrifood, Cranfield University, Cranfield, United Kingdom

Introduction

Most cocoa in Indonesia is grown in agroforestry systems providing permanent canopy cover which protects the soil (Smiley and Kroschel, 2010). Despite this, yields are constrained by declining soil fertility (Hartemink 2005; Jagoret et al., 2011). Although soil organic matter (SOM) levels tend to increase during the development of cocoa trees, they remain low. In Indonesia, producers have therefore asked for more information on the effect of organic matter additions on SOM and cocoa production.

Methodology

In response, a three-year research project has been developed to determine the relationship between organic matter additions, soil fertility and cocoa production. Because the long-term effects of organic additions cannot be determined in three years, a modelling approach is being used with additional field measurements in Sulawesi, home to about half of Indonesian cocoa production. This paper briefly describes the current progress regarding the modelling of the system.

Results

After establishing the above objectives, the next step was to determine the main criteria for the proposed model. There is a need to model both the impact of organic matter additions on soil properties and the resulting effects on cocoa yield. An example of a cocoa growth and production model is CASE2 (Zuidema & Leffelaar, 2002). Inputs such as litterfall, dead roots and branches will then serve as inputs for a SOM dynamics model. Examples of potential soil organic matter models include TAO and MOMOS. The TAO model can be used to describe the transformation of added organic matter in soil. MOMOS is a process-based model for carbon and nitrogen transfers in SOM (Pansu et al. 2004). To evaluate the impact on cocoa production, these soil changes will be fed back into the cocoa growth model. The effects of locally available amendments such as compost and manure are being included in the study through different scenarios. The planned results include validated simulations of the effects of organic addition on long-term SOM stocks and the consequences for cocoa production.

Keywords: cocoa production, soil organic matter, modelling, organic amendments, agroforestry.

References:

1. Hartemink, A. E. (2003). Cabi
2. Jagoret P et al. (2011). Agroforestry Systems, 81(3), 267-278.
3. Pansu M P et al. (2004). Global Biogeochemical Cycles, 18(4), 1-11.
4. Smiley GL, Kroschel J (2010) Agroforestry Systems 78, 97–114.
5. Zuidema, P. A., & Leffelaar, P. A. (2002). Report number 318476.

L17.P.14

Organoleptic quality of Ethiopian Arabica coffee deteriorates with increasing intensity of coffee forest management

Geeraert L.[1] (lore.geeraert@kuleuven.be), Berecha G.[2], Honnay O.[1], Aerts R.[1]

[1] *Biology, KU Leuven, Leuven, Belgium*; [2] *Horticulture and Plant Science, Jimma University, Jimma, Ethiopia*

Arabica coffee (*Coffea arabica* L.) grows naturally as an understory shrub in the moist evergreen montane forests of Southwest Ethiopia. In response to an increasing local human population pressure and a growing coffee demand on the world market, coffee producing forests are increasingly managed to boost coffee yield. We compared organoleptic coffee quality between natural coffee producing forests, large coffee agroforests, and small coffee agroforests. Accounting for variability in Arabica coffee genotype and environment, we found that blind consensus scores, given by a panel of certified Q-Grade cuppers, were negatively affected by increasing forest management intensity. Importantly, only coffee from natural coffee producing forests qualified as specialty coffee following the Specialty Coffee Association of America's standards. We suggest that the most important drivers of deteriorating coffee quality include decreased shade levels and changing micro-climate and biotic interactions. Due to the low yields of coffee in natural coffee producing forests and the lack of quality price premiums, Ethiopian smallholder farmers are inclined to optimize for coffee quantity, rather than for quality, causing a significant challenge for the conservation of Ethiopian natural coffee producing forests.

Keywords: Afromontane forest, Agroforestry, Coffea arabica, Crop wild relative, Cup quality.

L17.P.15

Nutritional quality of Canarium nuts and cocoa beans in an agroforestry system in Pacific

Hosseini Bai S.[1] (shossein@usc.edu.au), Hannet G.[2], Hannet D.[2], Nevenimo T.[2], Kapi S.[2], Wallace H. M.[3]

[1] *Central Queensland University, Branyan, QLD, Australia*; [2] *NARI, Keravat, Papua New Guinea*; [3] *University of the Sunshine Coast, Maroochydore, Australia*

Plant species selection and spacing regimes are two of major challenges to design a successful agroforestry system to maintain high nutritional security. Cocoa is considered an important cash crops worldwide. The cocoa trees are usually planted with shade trees. However, it is important that neighbouring trees would not negatively affect nutrient concentrations of crops. In this study, two shade trees were chosen as shade trees for cocoa trees including *Gliricidia sepium* and *Canarium indicum*. Canarium trees also produce canarium nut which are highly nutritious. This study was undertaken in Papua New Guinea, 8 years after agroforestry system establishment. This study aimed to investigate the nutrient concentrations of cocoa beans and canarium nuts planted under different spacing regimes. The spacing regimes of canarium trees were either 8 m × 8 m or 8 m × 16 m and the spacing regime of the *G. sepium* trees was 12 m × 12 m. The effects of shade tree species or spacing regimes on nutrient concentrations of cocoa beans were not consistently similar. For example, cocoa beans had higher phosphorus concentrations next to *G. sepium* trees and *C. indicum* trees with spacing of 8 m × 8 m compared with those next to *C. indicum* trees with spacing of 8 m × 16 m. Calcium concentrations of cocoa beans was not affected by shade trees nor spacing regimes of canarium trees. Nutrient concentrations of canarium nuts were not also affected by being planted next to cocoa trees. Therefore, agroforestry system designed in this study were acceptable to sustain food quality.

L17.P.16

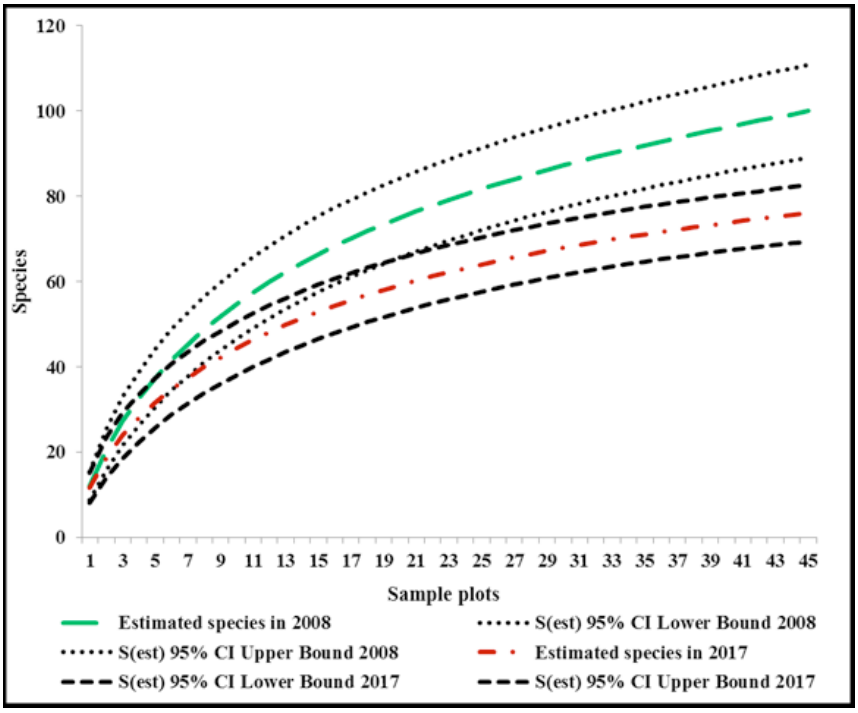
Can coffee based agroforestry conserve native biodiversity? Evidence of exotics replacing native trees

Kushalappa C. G.[1] (kushalcg@gmail.com), Bhavya C K[2], Rahghuramulu Y[3], Philippe V.[4], Garcia C.[5], Nanaya K. M[6]

[1] *UAHS(S), Collage of Forestry, Ponnampet, Karnataka, India*; [2] *Forest Biology and Tree improvement, UAHS(S), Collage of Forestry, Ponnampet, Karnataka, India*; [3] *Coffee board of India, Bangalore, India*; [4] *CIRAD, UMR Eco&Sols, Montpellier, France*; [5] *CIRAD, UR Forest & Societies; ETH Zurich, Montpellier, France*; [6] *UAHS(S), Collage of Forestry, Ponnampet, India*

Coffee based agroforestry (CAF) is been promoted as a conservation friendly land use system with immense potential to conserve native tree species. In the western ghats, these coffee based agroforestry farms have proven to harbor over 250 species of tree. Recent trends in cultivation practices and policy changes has motivated the farming community to increase productivity of coffee through intensification of tree management. Intensification comes at a cost to the numerous ecosystem services provided by the system including biodiversity conservation services.

The present study builds upon the baseline data collected on tree species across 11 farms of western ghats in 2008 as part of CAFNET project. The farms were revisited in 2017 and the results show all attributes that promote biodiversity conservation have a declining trend. The density of trees reduced from 420 trees ha-1 to 274 tree ha-1. Species richness reduced from 100 to 76 tree species, canopy cover reduced from 59 to 46 per cent and most importantly the study documents that native tree species are being gradually replaced by exotic tree *Grevillea robusta* which has increased from 19 to 29 per cent of all tree found in the CAF farms. These trends ascertain *Grevillea robusta* as the most dominant tree in the system. This dynamics has numerous practical implications for the future of CAF system as a conservation friendly land use system, as the trade-offs between biodiversity conservation and coffee production widen.



Species accumulation curve for 2008 and 2017 in coffee based agroforesty farms.

Keywords: Coffee based agroforestry, western ghats, biodiversity conservation, Grevillea robusta, dynamics.

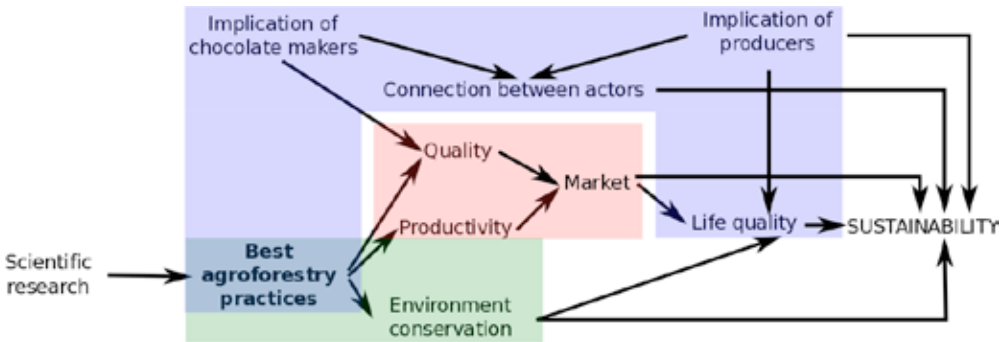
L17.P.17

Developping sustainable cocoa production in a damaged country: challenges and opportunities.

Laigle I. (idaline.laigle@gmail.com), Le Heurt G.

La finca brava SAS, Bucaramanga, Colombia

Colombia produces less than 1% of the world cocoa total production while presenting similar environmental conditions than Ecuador known for its high quality cocoa. Colombia is just going out from years of drugs trafficking war. Therefore, it presents today great opportunities to developp a cocoa production on good foundation. We have the ambition to develop and structure the production of a sutainable and ethic high quality cocoa. However, its yet complex socio-political situation lead to several challenges. We will present how we will overcome these challenges thanks to agroforestry and collaborative transnational teamwork. Cocoa agroforests have demonstrated high potential for sustainable cocoa production. However, knowledge about cocoa production in Colombia is scarce because of the situation of conflict that avoided scientific research. We will then undertake studies to determine best agroforestry practices for biodiversity, cocoa quality and productivity. We will provide information and support to often undereducated producers. To motivate them in the long term it is crucial to adapt these practices to their counstraints and objectives by involving them in decision making. Practices should also improve their wealth by including economic valuable tree species and giving them access to certification. Finally, we will boost a sustainable market by creating strong associations between Colombian producers and chocolate makers from Belgium and France.



Conceptual map of the project. The economical dimension is in red, the environmental one is in green, and the human one is in blue.

Keywords: Cocoa, sustainable, colombia, human dimension.

L17.P.18

Conservation of cacao intraspecific diversity in *la Convención* province, Peru

Lavoie A.[1] (andreanne.lavoie.3@ulaval.ca), Olivier A.[1], Thomas E.[2]

[1] *Department of plant science, Laval university, Québec, Québec, Canada*; [2] *Bioversity International, Lima, Peru*

Cacao plays a significant role in the lives of more than 20 million smallholder farmers (CacaoNet, 2012). It originates from the upper Amazonian rainforest (Thomas et al., 2012), where people quickly began interacting with its wild populations to create multiple varieties (Bergmann, 1969). Its diversity holds the potential to improve the productivity and quality of cacao production, as well as its capacity to resist biotic and abiotic stress factors.
Fieldwork was conducted in *la Convención* province in Peru in order to determine the extent of cacao diversity conservation on farms. We are especially looking at how management practices impact that diversity. Our long-term objective is to develop a typology of the cacao-productive systems to document which ones allow for the most effective intraspecific conservation in this area.
We conducted interviews with experts and questionnaires with farmers, complemented by field visits and collection of leaves samples, in spring 2018. Our results indicate that farmers are maintaining various subtypes of *chuncho*, a native variety, along with hybrids. Farmers have adapted their management to each variety. Their motivations behind on-farm conservation appear to be related to their desire to meet market preferences and their pride to maintain native diversity. However, this conservation also seemed to be influenced by the genetic material provided through development projects.

Cacao Chuncho

Keywords: Cacao, Intraspecific diversity, On-farm conservation, Peru, Management practices.

References:

1. Bergmann, 1969, Ann. Am. Assoc. Geogr., 59(1), 85–96.
2. CacaoNet, 2012, Bioversity International.
3. Thomas, et al., 2012, PLoS ONE, 7(10), e47676. https://doi.org/10.1371/journal.pone.0047676

L17.P.19

Developping sustainable cocoa production in a damaged country: challenges and opportunities.

Le Heurt G. (presidencia.lafincabravasas@gmail.com)

La Finca Brava Sas, bucaramanga, Country

Colombia produces less than 1% of the world cocoa total production while presenting similar environmental conditions than Ecuador which is famous for its high quality cocoa. Colombia is a very new market all in all as it is just going out from years of war for drugs trafficking, which make the challenges very interesting from a social and cultural perspective point. Furthermore the very high positionning of its coffee worlwide show us that the Country has succeeded to overcome various barrieres in the past in terms of international trade conditions and specifications. Therefore, it presents today great opportunities to developp a cocoa production on good foundation. Based on these observations and after a long journey of first-hand investigation we have the ambition to develop and structure the production of a sutainable and ethic high quality cocoa. However, the lack of knowledge and know how about cocoa production and its yet complex socio-political situation lead to several challenges to overcome, and we have identified three main ones. We aim to offer a new model of colaboration and practices within the colombian cocoa value chain thanks to agroforestery and collaborative transnational teamwork. The challenges are as follow:
1: The asymetry of information that can be resolved by solid and perrenial associations between colombian producers and french, belgium chocolate makers.
2: The lack of formation and discipline of the producers that can be overcomed by new educating system based on different methodologies that have been proved functionning in other sector as in the coffee industry in Colombia, and by involving the producers through the all process with more participation and critical decision making.
3: Colombia being now able to design and mold its new economic path thanks to the very recent Peace agreement (2017) gives us an opportunity to fill the gaps in terms of investigation and research (specially in the agriculture sector). Since there has been no investigation towards the effects of several agroforestry practices on biodiversity, quality and productivity of cocoa plantations in the past, we are determined to bring scientific and empirical insights to the developpment of its cocoa sector as a whole.
And to secure a smooth transition to a new way of growing and living for the producers we have ensured the integration of an expert team that would have the objective to coach them through this cultural transformation process with conflicts resolution protocoles and psicho-social plans to mitigate any kind of reluctant behaviors in other words, to avoid any tensions emerging from these new social and economical alternatives offered to the producers. Integrating them as much as possible into the definition of what should be the next steps for them once the project is over should garantee a continuity to our actions and allow them to decide with assertivness of their futur, socially, economically and as individuals and/or as a group.

Keywords: empowerment, cacao, agroforestery, asociativity, social transformation.

L17.P.20

Shade and pollination benefits within Ghanaian smallholder agroforestry: social, governance, and entomological evidence

Maguire-Rajpaul V. (victoria.maguirerajpaul@ouce.ox.ac.uk), Morel A.

Environmental Change Institute, University of Oxford, Oxford, United Kingdom

Smallholders in Ghana grow almost one quarter of the world's cocoa. Yet, intense cultivation has deforested Ghana's tropical south. As cocoa's natural habitat is in rainforests' lower storey, shade is essential for cocoa's continued supply to the global chocolate industry. Accordingly, agronomic officers who promote 'climate-smart' cocoa in our interviews aim to instruct farmers to maintain 16-18 shade trees per hectare. But in practice, few farmers receive this agroforestry recommendation, and fewer can maintain such shade tree density. This presentation elucidates socio-economic obstacles that impede smallholders from practicising their desired agroforestry.

Shade and pollination play important roles for cocoa yields and thus, farmer livelihoods. *Theombroma cacao L.* is strictly entomophilius whereby cocoa's fruiting depends on pollinating insects. We set up pollinator traps at 108 cocoa trees on 36 farms over 3 years to decipher how insect-mediated cocoa pollination: 1) depends on habitats in immediately surrounding forests; and 2) was affected by 2015-16's El Niño drought. We monitored interactions between forest biomass and pollinator abundance, and height from forest floor to understand agroforestry's cocoa-pollinating benefits, if any. Rather than Ceratopogonidae, we found a higher abundance of Cecidomyiidae. Our analysis suggests that pollination-enhancing techniques by farmers could boost cocoa yields and thus incomes, which could lower pressure on remaining forest.

Pollinator traps at 108 cocoa trees on 36 farms over 3 years

Keywords: smallholder, shade tree, Ghana, cocoa, pollinator.

References:

1. Hirons et al., 2018, Land use policy, 76, 405-413.
2. Schroth et al., 2016, Science of the Total Environment, 556, 231-241.
3. Frimpong et al., 2009, International Journal of Tropical Insect Science, 29(2), 62-69.
4. Adjaloo & Oduro, 2013, Journal of Applied Biosciences, 62, 4582-4594.
5. Asare et al., 2018, Climate and Development, 1-11.

L17.P.21

BREEDCAFS (Breeding Coffee for Agroforestry Systems) project in Vietnam

Marraccini P.[1] (marraccini@cirad.fr), Vaast P.[2], Nguyen H.[3], Nguyen C.[4], Vu T.[4], Nguyen T.[4], Nguyen V.[4], Nguyen D.[5], Do V.[5], Georget F.[6], Luu Q.[3], Etienne H.[6], Bertrand B.[6]

[1] *UMR IPME, Cirad, Hanoï, Vietnam*; [2] *UMR Eco&Sols, Cirad, Hanoï, Vietnam*; [3] *NOMAFSI, Phu Tho, Vietnam*; [4] *NOMAFSI, Son La, Vietnam*; [5] *AGI, Hanoï, Vietnam*; [6] *UMR IPME, Cirad, Montpellier, France*

Objective
The BREEDCAFS project plans to test F1 hybrids of *Coffea arabica* - high yielding, stress resistant and adapted to agroforestry - in coffee producing countries, such as Vietnam.
Materials
Several F1 hybrids (provided as *in vitro* plantlets, Fig.A) were sent from Agristart (USA) to Hanoi where they were acclimatized (Fig.B). Then, these plants were sent to NOMAFSI greenhouses (Mai Son, Son La province) where they were transferred in plastic bags to speed-up their development (Fig.C).
Methods
In order to study the responses of these F1 hybrids to abiotic stresses, a field experiment was set-up in the NOMAFSI station by planting these hybrids, as well as local varieties (i.e. catimor), under shade and full-sun conditions (Fig.D). In 2019, controlled irrigation and water withdrawal system (mimicking drought periods) will be implemented, therefore permitting to monitor regularly physiological traits (water status, photosynthetic efficiency, stomatal conductance, etc.) and molecular (transcriptomic) of hybrids and control plants. In order to test the responses of F1 hybrids to environmental conditions and farmers' management, twelve smallholder farms were also selected in the NW provinces of Son La and Dien Bien Phu to set-up the farmers' field trials under different altitudes (ranging from 600 to 1100m) and agroforestry systems (Figs.E-F). These trials were planted in June 2018 and should produce their first and significant production in 2021.

http://www.breedcafs.eu

Keywords: Coffea arabica, F1 hybrid, agroforestry, Vietnam.

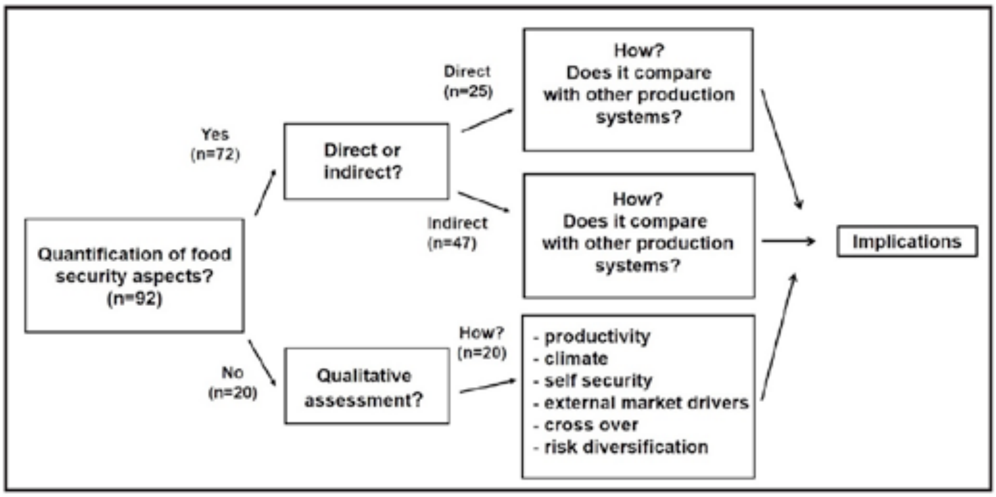
L17.P.22

Assessing food security and ecosystem services in multifunctional land-use systems

Mattsson E.[1] (eskil.mattsson@ivl.se), Ostwald M.[2], Nissanka S.P[3]

[1] *IVL Swedish Environmental Research Inst., Gothenburg, Sweden*; [2] *Chalmers University of Technology, Gothenburg, Sweden*; [3] *University of Peradeniya, Peradeniya, Sri Lanka*

In Sri Lanka, homegardens constitute a majority of the country's total annual crop and timber production. Despite Sri Lankan homegardens are considered desirable and sustainable land-use systems, the scientific evidence of its role for food security is not yet totally clear. By synthesising articles from scientific databases we investigated the links between homegardens and food security, in terms of quantifying homegarden products or ecosystem services, and identifying whether the characteristics of food security are assessed as direct- or indirect impacts, synergies or trade-offs. The indirect effects are the most commonly assessed impacts in the literature. These services are described as adaptation to climate change or a variety of ecosystem services such as increased carbon uptake, increased rainfall infiltration capacity and reduced soil erosion; all relevant characteristic for food production and sustainable food security. Our findings show that correlation between food security and ecosystem services is a fruitful way to assess synergies and trade-offs of these multifunctional land-use systems. However, many studies are descriptive and only provide location-specific information on single research focuses such as plant species, yield and management. Our data suggest a higher degree of inclusiveness of relevant stakeholders aligned with system approaches and long-term assessments would generate greater output of homegardens in terms of food security.



Keywords: agroforestry, Sri Lanka, trees, crops, landscape.

L17.P.23

Sustainable coffee agroforestry in adverse climatic conditions in Nicaragua

Padovan M. P.[1] (padovan@incaper.es.gov.br), Brook R. M.[2], Barrios M.[3], Cruz-Castillo J. B.[4], Galeano E. A. V.[5], Rapidel B.[6]

[1] *INCAPER, Vitoria, ES, Brazil*; [2] *Bangor University, Bangor, Gwynedd, United Kingdom*; [3] *CATIE, Managua, Nicaragua*; [4] *Universidad Nacional Agraria, Managua, Nicaragua*; [5] *INCAPER, Vitória, ES, Brazil*; [6] *CIRAD, Montpellier, France*

Coffee production has been threatened by increasing climate variability. Shaded coffee has been suggested as a promising strategy to cope with the effects of global climate changes. However, potential competition for water between coffee and shade trees and lower coffee yields under shade are among the main constraints of coffee agroforestry. Most advantages attributed to agroforestry are focused on ecological issues; little is published on ecological and economic aspects combined. This investigation analyzed and compared ecological and economic performance of unshaded arabica coffee (NS) and shaded (AFS) by a mixture of evergreen *Simarouba glauca* DC. and deciduous *Tabebuia rosea* Bertol. Both tree species are widely utilized for timber and other products but are poorly studied.

The study was carried out during 2012 and 2013, in a 12-year old agroforestry experiment in sub-optimal coffee growing conditions (27^{0}C mean annual temperature, 455 m altitude and 1470 mm annual rainfall) in Masatepe, Nicaragua. Water consumption by soil evaporation and coffee and tree transpiration was measured by using weighing lysimeters and the stem heat balance sap flow method, respectively. Coffee production over the 10-year period prior to the study was used to determine coffee economic performance. Timber production from four shade trees of each species in the study site was measured and results were extrapolated for the whole plot by using population density.

The AFS system was a more efficient water user than NS. Shade trees had the effect of reducing by 31% water loss from soil evaporation compared to NS, which represented more water available for coffee. Transpiration was greater in AFS plots; however, most of the water was transpired by coffee rather than by shade trees or evaporated from the soil. Temporal complementarity in water use between coffee and shade tree was observed with higher shade tree water consumption in the wet season contrasted with greater water use by coffee in the dry. Contrasting precipitation patterns in the two consecutive years of the study demonstrated competition for water only by the end of the very dry season in 2013. Evergreen shade tree characteristics seemed to be more suitable as coffee shade compared to deciduous in such environmental conditions.

Coffee production in AFS was 18% lower than NS from data averaged over 10 years. However, the lower coffee yield in AFS was compensated by greater productivity of the whole system. By the end of the experiment, 13-year old shade trees produced 125 m^3 ha^{-1} of timber from *Simarouba glauca* and 98.5 m^3 ha^{-1} from *Tabebuia rosea* (US$173 per m^3 local price). Further income could be derived from the firewood extracted over time. Therefore, both ecological and economic aspects showed advantages compared to the no-shade system, which suggests agroforestry with timber trees as an attractive system of land use for farmers in the sub optimal coffee growing conditions studied.

L17.P.24

Can Insetting create a win-win partnership between chocolate makers and cocoa farmers ?

Plédran O.[1] (oriane.pledran@gmail.com), Phélinas P.[2], Torquebiau E.[3]

[1] *Université Paris Diderot - CESSMA, Paris, France*; [2] *Université Paris Diderot - CESSMA / IRD, Paris, France*; [3] *AIDA, CIRAD - Université Montpellier, Montpellier, France*

Insetting is a way for chocolate makers to compensate their carbon emissions by financing the plantation of trees in supplying cocoa farms. It appears as a new way to finance agroforestry but also to create a link with producers and secure cocoa supply. However, whether insetting contributes to reduce smallholders' vulnerability and increase their fidelity is an empirical question that has to be addressed. A survey has been conducted in Peru (100 producers, 3 focus groups) to assess the benefits of the insetting programs and the challenges that remain. Results show that the partnership developed through the insetting program contributes to alleviate some difficulties preventing farmers to adopt agroforestry practices. However the implementation can be tricky and complex. Since insetting programs are based on a tripartite model dissociating the wood and the cocoa component, the planting of trees alone does not increase farmers' loyalty. In addition, an inadequate implementation might not impact farmers' vulnerability and could therefore lead to a negative vision of agroforestry.
Insetting can be a viable financing solution for agroforestry dissemination but cannot be dissociated from an holistic approach of the farm focusing on a joint management of the crops. Alleviating poverty in rural cocoa communities requires also to break out of the carbon paradigm and to turn towards bottom-up approaches favouring social considerations and mid-term visions.

1: Games during focus groups ; 2: a cocoa farmer

Keywords: Cocoa, Agroforestry, Insetting, Vulnerability, Contract farming.

References:

1. Banerjee A., et al., 2013, CIAT Policy Brief No. 12, 6 p.
2. Blare, T. et al., 2014, MEAS Case Study, 15p. doi : 10.13140/2.1.1895.5847
3. Fraval, P., 2000, MAE, Dir. générale de la coop. int. et du développement, 91 p.
4. Meckling, W. et al., 1976, Journal of Financial Economics 3 (4) : 305-60
5. Torquebiau, E.,Changements climatiques et agriculture du monde, 2015, Ed. Quae, 327 p.

L17.P.25

Soil ecosystem services of the under different uses in the Colombian Amazonia

Rodriguez Suárez L.[1] (l.rodriguezsuarez@outlook.com), Suárez Salazar J. C.[1], Casanoves F.[2], Ngo Bieng M. A.[3]

[1] *Universidad de la Amazonia, Florencia, Colombia*; [2] *CATIE, Turrialba, Costa Rica*; [3] *CIRAD, UR Forêts et Sociétés, Turrialba, Costa Rica*

Background
Agroforestry systems (AFs), where agricultural and livestock crops are associated with woody plants, are known as sustainable systems, that conserve biodiversity and improve the provision of ecosystem services without compromising productivity. This work focuses mainly on cacao AFs, which have been related to different ecosystem services in tropical regions. Especially, our study focuses on the ability of the cacao AFs to improve soil ecosystem services in the Colombian Amazon region. We focused on soil ecosystems ecosystem services in the Colombian Amazonia because: of the social importance of cacao production system in the study region, specifically within the post conflict context; the lack of knowledge on the capacity of cacao AFs to offer soil ecosystem services in the study zone and its capacity in restoring ecosystem services in degraded soils.
Aim
The objective of our work was to evaluate the soil quality in different cacao agroforestry systems in the Colombian Amazonia, and to compare these evaluated soil quality of soil quality in Forest and Pasture.
Material and methods
The study was conducted at the Macagual Amazon Research Center, located west of the Colombian Amazon. We evaluated soil quality in four types of AFs Cacao, presenting different establishment, composition and structural characteristics; but also in a plot of native forest composed of characteristic species of the area, and in a plot of pasture composed of grasses. In the different plot of each land use, we evaluated the diversity of macrofauna, the morphology of aggregate, the physical properties and the soil chemistry. We summarized these variables in a General Indicator of Soil Quality GISQ, characterizing soil quality in the different land uses.
Major results and Conclusion
It was found that the level of intensification among land uses (Bosque>AFs>Pasture) affects the decrease of the macrofauna populations, which was related to soil compaction (physical properties). Chemical fertility improved with the establishment of AFs influenced by the application of amendments and organic fertilizers. When establishing agroforestry systems from pasture areas at a certain level of degradation, the GISQ scale was found to increase by 42%. Our results indicate that AFs practices can definitely be used as a restoration strategy, for the recovery of degraded areas.

L17.P.26

Functional traits approach for characterizing woody species that can be integrated to cacao crops in Santander, Colombia

Rojas Molina J.[1] (jrojas@agrosavia.co), Perez Zuñiga J. I.[2], Monsalve Garcia D. A.[3], Mompotes Largo E.[3], Ospina Hernandez S. D.[4], Carvajal A. S.[5]

[1] *Corporación colombiana de Investigacion, Agrosavia, C.I La Suiza, km 32 vía al mar, Vereda Galápagos, Rionegro, Santander, Colombia*; [2] *Corporación colombiana de Investigacion, Agrosavia, C.I El Mira, km 38 vía Tumaco-Pasto, Nariño, Colombia*; [3] *Corporación colombiana de Investigacion, Agrosavia, CI El Nus, corregimiento San José del Nus, vía Cisneros-Puerto Berrio, San Roque, Antioquia, Colombia, Antioquia, Colombia*; [4] *Corporación colombiana de Investigacion, Agrosavia, C.I Palmira. Diagonal a la intersección de la carrera 36 A con calle 23, Palmira, Valle del Cauca, Valle del Cauca, Colombia*; [5] *Campo Montecillo, Colegio de Posgraduados, Mexico, Mexico*

There is evidence that not all woody species have the same function in ecosystems and that this is related to their plant functional traits and the abundance of these traits in the community. In order to contribute with functional knowledge to the design of agroforestry systems for cacao, plant functional traits of woody species, specific leaf area (SLA), total height (TH), penetration resistance (PR), leaf nitrogen concentration (LNC) and leaf phosphorus concentration (LPC) were measured according to Pérez-Harguindeguy et al. (2013) y Cornelissen et al. (2013) for five common woody species found within a range of cacao production systems in Santander (Colombia). A variation range of the woody species along an axis of resource acquisition and competitiveness, represented by species with less trunk hardness (higher PR) and high diameter at breast height was identified. In the opposite side, species with less foliar phosphorus concentration and diameter at breast height and higher trunk hardness (lower PR). *Albizia guachapele* present higher SLA, followed by *Cedrela odorata* and *Cordia gerascanthus*. In this sense and according to global ecological findings about SLA and its correlations these species have morphological traits for high photosynthetic rates. *Erythrina fusca* was the most different species according to its traits variation in a PCA. In the cacao region of Santander, these species had the higher potential for a photosynthetic answer given its less investment in wood structure or penetration resistance. The woody species that in cacao agroecosystems of Santander are more usually found: *C. odorata, C. gerascanthus, E. fusca, A. guachapele* and *Schizolobium parahyba* were explained by 57% of the trait variation in a PCA. At the same time, it is important to mention that the presence of the five common woody species in the region are also evidence that farmers had been slightly driving the woody species selection by given more attention to plant traits related to fast growth that can offer shade and companion and conserve the cacao crop productivity (Figure 1). The diameter at breast height as a common woody species measurement should be accompanied by the determination of SLA and other plant functional traits that contribute bridging knowledge to improve the design for multifunctional agroforestry systems that integrate the functional tree biodiversity in cacao production systems.

Keywords: Functional traits, specific leaf area, productivity, cacao, agroforestry systems.

References:

1. Cornelissen, J.H.C., Lavorel, S., Garnier, E., Diaz, S., Buchmann, N., Gurvich, D.E,. Reich, P.B., S
2. Pérez-Harguindeguy, N., Díaz, S., Garnier, E., Lavorel, S., Poorter, H., Jaureguiberry, P., Bret-Har

L17.P.27

Vanilla: between omnipresence and techno-economic vulnerability, realities of «black gold» in the Guadeloupe undergrowth

Romane C.[1] (jean-louis.diman@inra.fr), Vinglassalon A.[2], Apatout M.[2], Latchman C.[3], Hammouya D.[1], Arsens S.[2], Tormin P.[2], Diman J.-L.[1], Bezard M.[2]

[1] *PEYI, INRA, Petit-Bourg, Guadeloupe, France*; [2] *SYAPROVAG, Petit-Bourg, Guadeloupe, France*; [3] *GDA EcoBio, Baie-Mahault, Guadeloupe, France*

The VALAB initiative (Integrated Valorization of the Agrobiodiversity Ecosystem in the Guadeloupe Forest) is led by the union of vanilla producers of Guadeloupe (SYAPROVAG), a special look has therefore been devoted to the cultivation of this orchid strongly represented in agroforestry systems enhancing the guadeloupean undergrowth.
A qualitative survey was conducted among the region's vanilla producers to better understand their productive strategies. The technical practices are described and the technical and economic conditions of their implementation are characterized.
Cultivation techniques remain traditional, a legacy of old know-how without mechanization or synthesis inputs, and are very demanding quantitatively and qualitatively in terms of labor (for closure, sizing of hanging ends, pollination, scarification, drying, ripening, etc.). These techniques, not always mastered, cause large differences between plots, the climate creating in addition interannual productive variations.
Today, Guadeloupean vanilla production does not cover local demand (tourism, gastronomy, cosmetics...). The challenge is to improve technical control and, more generally, reduce the vulnerability of cropping systems implemented in particular by their diversification.

	Ad. Value/ha (€)		Ad. Value/plant (€)		Ad. Value/manxday (€)	
	Mini	Maxi	Mini	Maxi	Mini	Maxi
Without agroprocessing	125	1'250	0,05	0,5	0,9	9,0
With agroprocessing	1'400	21'000	0,56	8,4	10	634

Table 1: Variability of performance for some economic indicators in vanilla production in Guadeloupe (Chaigneau, 2018).

Keywords: Vanilla, cropping systems, technical management, Guadeloupe, economic indicators.

L17.P.28

What Barriers to the Adoption of Biodiversity-Friendly Cocoa?

Ruf F. (francois.ruf@cirad.fr)

ES, CIRAD, Montpellier, Fance

Although not fully demonstrated, one can assume that the collapse of biodiversity linked with 'monoculture-like' systems does contribute to negatives externalities such as fertility loss, increasing pressure from weeds, pests and diseases (for instance pests switching to the mono-crop because of the disappearance of their original host trees in natural forest). Finally these environmental externalities are re-internalized. Producers who use these 'monoculture-like' systems are frequently hit by rocketing maintenance costs and additional replanting costs.
One can thus assume that systems favouring certain forms of diversification and biodiversity make ecological and economic sense, and result in better cocoa sustainability in all senses of the term, including farmers' revenues and patrimony. Under these assumptions, what are the barriers to 'biodiversity-friendly cocoa'? What conditions are needed to make biodiversity-friendly cocoa' production a mainstream business? Are research and extension services able to offer technical alternatives to smallholders? Are these alternatives really economically efficient in the short term and can they be adopted by farmers?
Besides a review of the literature, the method is based on small samples of cocoa farms (40 to 100) surveyed between the late 1990s and the mid-2010s.
One possible option would be to combine certification of biodiversity-friendly cocoa and that of timber trees owned, planted and regenerated by smallholders (a kind of PSE). This double certification could reduce costs and perhaps serve a springboard for timber-cocoa systems. However, in the long term, the most elegant and widely-applicable solution would be to contribute to an institutional environment in which farmers would wish to regenerate and plant timber trees themselves. To achieve this goal, the first condition is to 'allow' farmers full access to timber markets, which implies they would receive the full market price for their timber.

Keywords: Deforestation, Monoculture, timber, tree-tenure, agrochemicals.

References:

1. Amanor, K.S., 2005. Equity in forest Benefit sharing and poverty alleviation. In: Nketiah, Ameyaw, O
2. Asare, R., 2005. Cocoa Agroforests in West Africa: a look at activities on preferred trees in the fa
3. Boni, S., 2005. Clearing the Ghanaian forest: theories and practices of acquisition, transfer and ut
4. Ruf, F , Deheuvels, O, and D. Sarpong, 2006. Intensification in cocoa cropping systems: is Agrofores
5. Sonwa D, Weise S, 2018. Structure of cocoa farming systems in West and Central Africa: a review. Agr

L17.P.29

Simple individual based model to unravel complex agroforestry systems, case of banana and cacao systems in Talamanca

Salazar-Diaz R.[1] (risalazar@tec.ac.cr), Tixier P.[2]

[1] *ITCR, Cartago, Costa Rica*; [2] *CIRAD, Montpellier, France*

To improve the management of complex agroforestry systems, it is crucial to understand how plants interact. However, in such complex systems, methods to disentangling plant interactions are lacking.The aim of this study was to address the questions: how the spatial structure of the plant community affects yields? We present an original individual-based statistical approach that allows the assessment of interactions in highly complex agroforestry systems. We applied our methodology in 19 plots in farmer fields in Talamanca, Costa Rica to analyse the effect of the structure of the plant community in the neighborhood of each individual cacao tree and banana plant on their yield. We found that the distance at which other trees alters the yield of banana or cacao was greater for fruit or wood trees than cacao trees or banana plants. Interestingly, higher strata trees had a smaller effect than lower strata trees, suggesting that moderate densities of tall trees could be compatible with high banana and cacao production. On an applied perspective, our results suggest that productivity could be maximized by a reasonably number of plant species, and then we proposed new direction to organize fields in order to maximize the production of cash crops while providing supplementary income for farmers and ecosystem services. The complete linear model predicted about 60% of the variance of the average response of the potential yield to the neighboring plant assemblage.

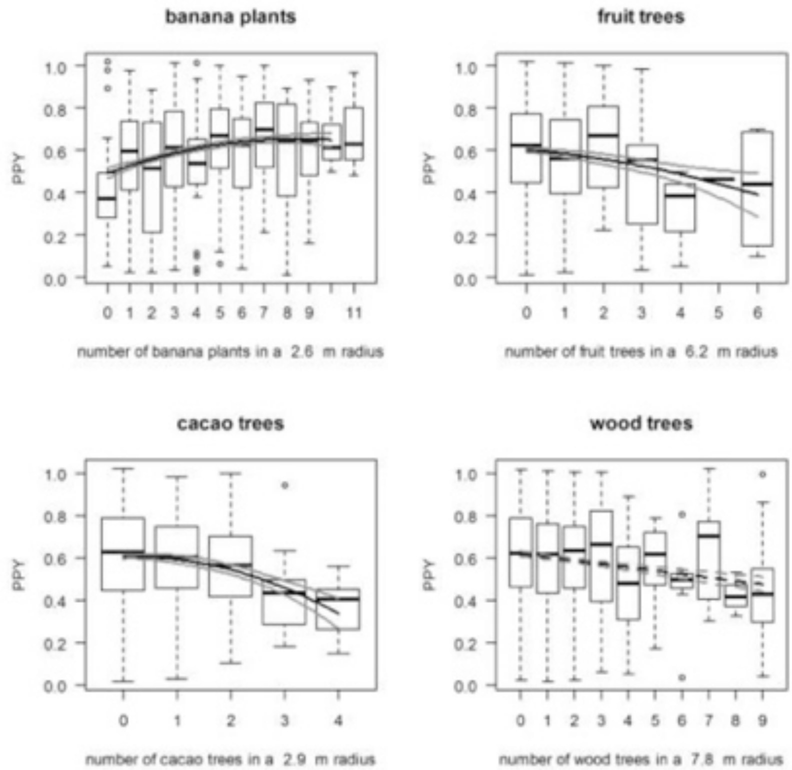


Figure 1. Model fit of the predictions of the proportion of the cacao potential yield (PPY) according to the number of banana plants in a 3.9 m radius, fruit trees in a 3.9 m radius, cacao trees in a 5.5 m radius, and wood trees in a 5.1 m radius. The black lines show the mean responses, and the grey lines show the standard errors predicted by the 'lmer' (dashed-lines show non-significant relations).

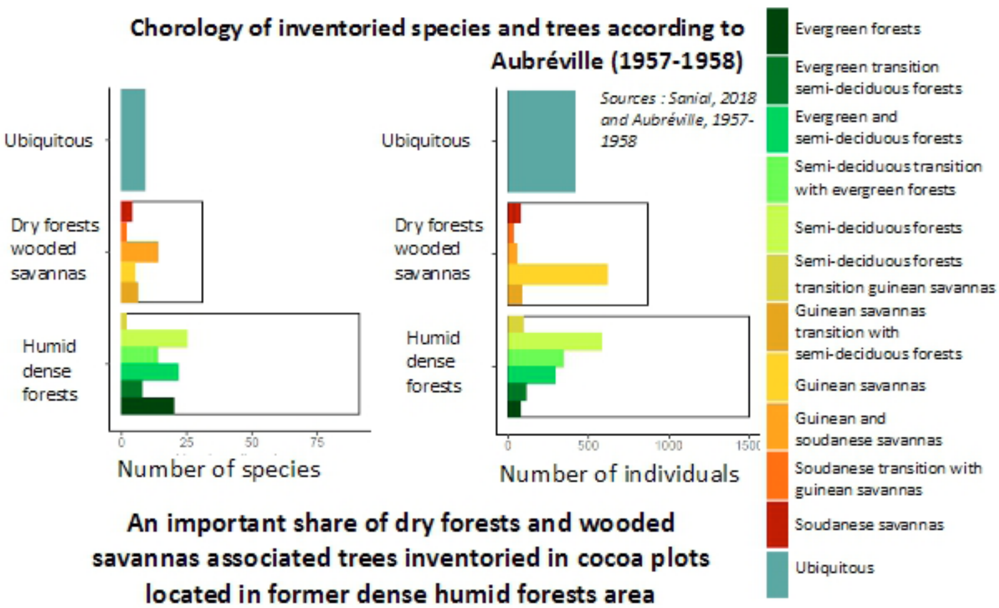
L17.P.30

Trees after the forests: agroforestry (re)adoption in a « post-forest » context. The case of ivorian cocoa

Sanial E. (elsa.sanial@univ-lyon3.fr)

Université Jean Moulin Lyon 3 and CIRAD, Lyon and Montpellier, France

Ivory Coast, producing 40% of world cocoa beans, has known wide conversion of forests into nearly monoculture systems under the progression of cocoa pionneer fronts. At the start of the XXIth century, it was considered that 90% of ivoirian cocoa orchard was grown in full sun conditions. However, cocoa producers are nowadays facing with a new environmental situation that could lead to the re-introduction of companion trees in their fields. Forest cover has almost completely disappeared, monocultures are showing their limits and recent climatic evolutions are less suitable to the crop. The conjunction of these different elements has led to a « *structural blockage* » (Leonard and Oswald, 1996) that could induce changes (innovative or not) in the way farmers grow cocoa.
This presentation, based on botanic inventories, interviews and diachronic mappings (1956-2017), analyses farmer's agroforestry practices at environmental and socio-political data crossroads. Results of 220 hectares botanic inventories will be presented to describe the structure of cocoa systems and illustrate which kind of « agroforests » farmers can (or desire to) re-built after years of monocropping. Then, environmental services (biodiversity, carbon storage, timber production) these light agroforests provide have been assessed. Finally, the drivers and constraints for present and future agroforestry are studied at landscape-level through geographic and diachronic studies in Divo and Soubré.



An important share of dry forests and wooded savannas associated trees inventoried in cocoa plots located in former dense humid forests area

Keywords: Theobroma cacao, Côte d'Ivoire, agroforestry, ecological intensification, environmental services.

References:

1. Léonard and Oswald,1996, Nature Sciences Sociétés, 202-2016
2. Sanial and Ruf, 2018, Human Ecology, 12, 10.1007/s10745-018-9975-0
3. Ruf, 2011, Human Ecology, 373-388, 10.1007/s10745-011-9392-0
4. Blaser et al., 2018, Nature Sustainability, 234-239, 10.1038/s41893-018-0062-8

L17.P.31

Volcanic ash deposits as test of resilience of agroforestry: short-medium term response to Mt Kelud eruptions, Indonesia

Saputra D. D.[1] (danie_soiler@yahoo.co.id), Sari R. R.[1], Widianto W.[1], Suprayogo D.[1], Hairiah K.[1], Van Noordwijk M.[2]

[1] *Soil Science, Brawijaya University, Malang, East Java, Indonesia*; [2] *Plant sciences, Wageningen University, Wageningen, Netherlands*

Short-term damage by ash deposits interacts with long-term soil fertility benefits. The eruption of Mt Kelud in 2014 affected a long-term study landscape. Soil organic carbon (SOC), soil texture, bulk density, porosity and macroporosity and soil infiltration had been quantified in 2007-2008 (before eruption/BE). Repeat measurements were made in 2017-2018 (after eruption/AE) in several land uses systems (LUS), including: Remnant Forest (RF), Complex Agroforestry (CAF), Simple Agroforestry (SF) and Crop Field (CF). Soil texture changed from loam to sandy loam, with soil bulk density decreasing from 0.98 g.cm-3 (BE) to 0.95 g.cm3 (AE) and no significant difference in SOC. Porosity increased from 46.5% (BE) to 55.2% (AE) and macroporosity from 3.8% to 4.8%. However, water infiltration decreased dramatically as volcanic ash created a 'cemented' hydrophobic layer on the soil. The highest soil infiltration among LUS were in RF (1 cm.hour-1) which were 50 times lower compared to condition before eruption, with the lowest were in CF (0.1 cm.hour-1). However, among the agricultural LUS, CAF provided fastest infiltration (0.7 cm.hour-1) followed by SAF (0.5 cm.hour-1). Slow soil infiltration increased surface runoff and increased dry season water shortages in the area. Countering the worst short-term effects of ash deposits agroforestry was more resilient than monoculture crop systems. Differential tree survival showed the benefit of tree diversity in CAF, supporting human resilience.

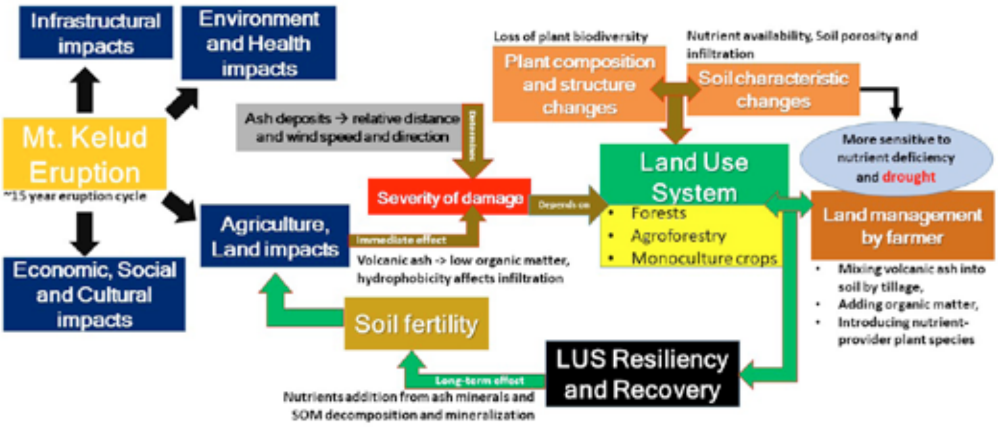


Figure 1. The agriculture land resiliency and recovery in response to volcanic eruption depending on the plant and soil management by the farmer.

Keywords: Agroforestry, Resilience, Volcanic ash, infiltration, macroporosity.

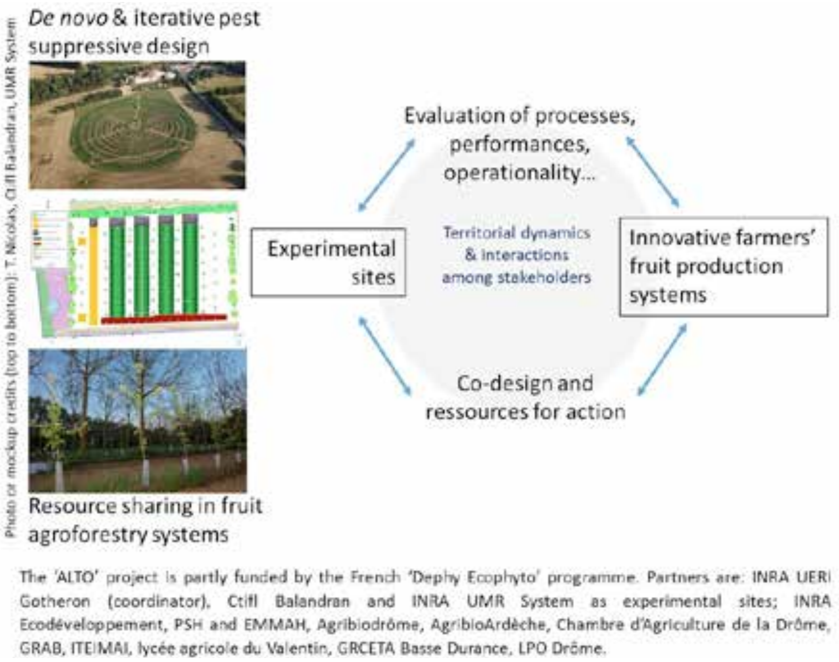
L17.P.32

Temperate fruit-based agroforestry systems: three case studies in Southern France in the framework of the 'ALTO' project

Simon S.[1] (sylvaine.simon@inra.fr), Ricard J.-M.[2], Lauri P.-E.[3]

[1] *Unité Expérimentale Gotheron, INRA, Saint Marcel lès Valence, France*; [2] *Ctifl Balandran, Bellegarde, France*; [3] *UMR System, INRA, Montpellier, France*

Fruit production systems rely on a heavy input use. Pesticide use reduction is challenging and can rely on reinforced ecosystem services through diversification of fruit tree species, cultivars, crops and companion plants in a 'pest suppressive' and productive arrangement designed at various scales. The design of such multi-layer and multi-production systems is complex and requires an interdisciplinary and multi-actors approach.
The aim of the French 'ALTO' project (2018-2023) is to design through ecological intensification low-input and/or pesticide-free fruit-based multi-production systems, to be assessed through multicriteria evaluation (yields, inputs/outputs, organizational aspects). Interdisciplinary knowledge, expertise, know-how and feedbacks from farmers, advisors, teachers and scientists are considered in a participatory approach. Three experimental sites were set up that explore i) *de novo* and ii) step-by-step 'pest suppressive' design (e.g. through barrier, dilution, push-pull or natural-enemy mediated processes) including the supraplot scale, and iii) the way to optimize resource use between associated and cultivated plants, and between vertical layers. More generally, this project will create a place for scientific, technical and educational interactions around temperate fruit tree-based agroforestry systems through long-term experiments, on-farm surveys and debates that foster interactions among stakeholders to co-produce knowledge.



Organization of the 'ALTO' project and interactions among stakeholders

Keywords: temperate agroforestry, fruit, ecosystem service, co-design, research project.

References:

1. Lauri PÉ et al., 2016, Acta Hort 1137, 255-265, http://dx.doi.org/10.17660/ActaHortic.2016.1137.37
2. Simon S et al., 2017, Eur. J Agron 82,320–330, http://dx.doi.org/10.1016/j.eja.2016.09.004
3. ALTO Project: https://www6.paca.inra.fr/ueri/Contrats-et-projets/ECOPHYTO-II-ALTO/En-savoir-plus

L17.P.33

Should agroforestry coffee have an O layer? Contributions of the agroforest floor to productivity and resilience

Staver C.[1] (c.staver@cgiar.org), Barrios M.[2], Navarrete E.[2], Navarrete L.[2], Sepulveda N.[2]

[1] *Bioversity International, Montpellier, France*; [2] *CATIE, Managua, Nicaragua*

The forest floor interfaces between above-ground and below-ground ecosystem processes like water retention, nutrient cycling and carbon sequestration. The agroforest floor condition has received little attention. We reviewed the results of a long-term experiment in Masatepe, Nicaragua, with a five-month dry season at an altitude of 450 meters comparing 4 tree treatments (2-species combinations of leguminous and non-leguminous deciduous and evergreen) and two intensities of organic and conventional coffee management to identify variables in the agroforest floor status (Haggar et al 2011). The 3-hectare experimental site initially was a patchwork of old coffee with highly variable tree and shade, avocado and weedy fallow. First-year botanical composition under all ground cover management treatments was annual grasses and annual and perennial broadleafs. O layer status was not recorded. After 12 years, herbicide-based total weed control resulted in 10-40% bare soil with leaf litter covering 40-60%. Selective control, either herbicide or manual, to favor low-growing, shallow-rooted vegetation, resulted in minimal bare soil, a declining area covered by competitive grasses and broadleafs and from 40-70% natural cover vegetation. Weed biomass under selective control was triple the biomass under total control. Tree presence compared to open sun coffee reduced bare soil and increased leaf litter and natural cover vegetation. A comparison of dry season ground cover showed increased accumulation for the whole leaf and fractionated leaf layers by year four with treatments including *Inga laurina*. Ten years later the dry season ground cover in *Inga* treatments had 18-22 tons leaf litter/ha, double the tree treatments without *Inga*. The fractionated leaf layer for *Inga* at 5.5-6t/ha was double the other tree treatments. The litter accumulation under *Inga* contained 410kg N/ha compared to 228 for tree treatments without *Inga* and 117 for open sun. Accumulated coffee yields were higher for open sun. Soil OM at both 0-10 and 10-20cm was increased for trees versus open sun, but not for *Inga* versus other trees. Weed control costs were decreased with increasing O layer. In conclusion in the Masatepe experiment, the O layer developed differentially by tree treatment, although was not correlated with coffee productivity. The O layer should play a role in the design and management of next generation multi-strata coffee systems. New types of data are needed to address neglected interactions - weed and living ground cover management; alternatives for more effective location of leaf litter for targeted benefits; mixtures of slow and rapidly decomposing leaf fall and prunings, twigs and small branches; interaction of agroforest floor with coffee food web; and water use efficiency among trees and coffee with differing degrees of O layer development.

References:

1. Haggar, J., et al. 2011. Agroforestry Systems. 285

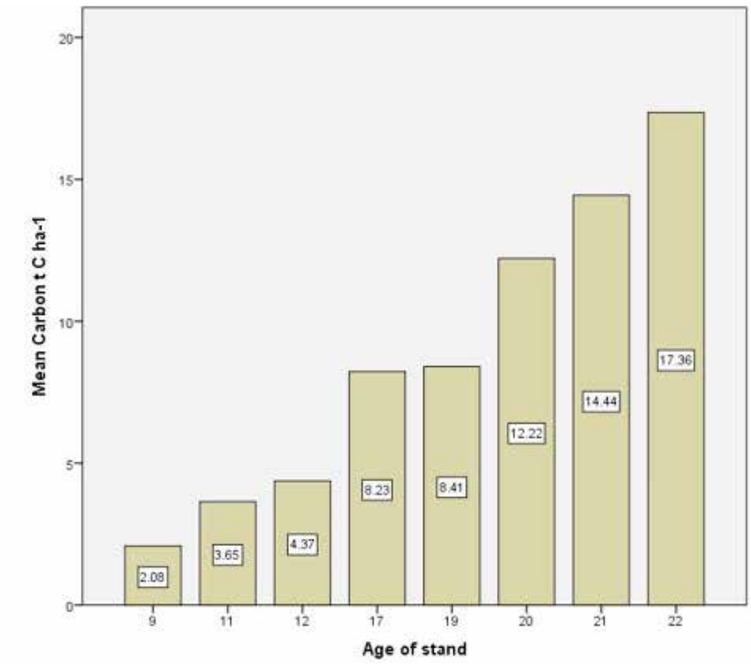
L17.P.34

Assessing the potential contribution of latex from rubber *(Hevea brasiliensis)* plantations as a carbon sink

Tawiah E. N.[1] (ekown.tawiah@gmail.com), Ashiagbor G.[2], Leeuwen - de Leeuw L. V.[3], Asante W. A.[4], Okojie J.[5]

[1] *Institute of Natural & Mathematics, Massey University, Takoradi, Western Region, Ghana*; [2] *Wildlife & Range Management, Kwame Nkrumah Univ. Sci. & Tech, Kumasi, Ashanti, Ghana*; [3] *Natural Resources, ITC - University of Twente, Enschede, Overijssel, Ghana*; [4] *Silviculture & Forest Management, Kwame Nkrumah Univ. Sci. & Tech, Kumasi, Ashanti, Ghana*; [5] *Natural Resources, ITC - University of Twente, Enschede, Overijssel, Netherlands*

Sequestered carbon is stored in carbon pools such as aboveground carbon, belowground carbon, carbon in the soil organic matter, dead wood and litter, however, the contribution of latex to carbon sequestration is overlooked. A comparison of aboveground, belowground and latex carbon pools for rubber was conducted as the focus of this study. Comparing three carbon pools, aboveground carbon had a significantly higher carbon sequestration capacity with an effect size of 75% whilst sequestered carbon by both the belowground carbon pool and the latex carbon pool had no significant differences between them with a recorded effect size of 4% each. Although the carbon sequestered by belowground pool was higher initially, than the carbon in the latex, the opposite occurs as the age of the plantation increases. The carbon found in the latex is no different from the carbon contained in the belowground pool, thus, latex is equally important for carbon accounting on rubber plantations.



Keywords: Carbon Pool, Latex, Rubber Plantation, Aboveground, Belowground.

References:

1. Blagodatsky, S., Xu, J., & Cadisch, G. (2016). Carbon balance of rubber (Hevea brasiliensis) plantat
2. Charoenjit, K., Zuddas, P., Allemand, P., Pattanakiat, S., & Pachana, K. (2015, March 19). Estimatio
3. Egbe, A. E., Tabot, P. T., Fonge, B. A., & Bechem, E. (2012). Simulation of the impacts of three man
4. Jayanthy, T., & Sankaranarayanan, P. E. (2005). Measurement of Dry Rubber Content in Latex Using Mic
5. Nguyen, B. T. (2013). Large-scale altitudinal gradient of natural rubber production in Vietnam. Indu

L17.P.35

Google earth images segmentation for carbon sequestration estimation across rubber plantations at different ages

Tawiah E. N.[1] (ekown.tawiah@gmail.com), Ashiagbor G.[2], Leeuwen - de Leeuw L. V.[3], Asante W. A.[4], Okojie J.[3]

[1] *Environment and Forestry, Environment & Agroforestry Foundation, Takoradi, Western Region, Ghana*; [2] *Wildlife & Range Management, Kwame Nkrumah Univ. Sci & Tech, Kumasi, Ashanti Region, Ghana*; [3] *Natural Resources, ITC - University of Twente, Enschede, Overijssel, Netherlands*; [4] *Silviculture & Forestry Management, Kwame Nkrumah Univ. Sci & Tech, Kumasi, Ashanti Region, Ghana*

The evolution of remote sensing technologies have improved scientific study and research. The often high cost of satellite images has led to research into alternative remotely sensed data for various analysis. Google earth data being cheap and readily available has been employed in many analysis including textural analysis with positive results. The application of OBIA to google earth image was employed in this study to assess the predictive ability of rubber tree diameter at breast height towards carbon modelling. Out of a total of 190 manually delineated tree crowns, 102 trees were found to have a 1 to 1 matching with segmented crowns on the Google Earth images were used. For the whole study area over- segmentation value was 0.43 (43% error) and the under-segmentation was 0.32 (32% error) with the D-Value computed as 0.38 (38% error) which means that the segmentation accuracy is 62%. Models developed from the segmentation process and field data were linear, quadratic and cubic models with R2 of 0.014, 0.137 and 0.139 respectively. Primarily, these poor R2 values are due to the fact that Google earth images have poor spectral values, red and infrared portions are absent which affect the clear crown detection of the tree canopies. The tree canopies are equally highly clustered, therefore with poor spectral values individual tree detection using OBIA procedure achieves very little success in the diameter at breast height prediction.

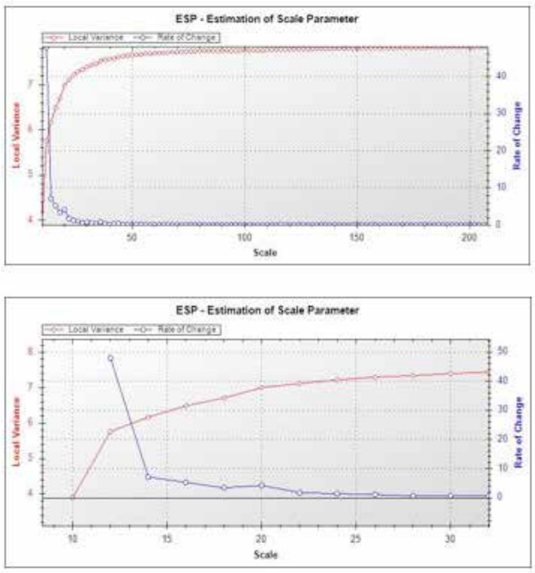


Figure 4: ROC-LV for ESP

Keywords: Carbon sequestration, Ghana, Image Segmentation, Rubber, Remote Sensing.

References:

1. Andrew E. Egbe. (2012). Journal of Ecology and the Natural Environment. DOI 10.5897/JENE11.14
2. Blagodatsky, S., Xu, J., & Cadisch, G. (2016). Agriculture Ecosystems & Environment. DOI: 10.1016/j.agee.2016.01.025
3. Charoenjit, K., et al. (2015). DOI 10.1117/1.JRS.9.096072
4. Chen, B., et al. (2016). International Journal of Applied Earth Observation and Geoinformation. DOI 10.1016/j.jag.2016.03.011
5. Li, Z., & Fox, J. M. (2012). Applied Geography. DOI 10.1016/j.apgeog.2011.06.018

L17.P.36

Productivity and use of arboreal and arborescent species in cocoa-trees agroforestry complexes (Centre of Cameroon)

Tchieudjo Nzukou C.[1] (christynzukou@outlook.com), Chekuimo G. H.[2]

[1] *Department of Geography, FALSH, The University of Yaounde I-UY I, Yaounde, Centre, Cameroon*;
[2] *Department of Forest Phytology, Mendel University, Brno, South Moravia, Czechia*

Climate change is a global phenomenon posing new challenges in achieving food security and improving the livelihoods of the poor who are in the majority in developing countries. Climate change is likely to change the interactions between humans and forests in several important ways. Degradation of forests soils and related loss of soil carbon, as well as exogenous inputs in agriculture, also contribute to global climatic change.
Many plant species grow spontaneously in cocoa-trees agrosystems or can be deliberately introduced to provide many goods and services. This study was carried out in Nkolo-Bang and Ngat (in the Centre Region of Cameroon) with objective to assess the productivity and the use of the arboreal and arborescent species in cocoa-trees agroforestry complexes. We investigated how climate change and changed human use interacted and what these effects have had on these agroforestry systems.
We have identified other tree species present in cocoa-trees plantations, products and services rendered by these tree species; we also determined the seasons, frequencies and quantities produced annually; and finally determined the motivations of cocoa-trees farmers to associate these species with cocoa-trees, as well as the relative importance they attribute to different species. The Sorensen index gave a value of 0.55, indicating that there is a 55% probability of finding identical species in both zones. The motivations of the producers to associate the species are to: generate income, produce wood, increase the fertility of the soil and create shading, and especially to fight against climatic change.
Farmer's decisions regarding agroforests' management are crucial to fostering the desired balance between conservation and productivity, as it affects the vegetative composition.

Keywords: agroforest, cocoa-trees, productivity, food security, Cameroon.

L17.P.37

Assessing the performance of an agroforestry system including cocoa, annual crops and trees in eastern Côte d'Ivoire

Toualy S.[1] (wsylvie@yahoo.fr), Boscher C.[2], Dago F.[2], Kaboré A.[3]

[1] *Forestry and Environment, INPHB, Yamoussoukro, Côte d'Ivoire*; [2] *AVSF Côte d'Ivoire, Abidjan, Côte d'Ivoire*; [3] *Anader, Abengourou, Côte d'Ivoire*

Introduction

Côte d'Ivoire is currently the world's largest cocoa producer with 40% of global production and this production is at the heart of its economy largely managed by smallholder farmers planting on 1-3 hectares (Firca, 2008). But Cocoa growing conditions in Côte d'Ivoire are bleak because of economic, environmental and social pressure on cocoa sector (Fsg-Impact, 2009). In this context, a project is being conducted in eastern Côte d'Ivoire. The project aims to improve in priority cocoa farmer income by increasing farm productivity and promoting crop diversification. And the second goal is to improve environmental management of cocoa Growing areas by developing agroforestry systems.

Before extending an AFS designed and tried on a few farmers, it's necessary to test its performances in order to improve it.

Materiels and methods

We studied a network of 12 plots (31m x 31m) in which we identified pest attacks, diseases, shading rate, the presence of weeds, and soil conservation. And then we measured the growth (height, diameter or circumference of the collar) and the production (crop yield) of each plant.

Results and discussion

Characterization: The first results showed that a success rate of 95% among young cocoa trees and almost 100% with banana. The shade trees have too a good pass ration towards 80%. The annual crops excepted yam, banana, peanut and pepper, have been negatively affected by lack of the rain. All of the plants are healthy and the weeds have been well controlled. Only few attacks on cocoa leaves have been observed.

Growth performance: Almost cocoa trees of the 12 plots presented good growth according to the measures of the average height and average circumference taken on February 2018 (Period 1, P1) and on August 2018 (Period 2, P2). We recorded an average of 6 cm on P1 vs 10 cm on P2 for circumference.

The shade trees also recorded a good growth. As trees have only recently been planted and because the trees are comparatively slow growing, the full effects of the trees on the cocoa will take time to develop. By the time banana trees offer shade to the young cocoa trees with an average height of 250 cm.

Production performance: We expected to have as first results the production of all annual crops but we recorded only yam, banana and pepper production. The others have suffered from dryness. Yam's production is estimated after harvesting between 15 and 20 tons ha-1. Cocoa harvesting will occur later

Conclusion

The evaluation of the global performance of an AFS is crucial because it allows to determine an optimal AFS for all farmers. So our research approach permitted us to take into account all of the elements of the AFS designed with farmers. But further, economic, environmental and social performances will be included to complete the study that needed a long time.

Keywords: cocoa, diversification, management, income, environment.

References:

1. Firca, 2008. Guide de la régénération des vergers de cacaoyer et de caféier en Côte d'Ivoire, 119 p.
2. Fsg-Impact, 2009. Managing Risk in Côte d'Ivoire's Cocoa Sector, 19 p

L17.P.38

The potential of shade-grown coffee to contribute to the protection of coffee yield quantity and quality

Wagner S. (sigrun.k.wagner@stu.mmu.ac.uk)

Science and the Environment, Manchester Metropolitan Univerersity, Manchester, United Kingdom

Coffee, an important agricultural export commodity, supports many small-scale farmers. Tanzania, Africa's fourth largest coffee producer aims to improve coffee production[1]. Climate change however, poses a significant threat to coffee production[2]. Shade trees might be an adaptation strategy because, depending on the context, research shows improved coffee quality, and bean size when shade trees are present[3]. On the other hand, shading increases berry borer infestation and high shade density reduces yield[45]. The aim of this study is to evaluate the effect of shade density on coffee yield and quality at Mt. Kilimanjaro. The 80 studied plots in commercial coffee plantations (coffee and shade trees) and homegardens (diverse, including bananas and other crops beside coffee and shade trees) cover a range of shade density (0-99%). The total number of berries per plant are counted to estimate yield. Red berries are harvested, weighed and opened to record single beans (pea berries) and bean quality. Correlations and regressions between shade density and response variables are calculated. Coffee plantations have a higher yield and higher average berry weight than homegardens, but the effect of shade density is not significantly different between the two systems (Figure 1). The results show that shade trees can improve coffee quality, especially in homegardens. It is critical to find the right shade tree species and density for optimal balance between yield loss and improved quality.

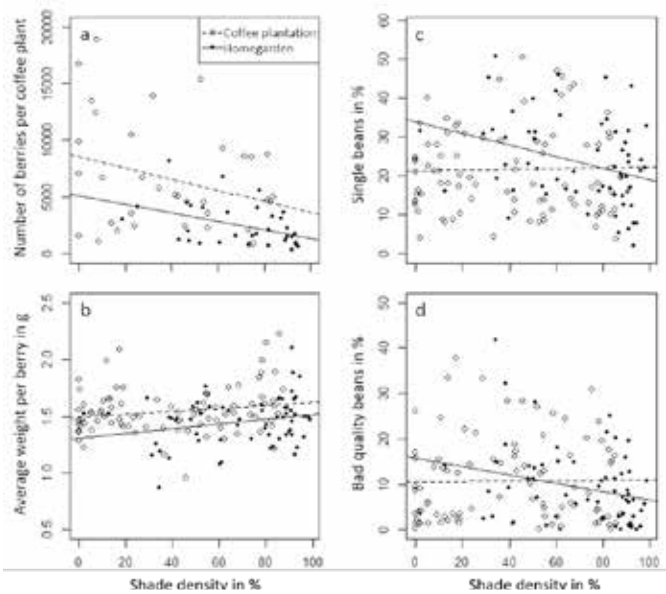


Figure 1: Effect of shade density on coffee yield (a), and quality parameters (b-d). Number of berries and shade density are negatively correlated (-0.30, $P = 0.085$ coffee plantations; -0.43, $P < 0.01$ homegardens) (a), while average berry weight is positively correlated (0.19, $P = 0.073$ coffee plantations; 0.24, $P= 0.057$ homegardens). Percent of single beans (pea berries) (c) and percent of bad quality beans (float on water or black/rotten) (d) are reduced by shade density in homegardens (-0.33, $P < 0.01$ single beans; -0.26, $P = 0.038$ bad quality beans), but not in coffee plantations.

Keywords: Shade density, Coffee yield, Coffee quality, Climate change adaptation, Ecosystem services.

References:

1. Tanzania Coffee Board, 2012, Tanzania Coffee Industry Development Strategy 2011/2021.
2. Craparo, et al., 2015, Agric For Meteorol, 1–10; 10.1016/j.agrformet.2015.03.005.
3. Vaast, et al., 2006, J. Sci. Food Agric, 197–204; 10.1002/jsfa.2338.
4. Mariño, et al., 2016, Agriculture, Ecosystems & Environment; 258–266; 10.1016/j.agee.2015.12.031.
5. Soto-pinto, et al., 2000, Agriculture, Ecosystems & Environment, 61–69.

L17.P.39

Agroforestry practices of cocoa small-holders and their contribution to food security in Mexico

Zequeira-Larios C.[1] (czequeira@me.com), Hipólito-Romero E.[2], Ramos-Prado J. M.[2], Castillo-Acosta O.[1]

[1] *División Académica de Ciencias Biológica, Universidad Juárez Autónoma de Tabasco, Villahermosa, Tabasco, México*; [2] *Ecodiálogos, Universidad Veracruzana, Xalapa, Veracruz, México*

The cultivation of cocoa is a commodity of great importance worldwide. In Mexico, cocoa is grown in the states of Tabasco and Chiapas in agroforestry systems since pre-Hispanic times, more than 2,500 years ago. The Mayans grew cocoa under the canopy of great trees in the rain forests. This has been an ancestral practice that is still preserved. However, crops such as sugar cane and oil palm as well as livestock activity have gradually decreased the area previously devoted to cocoa cultivation in both States. Despite this decline, farmers keep small portions of the cacao agroforestry systems to maintain the floristic diversity that accompanies them. This practice seems to be a successful contribution to food security. In order to know the management practices used by farmers in the agroforestry cocoa systems and the diversity of products they harvest, a non-probabilistic sampling was carried out in the states of Tabasco and Chiapas, 19 plots were sampled in Chiapas and 37 in Tabasco. Quadrants of 20 x 50 m2 were established and all individuals with DBH ³ 5 were identified and measured. A survey to 56 farmers was applied and informal interviews were conducted to the wives of the farmers or a family member. It was found that the farmers have different shapes, sizes and distribution of land. Great producers (38% of the farmers) own a land over 8.5±5.4 ha average, they only cultivate 33% of their production units with cocoa, in the rest, 67%, they cultivate either sugarcane, or raise livestock, or both; differently than the small holders (62% of the framers) with a land 2±1.03 ha average cultivate just cocoa. In both cases, major and small holders obtain a wide variety of products for self-consumption and local market from their cocoa agroforestry systems. They associate to cacao, timber, spicies and fruit trees. The farmers obtain incomes from the sale of other products associated to the cultivation of cocoa: fine woods obtained from trees such as *Cedrela odorata*, *Swietenia macrophylla* and *Tabebuia rosea* among others; fruits of trees, such as *Pouteria sapota*, *Citrus sinensis*, *Citrus sp*., *Citrus limon*, among many others and crops of shrub species such as *Zea mays*, *Phaseolus vulgaris*, *Manihot esculenta*, *Ipomea batatas*, *Colocasia esculenta*, *Cucurbita sp.* and *Calatea lutea*. The management practices employed by cocoa small-holders have allowed them to conserve these agroforestry systems, obtain income from the local market by selling a great variety of products grown in this system as well as satisfying their own food needs. The wide floristic diversity in these agroecosystems constitutes a bank of germplasm that could favor the increase of agroforestry plantations associated with the cultivation of cocoa; therefore, small farmers could contribute to food security.

Keywords: Cocoa management practices, cocoa cultivation, Tabasco México, tropical products, land tenur.

References:

1. Bergman John F, 1968, Annals of the Association of American Geographers, 85.
2. Belsky Jill M S, 2003, Agriculture and Human Values, 277.
3. Cerda R et al., 2014, Agroforestry Systems, 957.
4. Mbow C et al., 2014, Current Opinion in Environmental Sustainability, 61.
5. Rosegrant Mark W. C, 2003, SCIENCE, 1917.

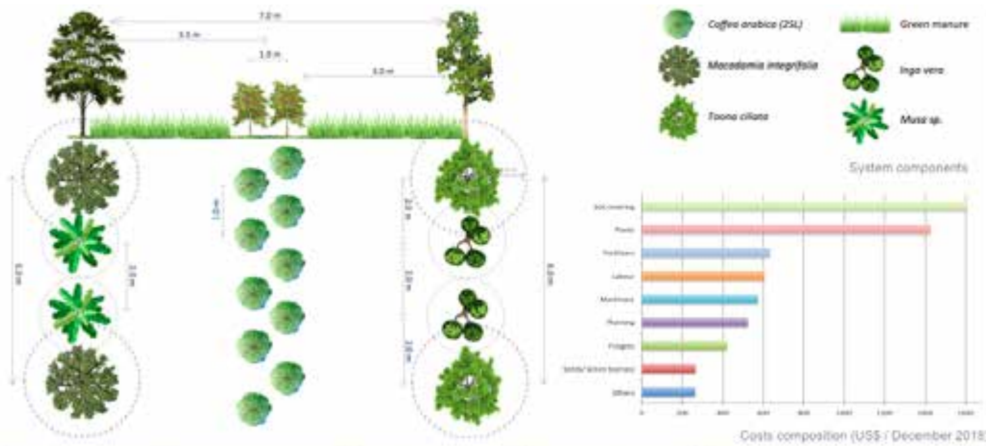
L17.P.40

Thriving climate change in Mantiqueira, Brazil. Coffee agroforestry design for soil and crop resilience in slope zones

Ziantoni V.[1] (ziantoni.valter@gmail.com), Costa P.[2], Araujo P.[3], da Mota M.[4]

[1] *Agroforestry, PRETATERRA, Timburi, SP, Brazil*; [2] *Agroforestry, PRETATERRA, Sao Paulo, SP, Brazil*; [3] *Communication, Fazenda da Toca, Itirapina, SP, Brazil*; [4] *Research, Café dos Contos, Monte Sião, MG, Brazil*

Mantiqueira region, Brazil is under desertification process, facing droughts and soil degradation. Regenerative models, considering soil conservation are needed to thrive under harsh conditions while diminishing chemical fertilizers. An agroforestry system was designed, maximizing soil infiltration and improving coffee resilience on slope zones in Monte Sião. Final model and costs are shown in table 1. For soil conservation, aggregation and retention, an ancestor method based on *Anthropogenic Dark Earth* (TPI) was used, based on charcoal and sawdust deposition. N_2 fixer species were selected for alley green manure. Species selection and arrangement considered succession, stratification, shade, architecture, permeability, lifecycle and root depth. Components are: *M. integrifolia*, *C. arabica*, *T. ciliata*, *Musa sp*, and *I. vera*. Seed-mixture for alley enrichment is: *U. brizantha*, *C. cajan*, *H. annus*, *P. glaucum* and *C. spectabilis.* Soil management and mulching used a mix for fertilizing purposes, charcoal residues for raising soil CEC, coffee husks + poultry manure (10% N) and eucalyptus sawdust for soil covering. Design attributes were systematized. With a cost of USD 6,316, the first 1 hectare was implemented in Dec, 2018 in the Farm "Café dos Contos". Integrated systems diversify revenues. A replicable agroforestry model for Mantiqueira coffee-based agriculture will drastically improve soil conservation and crop resilience, while building a new sustainable productive paradigm.



Main System				Green manure		Fertilizer		Soil cover	
Species	Cycle	Spacing	Plant / ha	Species (seeds)	Kg/ha	Product	Kg/ha	Element	Ton/ha
Coffea arabica (Catucaí 25L)	25	6 X (1 X 1)	2857	*Cajanus cajan*	30				
Toona ciliata	25	14 X 6	119	*Helianthus annus*	20	agricultural lime	893		
Macadamia integrifolia	25	14 X 6	119	*Pennisetum glaucum*	10	Agricultural Gypsum	400	Charcoal / Ashes	3
Musa sp.	4	14 X 2 (-Ma)	238	*Crotalaria spectabilis*	10	superphosphate simple	893	Poultry Manure + coffee husk compost	30
Ingo vera	8	14 X 2 (-To)	238	*Urochloa brizantha*	30	Fertilizer 10:10:10	179	Eucalyptus sawdust	12

General quantities

Table 1. Complete information of (a) design, (b) table of quantities and (c) general costs.

Keywords: Shade-grown coffee, Terra Preta de Indio, desertification, Anthropogenic Dark Earth, Soil conservation.

References:

1. Wiedner, 2015, Catena, 114-125; doi.org/10.1016/j
2. Maezumi, 2018, Nature Plants, 540-547; doi.org/10.1038/s41477-018-0205
3. Primavesi, in: Manual do Solo Vivo, 2016, Expressão Popular, 35 - 100
4. Campanha, 2004, Agroforestry Systems, 75-82; DOI: 10.1023/B:AGFO.0000049435.22512.2d

ABSTRACTS

Specific agroforestry systems

Let’s drill down: the amazing varieties of agroforestry

- L18 -
Cereals and annual crops in agroforestry

Waving fields of alley gold? No: Cereals in agroforestry!

What are the benefits of growing crops with trees? It is often argued that agroforestry could reduce input requirements or buffering yield variability.
Does this mean that sustainable mixed grain systems prevail for food security? Under what conditions is it true that sustainability is a path to sustainable agriculture? Are there limiting factors? If yes, how can we go beyond by using newly developed shade tolerant crops or bred and selected perennial cereal derivatives in companion with trees? Only some of the many questions worth to examine! The session aims to address:

- the impacts of system design and crop variety on yield and quality (e.g. effect of trees - and distance from trees and hedges - on yield and quality. In absolute value but also in variability (for example, lower yields but more stable over time?),
- the selection of species and varieties for shade tolerance and/or competition for water and nutrients,
- the effect of the quantity and quality of light on crop growth and development
- changes in practices (rotation, tillage, pesticides, fertilization) induced by the transition to agroforestry,
- the effect of the herbaceous strip under the trees on crop management and crop protection (e.g. are more herbicides required to face possible spill-over? are beneficial organisms efficient enough to do without pesticides?).

L18_O.01

Silvoarable agroforestry systems in temperate regions: impact of tree rows on crops, soil and biodiversity

Pardon P.[1] (paul.pardon@ilvo.vlaanderen.be), Reubens B.[2], Reheul D.[3], Mertens J.[3], Coussement T.[4], Verheyen K.[3]

[1] *ILVO & UGent, Merelbeke, Belgium*; [2] *ILVO, Merelbeke, Belgium*; [3] *UGent, Ghent, Belgium*; [4] *BDB, Leuven, Belgium*

Integrated results are presented from a PhD research whereby the effects of tree row presence on soil characteristics, biodiversity and crop yield were simultaneously quantified near boundary planted tree rows and near tree rows in young alley cropping fields in Belgium.

We assessed the effect of tree row presence on SOC, total N, P, K, Mg, Na, Ca and pH in the plough layer of the experimental fields. Although no effects were observed near the young tree rows, significantly increased SOC and soil nutrient concentrations were observed near the boundary planted tree rows. The noted increase of these soil variables was strongly related to the distance from the tree row, resulting in considerable spatial gradients. In addition, the magnitude of the observed effects differed according to tree species and the increase in SOC, total N, K, and Na near the poplar rows was related to the size of the trees, indicating a continuous evolution in SOC and soil nutrient status of the agroforestry system as trees mature. The main causal factor was assumed to be the input of carbon and nutrients in the top soil layer through tree litter, in particular tree leaves, and to a lesser extent via nutrient enriched throughfall water and a potentially reduced nutrient uptake of the arable crops.
Next, the effect of tree row presence on the activity-density and diversity of two types of macro-detrivorous arthropods (woodlice and millipedes) and two types of carnivorous arthropods (carabids and rove beetles) was assessed. Strongly increased activity-density values and diversity of the macro-detritivoreous arthropods were detected in silvoarable fields. Near the (larger) boundary planted trees, these effects extended into the neighboring arable zone. Contrasting gradients in abundance were observed for carabids and rove beetles, with increased activity-density values in the arable zone.
Finally, the influence of tree rows on yield and quality of key western European arable crops was quantified. Tree size, crop type and distance to the trees were main determinants of the crop yield and quality in the silvoarable fields. While effects on crop yield were limited for all crops near young tree rows, substantial yield reductions were observed near mature trees, in particular for maize and potato. Effects on crop quality were limited for all crops under study, with substantial effects only arising near the oldest tree rows. To optimize the provisioning service of agroforestry systems, the cultivation of winter cereals may be advisable over maize and potato towards the end of the lifecycle of the tree component. In addition, poplar trees should be harvested when they reach their target diameter for industrial processing. If tree rows are preserved for the delivery of other ecosystem services, however, substantial impacts on crop yield and quality should be taken into account.

Keywords: Alley cropping, Poplar, Yield, Soil characteristics, Biodiversity.

L18_O.02

Interventions to improve productivity and sustainability of poplar-based agroforestry system in Indo Gangetic plains

Gill R. (rishigill@pau.edu), Singh B., Kaur N.

Forestry and Natural Resources, Punjab Agricultural University, LUDHIANA, Punjab, India

Innovative technological interventions can help to make the agroforestry practices more profitable and socially acceptable. In this direction, different cereals, oilseeds, vegetable crops along with their varieties were screened under poplar (*Populus deltoides* Bartr.) block plantation established at different spacings and row directions at PAU Ludhiana, Punjab, India. Litterfall addition, nutrient return through litterfall and changes in soil organic carbon pools in a chronosequence of poplar plantations were also determined. Wheat varieties PBW 725 and PBW 677 produced significantly higher grain yield and were tolerant to yellow rust as compared to other prevalent varieties. Optimum wheat yield was obtained by sowing wheat during first fortnight of November with 25 per cent higher seed rate (125 kg ha^{-1}) over the recommended dose to sole wheat (Kaur *et al* 2010). Wider spacing (8 x 2.5 m) of poplar trees with 8 m wide strip in N-S direction minimizes the negative effect of tree shade on intercrops compared to narrow spacing (5 x 4 m). The grain yield of wheat reduced from 5.14 to 3.26 t ha^{-1} during first to sixth year of poplar indicating suitability of wheat with poplar plantation till harvest. The yield reduction of turmeric from sole crop varied only from 20.5 to 36.8 per cent during first to fourth year of poplar plantation. The tuber yield of potato reduced from 21.5 to 13.1 t ha^{-1} during first to sixth year of poplar plantation. Among varieties, significantly higher tuber yield was recorded in Kufri (K.) Pukhraj sown during mid-November compared to K. Badshah, K. Jyoti, K. Pushkar, K. Chipsona-1 and K. Chipsona-3 screened from October to February. The extent of frost injury in potato was also less under agroforestry system as compared to sole cropping. White onion variety PWO-35 planted during end-December under poplar gave highest bulb yield, dry matter content and total soluble solids compared to Pb-Naroya, PRO-6 and PRSC-10. Addition of litterfall from trees improves the soil organic carbon and nutrient status. Six-year-old poplar plantation adds about 20.1 t ha^{-1} leaf litter and 176, 21.7, 133 and 368 kg ha^{-1} N, P, K and Ca, respectively through litter fall to soil (Singh 2009). Organic carbon in the surface soil layer (0-15 cm) of a six-year-old poplar plantation was 9.9 t ha^{-1} which increased to 20.3 t ha^{-1} after 24 years depicting improvement in the stable pools of soil organic carbon (Sharma *et al* 2015). The integrated use of pendimethalin or alachlor applied PRE with paddy straw mulch significantly reduced density and biomass of both grass and broadleaf weeds compared to herbicide or straw mulch used alone, and provided similar level of weed control to hand weeding (Kaur *et al* 2018). Cultural and management practices right from nursery to plantations such as weed control, irrigation in water channels, amelioration of deficiency, insect pest control etc., help to improve the production and productivity of system (Gill *et al* 2014).

Keywords: leaf litter, onion varieties, potato varieties, soil organic carbon, wheat varieties.

References:

1. Gill RIS et al. (2014) Pandey CB & Chaturvedi OP (ed) Agroforestry Systems and Prospects. Pp: 247-72
2. Kaur H et al. (2018) Weed Technol 32: 284-289. DOI 10.1017/wet.2017.112
3. Kaur N, Singh B and Gill RIS (2010) Indian J Agron 55: 68-74
4. Sharma S et al. (2015) Agroforest Syst 89: 1089-1063. DOI 10.1007/s10457-015-9834-6
5. Singh B (2009) J Indian Soc Soil Sci 57: 214-218

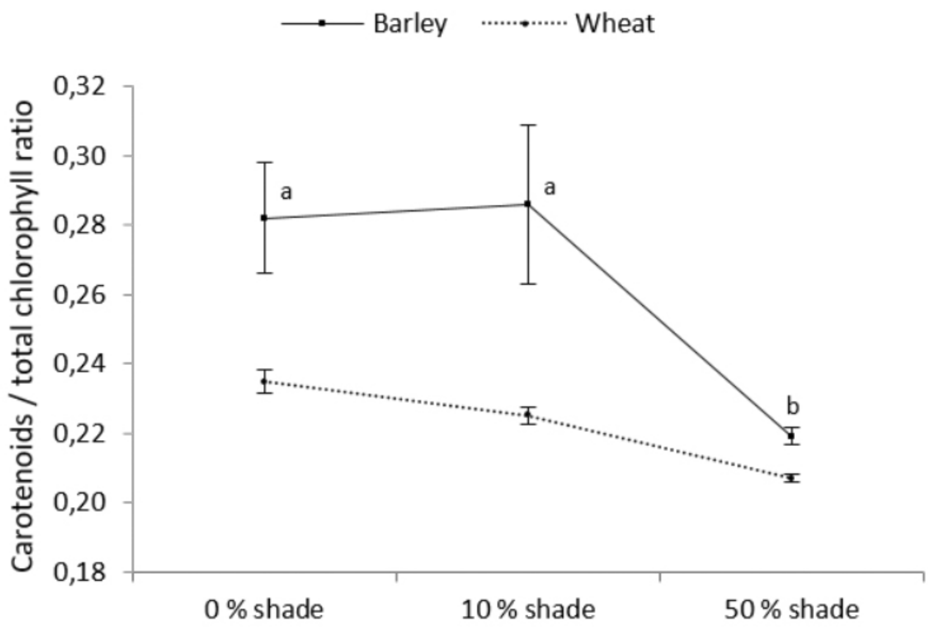
L18_O.03

Shade improves physiological performance and grain yield in barley cultivars in central Spain

Arenas-Corraliza M. G. (garenascorraliza@unex.es), López-Díaz M. L., Juárez E., Moreno G.

INDEHESA, University of Extremadura, Plasencia, Cáceres, Spain

Selections programs to grow cereals under tree shade are needed to establish successful agroforestry systems in order to cope with the reduction of crop yields as a consequence of climate change (Zhao, 2017). A greenhouse trial with three levels of photosynthetically active radiation (0 %, 10 % and 50 % of shade) was performed in central Spain to assess the influence of the solar radiation in the yield and the physiological mechanisms of winter wheat and barley. Nine cultivars of each species, widely used in the area, were studied. Most of barley cultivars showed higher grain yields in the 50 % shade treatment compared to those with higher light availability. In the same way, the ratio of photoprotective pigments (carotenoids)/ total chlorophyll was lower in 50 % shade in both species, especially for barley, showing a less need to photoprotection. The acclimation of barley to lower radiation was confirmed by barley grown in 50 % shade, which had a lower light saturation point in terms of electron transport rate compared to barley grown in 10 % and 0 % of shade respectively, while no adaptation was found in wheat. These findings are remarkable since all cultivars studied were selected originally to full light conditions. Therefore, our results prove the potential of barley cultivars to be intercropped in agroforestry systems in Mediterranean countries where recent early heat events had detrimental effects on cereal crops cultivated in open fields (Arenas-Corraliza et al 2018).



Ratio of carotenoids to total chlorophyll in leaf tissue of barley and wheat at flowering stage in 0%, 10% and 50% of shade treatments. High values indicate greater thermal dissipation.

Keywords: Agroforestry, shade, Mediterranean, barley, wheat.

References:

1. Zhao et al. 2017, Proc. Natl. Acad. Sci. 114: 9326–9331. DOI: 10.1073/pnas.1701762114
2. Arenas-Corraliza et al. 2018, Agr Ecosyst Environ. 264: 111-118. DOI: 10.1016/j.agee.2018.05.024

L18_O.04

Durum wheat in an olive orchard: impact on yield, yield components and morphology of different durum wheat cultivars

Panozzo A.[1] (nn.panozzo@gmail.com), Desclaux D.[2], Bernazeau B.[2], Huang H.[2]

[1] *Department. of DAFNAE, University of Padova, Legnaro (PD), Italy*; [2] *INRA - DiaScope unit, Mauguio - Domaine de Melgueil, France*

In the Mediterranean region, durum wheat productivity is mainly affected by heat stress and drought and this situation is expected to intensify in the near future (Moriondo et al. 2007). Is-it possible to mitigate such stress by cultivating durum wheat in olive orchards?
Durum wheat was sown for 3 years, at INRA Mauguio (South of France), in 3 conditions: a yearly pruned olive orchard (AF), a never pruned olive orchard (AF+), and in open field (C).
The average yield was reduced in AF (-43%) and AF+ (-83%), with % reduction in line with literature (Artru et al. 2017; Dufour et al. 2013), but this reduction varied greatly according to the cultivar. Despite a similar sowing density, final density was higher (+22%) in AF treatment than in C. The most affected component was the number of grains/spike (-37% in AF, -62% in AF+), then the number of spikes/plant (-32% in AF); the TGW was higher in AF compared to C (+12%). Harvest index was 6% higher in AF treatment compared to C. Plant height and spike length were significantly decreased in the two AF treatments, whereas the distance between the flag leaf and the spike was greater in AF compared to C. A wide genetic variability was observed: modern pure lines reached higher yield and yield components, compared to populations and ancient pure lines in C; but in AF treatment populations reached higher yield than modern and ancient pure lines. These data conduct to frame ideotypes needed to implement an AF-oriented breeding program.

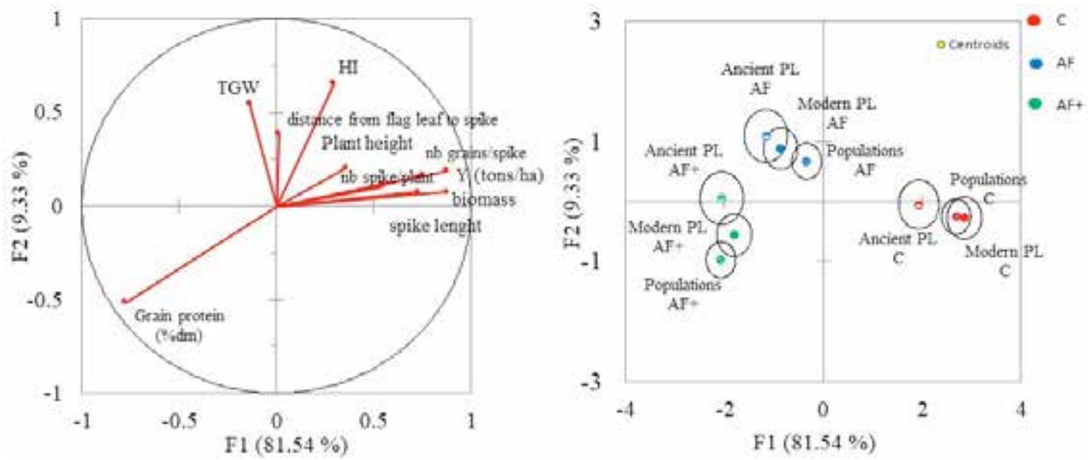


Figure 1. Principal component analysis (PCA; left) with variable loadings, and discriminant analysis (DA; right) for the 3 durum wheat genetic profiles considered in the study (ancient pure lines (PL), populations and modern well-known pure line (PL) varieties) within C, AF and AF+ treatments.

Keywords: durum wheat, number of grains per spike, genetic variability.

References:

1. Artru et al., 2017, J Agron, 60-70
2. Dufour et al., 2013, J Agron Crop Sci, 217-227
3. Moriondo et al., 2007, ITAL J AGROMETEOROL, 5-12

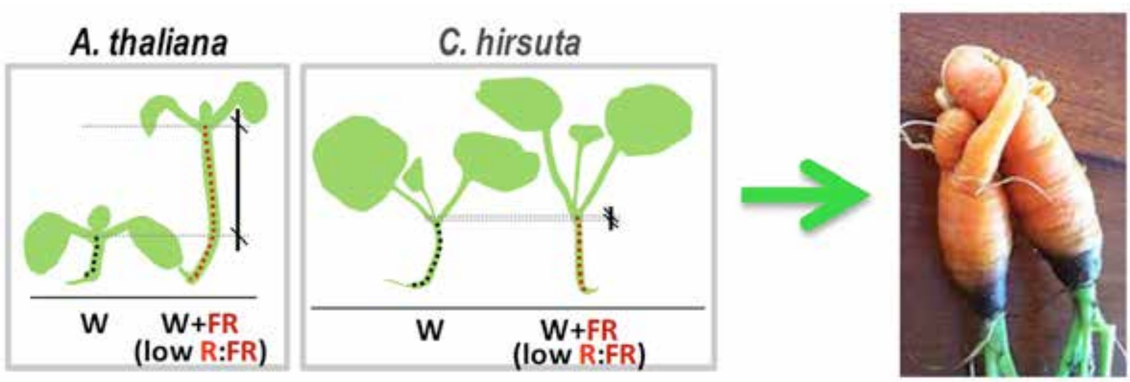
L18_O.05

How to deal with too close neighbors: from model systems to crops.

Martinez-Garcia J. F.[1] (jaume.martinez@cragenomica.es), Paulisic S.[2], Moreno-Romero J.[2], Pastor-Andreu P.[2], Qin W.[2]

[1]*ICREA and CRAG, Barcelona, Spain;* [2]*CRAG (CSIC-IRTA-UAB-UB), Bellaterra, Barcelona, Spain*

The use of newly developed shade-tolerant crops to grow in companion with trees will help to reach a more sustainable agriculture. To follow this path, we need to understand how plants respond to vegetation proximity **(Figure)**.
Plants sense the presence of competing neighboring vegetation as a changes in the ratio of red to far-red light (R:FR), a signal perceived by the phytochrome photoreceptors. The responses to vegetation proximity and shade (known as the *shade avoidance syndrome*) involve changes intended to adapt growth and development to environments of high plant density. In *A. thaliana*, a **shade-avoider** species, plant proximity perception results in increased hypocotyl elongation. Other plants have evolved to **tolerate** vegetation proximity or canopy shade. This is the case of *C. hirsuta*, an *A. thaliana* relative whose hypocotyls are unresponsive to plant proximity **(Figure)**.
As a way to dissect the genetic and molecular basis for shade tolerance, we have been carrying out forward and reverse genetic analyses looking for *C. hirsuta* plants with a restored response to simulated shade. As a result we have found a role for specific components. Our latest results will be presented.



Our basic research in model systems will help to make crops able to thrive closer to each other

Keywords: Vegetation proximity, shade avoidance, shade tolerance, Arabidopsis thaliana, Cardamine hirsuta.

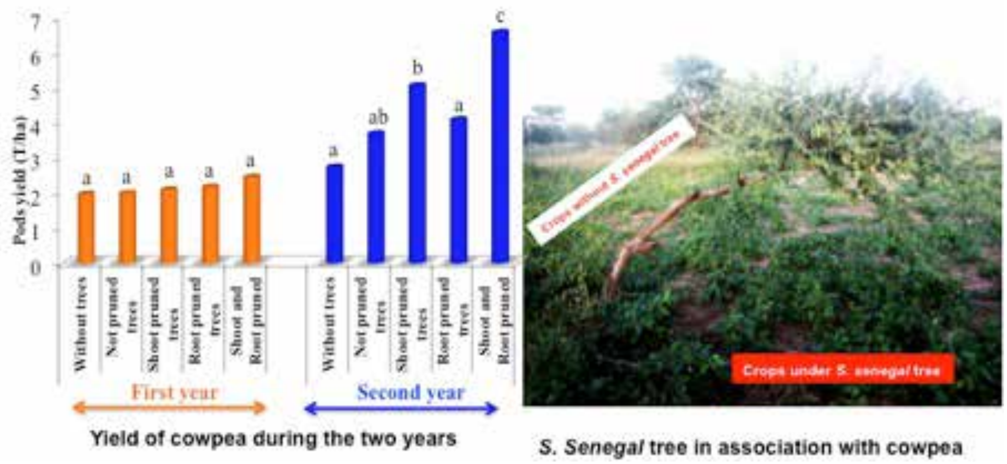
L18_O.06

Importance and trees management of *Senegalia senegal* on soil fertility and yield of associated crops in northern Senegal

Fall D.[1] (dioumacorfall@yahoo.fr), Wilson J.[2], Kane A.[3], Bakhoum N.[4], Ndoye F.[5], Sylla E. H. S. N.[3], Lesueur D.[6], Diouf D.[3]

[1] *Senegalese Institute of Agricultural Res, Bambey, Senegal*; [2] *Centre for Ecology & Hydrology, Edinburgh, United Kingdom*; [3] *University of Cheikh Anta DIOP (UCAD), Dakar, Senegal*; [4] *LCM-Laboratoire Commun de Microbiologie, Dakar, Senegal*; [5] *Université du Sine Saloum El-Hadj Ibrahi, Kaolack, Senegal*; [6] *CIRAD, CIAT Asia, Hanoi, Vietnam*

Trees are usually eliminated in field due their possible competition with crops for water and nutrients. Our work aimed to investigate how to manage *S. senegal* trees to optimize their association with crops. A field trial was conducted under natural conditions in a *S. senegal* plantation 10 years old. Investigations were conducted during two years to evaluate the effect of *S. senegal* trees management on gum arabic yield, associated cowpea yield, soil mycorrhizal fungi spores density and enzymes activities reflecting soil fertility such as fluorescein diacetate (FDA), acid phosphatase and dehydrogenase. Four treatments of pruning were applicated (control, shoots, roots, shoots and roots pruning) and tapped in november. Soil samples were collected during dry and wet seasons at 0-25 cm layer. Cowpeas were sown at the beginning of rainy season in rows 0.5 m apart. Results showed that shoots pruning significantly increased gum arabic while a negative effect of roots pruning was noted. The presence of *S. senegal* increased soil fertility and cowpea yield. Any significant effect of treatments was noted on pods yield during the first year. However, shoots pruning, shoot and roots pruning increased significantly pods yield during the second year. Shoots and roots pruning seemed to decrease FDA and spores density depending on the season. Our results showed that shoots and roots pruning increased the positive effect on soil fertility and the association of *S. senegal* with annual crops.



Effect of S. senegal tree management on cowpea production

Keywords: S. senegal, trees pruning, soil fertility, crops, Agroforestry.

References:

1. Abdoulkadri et al. 2019, Adv. Agri. Sci., 7 (01) : 74-84
2. Fall et al. 2012, J. Env. Manag., 95 : S260-S264. DOI:10.1016/j.jenvman.2011.03.038
3. Morais et al. 2012, Exp. Agri., 48(02). DOI: 10.1017/S0014479711001141
4. Maudu et al. 2010, J. Med. Plant Res., 4(22) : 2353-2358. DOI: 10.5897/JMPR10.486
5. Dommergues 1995, Fert. Res., 42: 245-271

L18_O.07

Corn yield in different integrated crop-livestock systems: the effect of shade

Pontes L. D. S. (laisepontes@iapar.br), Stafin G., Rodrigues D., Moletta J. L.

IAPAR, Ponta Grossa, Paraná, Brazil

In the Brazilian subtropics, the inclusion of animals during the winter seasons together with the annually cultivated summer pastures like corn is an attractive alternative to utilize the vast unproductive expanses of land during this season (MORAES *et al*., 2014). Besides, including trees for wood production in integrated crop-livestock systems (ICLS) offers benefits, like the diversification of the producers' income sources. However, any alterations in the solar radiation, either in quality or quantity, will affect the yield of the crops in the woody ICLS, a phenomenon especially observed in the C_4 grasses, like corn (PENG *et al*., 2009). As this culture is crucially important, and the aim is to encourage the use of woody ICLS in the Brazilian subtropics, the likely losses need to be quantified. Therefore, the objective of this study was to assess the influence exerted by two different types of ICLS, crop-livestock only (CL) or crop-livestock-tree (CLT), and the residual effect of two N supply levels (90 and 180 kg N/ha, N90 and N180, respectively, added to the winter pastures), on corn yield (CY). Adopting the complete randomized block design, the four treatments (CL N90, CL N180, CLT N90 and CLT N180) included three replicates. In 2006, following the 14 x 3 m spacing (238 trees/ha) the trees (eucalyptus, pink pepper and silver oak) were planted in the same rows running crosswise in relation to the slope, in 6 out of the 12 plots. While the corn (Balu 280 Pro, 0.80 m spacing) was implemented during summer of 2017/2018, under the no-tillage system, cattle grazing on the annual pasture was done during the prior winter, in both ICLS. After applying 400 kg/ha of NPK as the base fertilization in the 10-30-30 formulation, cover fertilization was done at 51 days post planting, using a single dose of 270 kg/ha of urea. At 185 days post sowing, the CY was recorded in 5 m of maize line per plot, and corrected to 13% of the moisture content. Analyses of variance was done to test the effect of block (degrees of freedom, DF = 2), N (DF = 1) and ICLS (presence or absence of trees, DF = 1). Compared with the treeless system (9722 ± 492.7 kg/ha), the CY value was significantly ($P < 0.05$) lower in the CLT (-27%), regardless of N level. Eleven years post tree planting, and after some thinning (currently with 40 trees/ha of eucalyptus), the shading value was 35%. This restriction of solar energy available acted as the determinant for the finding recorded. It is notable that the CY in the CLT system was extrapolated to hectares to analyze the CY *per se*. However, corn occupied 85.7% of the area, with the remaining 14.3% being taken up by the trees. Thus, the real CY achieved in 1 ha of this association of corn plus trees would be 6070 kg/ha (-38%). The challenge is to determine which are the acceptable levels of tree competition during the entire period of tree development.

Keywords: Agroforestry, Eucalyptus dunnii, Nitrogen fertilization, Subtropics.

References:

1. Moraes, et al., 2014. European Journal of Agronomy, 57, 4–9, http://dx.doi.org/10.1016/j.eja.2013.10

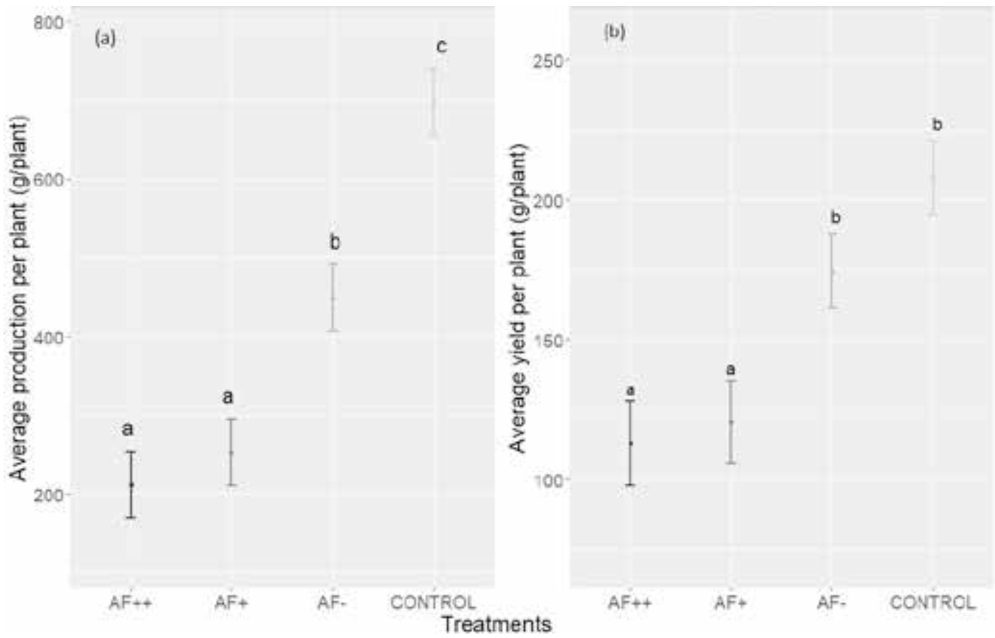
L18_O.08

Agroforestry impacts tomatoes production in a vegetable organic alley cropping temperate system

Béral C. (beral@agroof.net), Martin-Chave A., Liagre F.

AGROOF, Anduze, France

In organic vegetable crop systems, agroforestry is identified as a possible solution for a better economic and climatic resilience of farms. However, few references exist on the response of vegetable crops under trees. This study was conducted in southern France, in a 20-year-old agroforestry system where hybrid walnut at 100 stems.ha-1 were intercropped with organic vegetables crops. We assessed the growth, development, production and commercial quality of tomatoes in different canopy openness (CO) treatments (AF ++ with 22.9 to 27.2% CO ; AF + with 32.8 to 39.4% CO ; AF- with 40.6 to 47.2% CO ; CONTROL with 96% CO). We found that for the two most shaded treatments tomatoes had a significantly delayed growth than in AF- and CONTROL. The first flowering and harvest appeared on average 15 days later in AF ++ and AF+. Moreover, the global production period was significantly reduced in AF++ and AF+ compared to AF- and CONTROL which produce an average of 20 days more. The total production was significantly higher in CONTROL (697.5±42.9 g.plant-1) than in AF- (449,5±42.3 g.plant-1), than in AF+ (253.1±41.8 g.plant-1) and AF++ (212.4±41.8 g.plant-1). When excluding waste, average yield is similar between AF- and CONTROL. The global commercial quality of fruits was superior in AF- than in CONTROL. To conclude, trees can induce strong competition on tomatoes, but pruning management appears to be an interesting lever to reduce this competition while producing woody biomass.



Average total production (a) and average yield (b) of tomatoes in the different canopy openness treatments in 2016 (error bars = standard error)

Keywords: Alley crops, Tomato, Canopy openess, Organic cropping.

L18_O.09

Measuring impact of shelterbelts on canola yield in the Canadian Prairies

Hodge K.[1] (kim.hodge@canada.ca), Akhter A.[2], Bainard L.[3]

[1] *Science and Technology Branch, Agriculture and Agri-Food Canada, Regina, SK, Canada*; [2] *Science and Technology Branch, Agriculture and Agri-Food Canada, Indian Head, SK, Canada*; [3] *Science and Technology Branch, Agriculture and Agri-Food Canada, Swift Current, SK, Canada*

In the Canadian prairies agriculture production is typically a monoculture, dominated by small grains and oilseeds. In 2017 canola was planted on 5 million hectares in Saskatchewan, surpassing wheat as the most widely planted crop in Canada. This crop is one of the highest-yielding and most profitable and also one of most expensive and input-intensive for producers. Within this landscape, shelterbelts, and other natural areas, are scattered throughout providing ecological goods and services. In this study, the effect of natural and planted shelterbelts on canola yield was compared over two years in 15 canola fields, 5 with naturally occurring trees, 5 with a row of planted trees and 5 without any trees. In each field RGB and multispectral sensors were used to collect a variety of variables, such as elevation, slope and micro topography as well as vegetation indices, such as NDVI, EVI, SAVI in order to determine whether there was a relationship with canola yield. This data is currently being analysed.

Canola field with natural shelterbelt in prairie landscape

Keywords: Agroforestry, Shelterbelt, Canola Yield, Prairies, Canada.

L18_O.10

Effect of water gradient on the intensity of competition and productivity of annual crops intercropped with olive trees

Temani F.[1] (fida.temani@cirad.fr), El Mrini S.[2], Daoui K.[3], Bouaziz A.[2], Wery J.[4], Barkaoui K.[1]

[1] *Cirad, Montpellier, France*; [2] *IAV-HassanII, Rabat, Morocco*; [3] *INRA, Meknès, Morocco*; [4] *ICARDA, Cairo, Egypt*

Olive-based agroforestry with annual crops is wide spread in Northern Morocco and more generally in the Mediterranean, but poor information is available on their functioning in the context of increasing aridity. In order to evaluate the changes in tree-crop interactions due to water shortage, we assessed the productivity of both a cereal (durum wheat) and a legume (faba bean) species intercropped with olive trees under three contrasting levels of water availability in an experimental trial in Morocco during 2017-2018. Water availability treatments were determined by adding different amounts of irrigation water to precipitation (P) during the growing phase (very wet treatment =P+37%; moderately wet treatment =P+15%; and control rainfed treatment =P).We assessed crop aboveground biomass, height, yield components and determine final grain yield at harvest. Water dynamics was also monitored each two weeks. Crops under olive trees were compared to full sun crops as control. Aboveground biomass and grain yield of both crops were significantly lower under olive trees than in full sun control (up to 27% yield reduction for durum wheat and 38% for faba bean). Indeed, strong reductions in number of grain per m2 explained observed yield reductions. Our results suggest that competition for light under olive trees is intense and prevails under Mediterranean subhumid conditions (experienced in 2017/2018) but trees could have beneficial impacts on crop water efficiency in a drier future.

Olive-based agroforestry system: durum wheat intercropped with olive trees

Keywords: agroforestry, annual crops, olive tree, interactions, water gradient.

L18.P.01

Is it possible to mix olive trees and crops efficiently? Setting from the rich diversity of agroforestry in Morocco

Amassaghrou A.[1] (amassaghrou.asmae@gmail.com), Bouaziz A.[1], Daoui K.[2], Barkaoui K.[3], Belhouchette H.[4]

[1] *IAV Hassan II, Rabat, Morocco*; [2] *INRA, MEKNES, Morocco*; [3] *CIRAD, Rabat, Morocco*; [4] *Institut Agronomique Méditerranéen de Montpellier, Montpellier, france*

Agroforestry in Morocco is an ancient traditional practice; however there is no study on its performances and limits.The objectives of this work, based on surveys was to characterize the diversity of associations, practices, and to evaluate the efficiency of agroforestry. 72 surveys were conducted in Moulay Driss Zerhoun (Meknes, Morocco). **Cereals and legumes** are the main intercropping crops with **olive tree,** the analysis of collected data shows there was a significant difference between soft wheat and barley grain yield in agroforestry and full sun crops: we recorded a reduction of 57% of soft wheat grain yield in agroforestry versus full sun crops, and a decreasing of 42% of barley grain yield. However, there was no significant difference between grain yield of agroforestry and full sun for faba **bean, lens** and **chickpea**. The land equivalent ratio shows that the association with **faba bean** is the most important with a ratio of 1.6 , 1.5 for **lens,** 1.4 for **chickpea** ,1.2 for **barley** and 1.1 for **soft wheat**. Since the association with legumes is promising, and to understand interactions, two experiments were carried out during two years: 2016 and 2017 under 25-year old **olive tree** and two agricultural witnesses in the same years. The first year of experimentation experienced a water deficit, at this year the grain yield was not significantly different in agroforestry and pure crops; however we recorded a low yield in both agroforestry and full sun. In 2017, there was a highly significant difference between **faba bean**, and l**ens** grain yield in agroforestry and full sun crops we recorded a reduction of 72% of **faba bean** grain yield in agroforestry and 47% for **lens**, however there was no significant difference between **chickpea** grain yield. Results are variable from one year to another; further studies are needed to confirm results.

Keywords: Efficiency, olive, legumes, cereals.

Is it possible to mix olive trees and crops efficiently? Setting from the rich diversity of agroforestry in Morocco

Amassaghrou A.[1] (amassaghrou.asmae@gmail.com), Bouaziz A.[1], Daoui K.[2], Barkaoui K.[3], Belhouchette H.[4]

[1] *IAV Hassan II, Rabat, Morocco*; [2] *INRA, MEKNES, Morocco*; [3] *CIRAD, Rabat, Morocco*; [4] *Institut Agronomique Méditerranéen de Montpellier, Montpellier, france*

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Keywords: Efficiency, olive, legumes, cereals.

L18.P.03

Agroforestry in the Hauts-de-France – A Research and Demonstration Experimental Site in Ramecourt

Andrianarisoa S.[1] (sitraka.andrianarisoa@yncrea.fr), Delbende F.[1], Pruvot C.[1], Choma C.[1], Bouchard M.-A.[1], Guillou A.[2], Dequidt A.[3], Zeller B.[4], Oste S.[5], Petit K.[5], Vandoorne B.[1]

[1] *Yncrea Hauts-de-France, ISA Lille, Lille, France*; [2] *Les Planteurs Volontaires, Lille, France*; [3] *SCEA Dequidt, Ramecourt, France*; [4] *UR 1138 INRA BEF, Champenoux, France*; [5] *FREDON Nord Pas-de-Calais, Loos-en-Gohelle, France*

As the current agricultural practices in the Hauts-de-France region result in soil erosion, nitrate leaching and a decline in biodiversity, agroforestry systems (AFs) may be an alternative to conciliate productivity with lower environmental impact (Dupraz and Liagre, 2008). We set up the first AF experimental site to study its agro-economic and environmental performance in local agro-pedoclimatic conditions. The experimental site was established in autumn 2018 on an 18-ha plot in Ramecourt on a deep luvic cambisol with a silt loam texture developed on a flint clay. Due to a high silt content (73% silt) and a low organic matter content (2%), as well as a slope of 8%, the plot is highly affected by channel erosion. Modalities with or without nitrogen-fixing trees in AF treatment are compared with sole-crop (CC) and pure-forest control (FC) plots (Figure 1A) according to a randomised block design with 3 replicates. Tall trees in rows are intercalated with 9 species of shrubs (Figure 1B) and will be intercropped in AFs by sugar beet, potato, wheat, barley and flax. The tree density is 50 and 430 trees ha-1 for AFs and FC respectively, and the average size of the microplots is 0.9 ha. Using this experimental approach, we hypothesised that AFs should limit soil erosion, restore soil fertility and biodiversity, improve natural-resource use efficiency and water quality, reduce inputs and increase farmers' incomes.

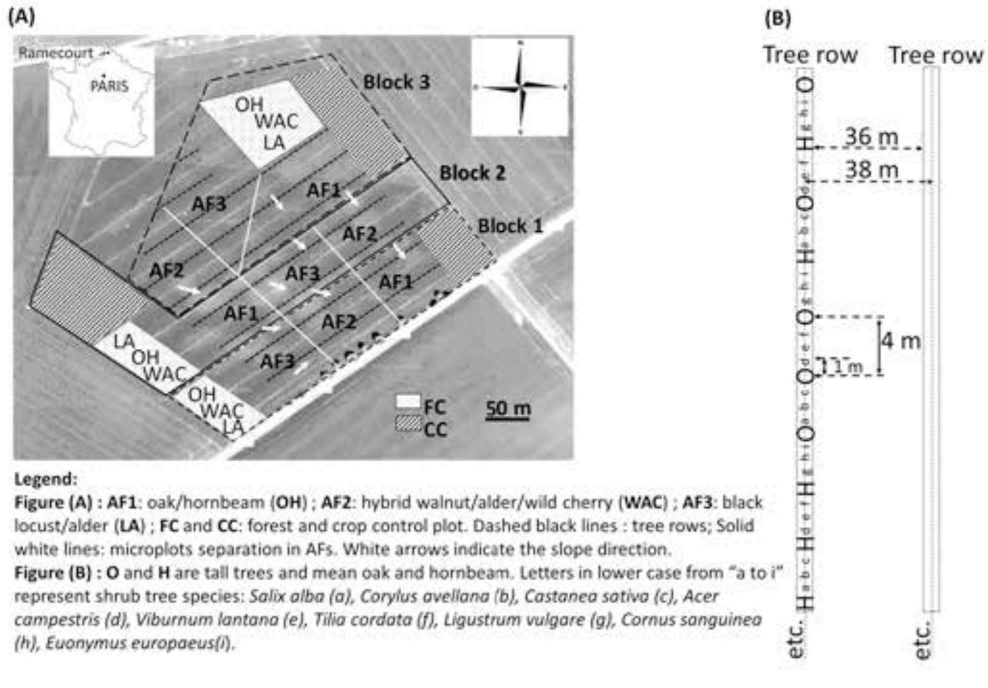


Figure 1 : Schematic representation of the experimental design (A) and an example of a plantation scheme (B).

Keywords: Experimental site, Agroforestry, nitrogen-fixing trees, Soil erosion, Biodiversity.

References:

1. Dupraz C., Liagre F. 2008. Agroforesterie : des arbres et des cultures, Editions France agricole.

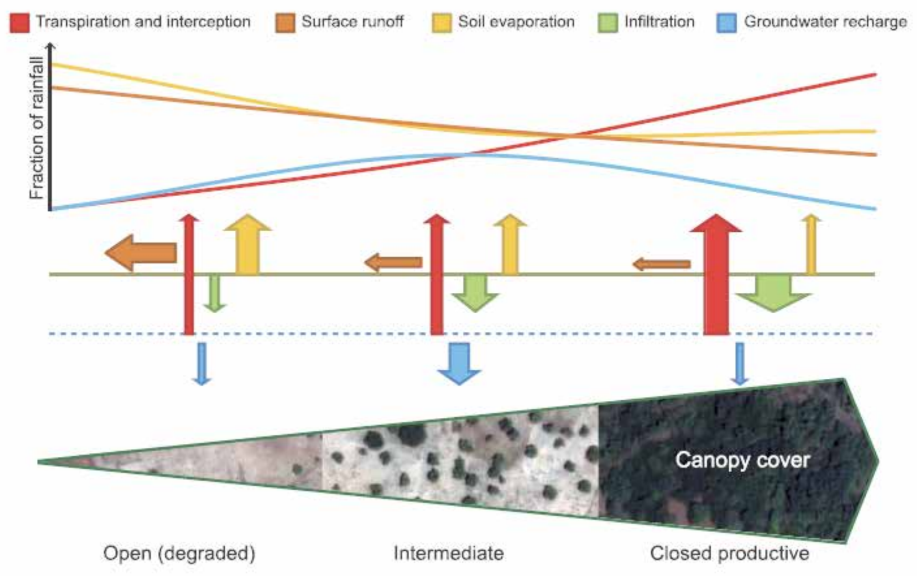
L18.P.04

Interaction Tree crop and agroforestry parkland Intermediate tree cover can maximize groundwater recharge in dry tropics

Bazié H. R.[1] (baziehugues@yahoo.fr), Bayala J.[2], Ilstedt U.[3], Sanou J.[4], Bargués Tobella A.[5]

[1] *Agroforestry-plant biology and physiolog, University of Ouagadougou, Ouagadougou, Burkina Faso*; [2] *ICRAF, Bamako, Mali*; [3] *SLU, Umea, Sweden*; [4] *INERA, Ouagadougou, Burkina Faso*; [5] *SLU-ICRAF, Umea, Sweden*

Parkland is a land use system in which woody perennial species are grown in with annual crops or livestock and are the most widespread systems in the Sahel.
Water scarcity contributes to the poverty of around one-third of the world's people.Despite many benefits, tree planting in dry regions is often discouraged by concerns that trees reduce water availability and crop yield. The aim of the research was to contribute to understanding the interaction in the tree-crop , and the impact of *tree* on the groundwater recharge. We developed and tested an optimum tree cover theory in which groundwater recharge is maximized at an intermediate tree density and crop yield. We found that complementary irrigation, nitrogen and phosphorous are not limit factor for crop yield. However, crown pruning has had a very significant increasing sorghum yield. Thereby suggesting that light is the limiting factor. Results, based on groundwater budgets calibrated with measurements of drainage and transpiration in parkland, demonstrate that groundwater recharge was maximised at intermediate tree densities. In contrast to the prevailing view, we therefore find that moderate tree cover can increase groundwater recharge, and that tree planting and various tree management options can improve groundwater resources. These results suggest that they are likely to be common in the seasonally dry tropics offering potential for widespread tree establishment and increased benefits for hundreds of millions of people



Keywords: Limiting factor, groundwater, Infiltration, Sapflow, tree density.

References:

1. Bazié H.R.et al., 2012. Agroforest Syst 84:377–388
2. Bazié H.R.et al., 2017. Agroforest Syst. DOI 10.1007/s10457-017-0115-4
3. Ilstedt U. et al 2016.. Scientific Reports | 6:21930 | DOI: 10.1038/srep21930
4. Bargués Tobella A et al 2016.Ecohydrology, doi: 10.1002/eco.1808
5. Karlson M etal., 2016.International Journal of Applied Earth Observation and Geoinformation 50:80-88

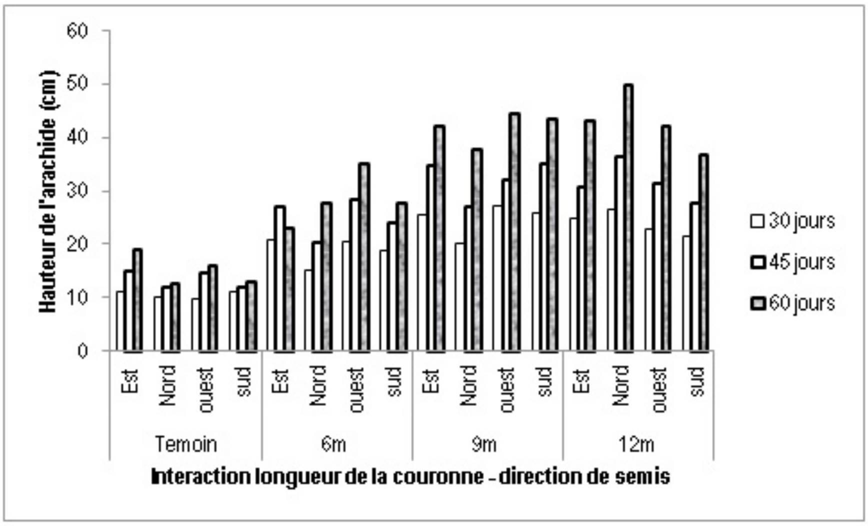
L18.P.05

Influence of the lenght of the crown of Anacardium occidentale L. on Arachis hypogea yields in Toubacouta, Senegal

Cheikh Oumar S.[1] (omarsamb2004@yahoo.fr), Mamadou B.[2], Elhadji F.[3], Mouhamadou Moustapha D.[1]

[1] *CNRF, ISRA, Dakar, Dakar, Senegal*; [2] *ISFAR, UT, Bambey, Bambey, Senegal*; [3] *ISFAR, Université de Thies, Bambey, Bambey, Senegal*

In Senegal, Agricultural production system is dominated by rainfed farming and one alternative for sustainable production is the combination of woody-farming. Introduction of new species with high value-added on farming land might be one of those solutions for a sustainable and diversify agricultural production. Cashew having which plays large part in the Senegalese agricultural sector, could be part of the species with high agroforestry potential has yet to be properly evaluated. The objective of this work is to contribute to the assessment of agroforestry potential of emerging species by examining the influence of crown length of *Anacardium occidentale L*. on *Arachis hypogaea L* yields. To do this, 1.5 ha of cashew tree plot has been chosen then divided in 3 lots of 0.5 ha. In each lot, three single tree type of 6 m, 9 m et 12 m have been chosen. Three off-cover control plots of cashew were delineated. Agronomic characteristics of *Arachis hypogaea* were evaluated. Results reveal that association peanut and cashew trees within less than 6m of crown length give best peanut yield. The maximum yield (676.51 kg ha-1) was recorded for trees having 6m of crown length compared to controls (399.58 kg ha-1). The management of the crown cashew tree is essential to optimize peanut yield. The broadening of the range of species associated with cashew would help to consolidate agroforestry potential of the species



Influence of the lenght of the crown on leaf biomass

Keywords: Senegal, Anacardium occidentale L., Arachis hypogaea L, length of the crown, yields.

References:

1. Chaneau, C. E. (1965). Agronomie Tropicale 20: 600-625.
2. Gerakis, P. e. (1970). Plant Soi1 33: 8 1-86.
3. Kessler, J. (1992). Agrofor. Syst. 17: 97-1 18.
4. Opoku-Ameyaw K., O. F.-F.-B. (2003). J. Agri. Sci. 36 :13 - 21.
5. Samb, C. O., Faye, E., Dieng, M., Sanogo, D., Ndiaye, S. A., et Koita, B. (2018). AS, 366-375

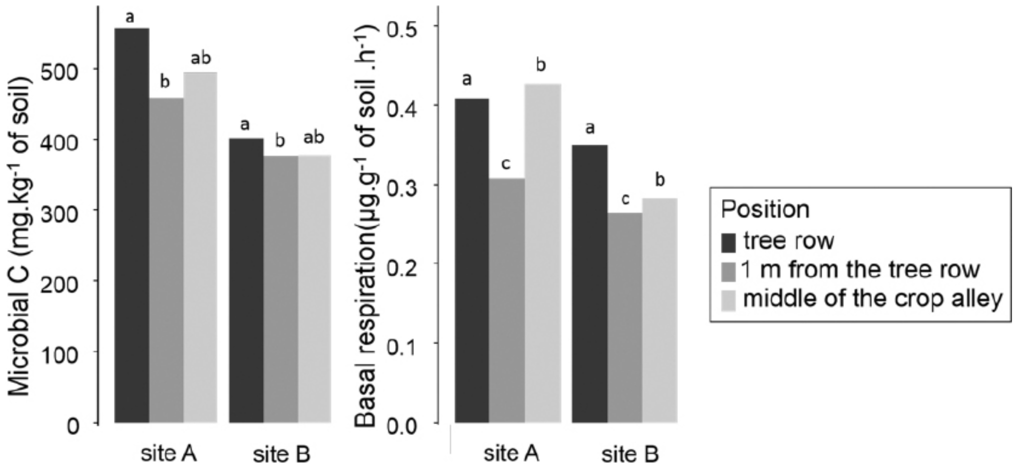
L18.P.06

Tree-row proximity did not increase soil organisms presence or soil fertility in two temperate alley-cropping systems

D'Hervilly C.[1] (c.dhervilly@gmail.com), Marsden C.[2], Hedde M.[1], Bertrand I.[1]

[1] *INRA, Montpellier, France*; [2] *Montpellier SupAgro, Montpellier, France*

Herbaceous vegetation of sylvoarable tree rows contributes significantly to soil carbon storage (Cardinael et al. 2015). However, its impact on soil organisms and fertility is poorly studied. It could especially play a significant role in young systems in which the tree influence is limited. We hypothesized that due to the herbaceous vegetation, soil chemical and biological fertility is increased in tree rows and close to them (at 1 m). We sampled two 10 year-old wheat alley-cropping sites of South-West France in spring 2017. We defined three positions: in the herbaceous vegetation of the tree row, at 1m from the tree row and in the middle of the crop alley. In each position, we determined macrofauna density, microbial biomass and respiration and soil C, N and P content. Soil organic carbon and available phosphorus contents were higher in the tree row than in the middle of the crop alley. However, we did not find higher values close to the tree row. Microbial biomass and respiration were higher in the tree row compared to the closest position in the crop alley only, indicating that positions close to the tree row did not benefit from the higher microbial growth and activity observed in the tree row. Soil macrofauna presented different patterns between sites and was more abundant in the tree row than in the crop alley in one site only, especially for saprophages and predators. In addition, some specific taxa of soil macrofauna were present only in the tree rows.



Mean values of microbial biomass carbon with the fumigation-extraction method and basal respiration (in presence of water only) with the MicrorespTM method for each position and each site. Different letters indicate significantly different values between positions after one-way analyses of variance for both sites together with factor site as a random factor.

Keywords: herbaceous vegetation, macrofauna, microorganims, soil fertility, sylvoarable.

References:

1. Cardinael et al., 2015, Geoderma 259-260, pp 288-299

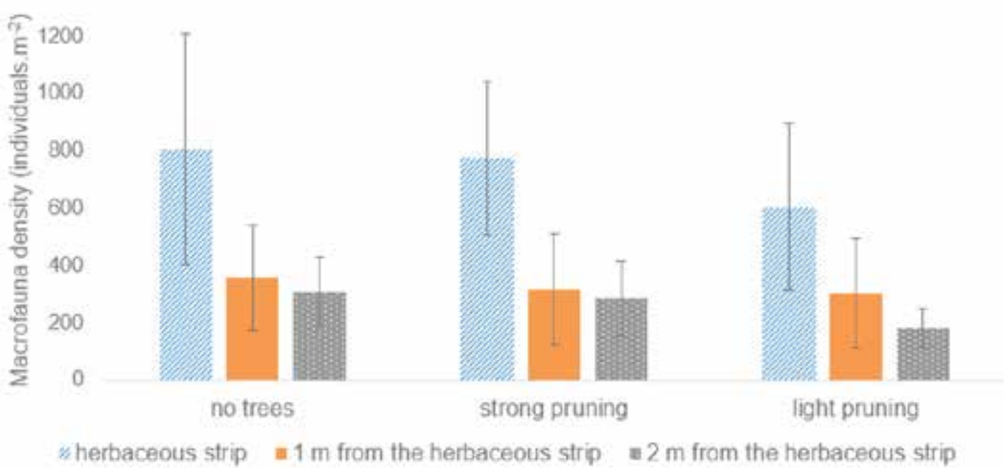
L18.P.07

Trees and tree row herbaceous vegetation impact soil organisms distribution in a market gardening agroforestry plot

D'Hervilly C.[1] (c.dhervilly@gmail.com), Marsden C.[2], Delapré-Cosset L.[1], Capowiez Y.[3], Bertrand I.[1]

[1] *INRA, Montpellier, France*; [2] *Montpellier SupAgro, Montpellier, France*; [3] *INRA, Avignon, France*

The herbaceous vegetation in agroforestry tree rows is a poorly studied potential trophic resource and habitat for soil organisms. This could enhance nutrients turnover (Porazinska et al., 2003), and thus be beneficial for the crop. We studied soil macrofauna density, soil microbial biomass and soil organic carbon in a 22 year-old organic market gardening plot with walnut trees, located in the South of France. We hypothesized that 1) the herbaceous strip impacts soil organism development and that 2) soil organism development also varies with tree management. Three treatments were studied: no trees in the herbaceous strip, lightly-pruned trees and heavily-pruned trees. Three positions were sampled: in the herbaceous strip, at 1 m from the herbaceous strip and at 2 m from the herbaceous strip. Sampling was carried out in April, June and November 2018. The first results for the Spring and Summer seasons demonstrate that the heavy pruning treatment presented the highest microbial biomass, and soil carbon content was higher in treatments with trees. However, macrofauna density did not vary according to the pruning treatment. Macrofauna density was increased in the herbaceous strip compared to the crop alley in all treatments, but not microbial biomass. Our first results suggested different impacts of trees and herbaceous vegetation: a stronger effect of the herbaceous vegetation for macrofauna density, and a stronger effect of the pruning of the tree for microbial biomass.



Mean macrofauna density for each position and each pruning treatment.
Error bars represent standard deviation .

Keywords: herbaceous vegetation, pruning, macrofauna, microorganisms, soil carbon.

References:

1. Porazinska et al., 2003, Ecological Monographs 73(3), pp. 377-395 ; 10.1890/0012-9615(2003)073[0377:

L18.P.08

Productivities and productivity trends of cereals and legume crops intercropped with olive trees

Daoui K.[1] (daoui_khalid@yahoo.fr), Hachli B.[2], Ouknider M.[3], Fatemi Z. E. A.[4], Razouk R.[4]

[1] *Agronomy, INRA, Meknès, Morocco*; [2] *Meknès, ENAM, Meknès, Morocco*; [3] *ENAM, Meknès, Morocco*; [4] *INRA, Meknès, Morocco*

Agroforestry based on olive tree is a common practice by small farmers in Morocco. The objective of this work is to evaluate productivity of annual crops sown in the alleys of an olive grove. Two cereals (*Triticum aestivum* and *Triticum durum*) and two legume crops (*Vicia faba* and *Lens culinaris)* were sown in the alley of an olive grove (over 30 years old, density: 10 m x 10 m) under rainfed conditions (rainfall 702 mm) at the experimnetal station of Douyet (latitude 34°2˝, longitude 4°, altitude 416 m).
Results show that the sowing lines under the foliage of the olive tree give the lowest yields compared to those sown in the middle part where maximum yields are : 81.5 g / Lm for *T. aestivum* and 61 g / Lm for *T. durum* while for legume crops, it reaches 59.91 g / Lm for *L. culinaris* and 15.91 g / Lm for *V. faba*. The lowest yields are obtained under foliage of the olive tree with it: 24.05 g / Lm (*T. aestivum)* and 24.75 g / Lm (*T. durum)*, 14.79 g / Lm (*L. culinaris)* and 4.41 g / Lm (*V. faba).* It appears that olive tree negative impact is more pronounced on *T. aestivum* and *L. culinaris* comparatively to *T. durum* and *V. faba* respectively when comparing yields obtained in the midle of the cropped alley with those obtained under foliage.
Crop roductivity in transects across the alley are indicated in figure 1. We conclude that *T. aestivum* as cereal and *L. culinaris* as legume crops give better yields comparatively to *T. durum* and *V. faba* respectively.

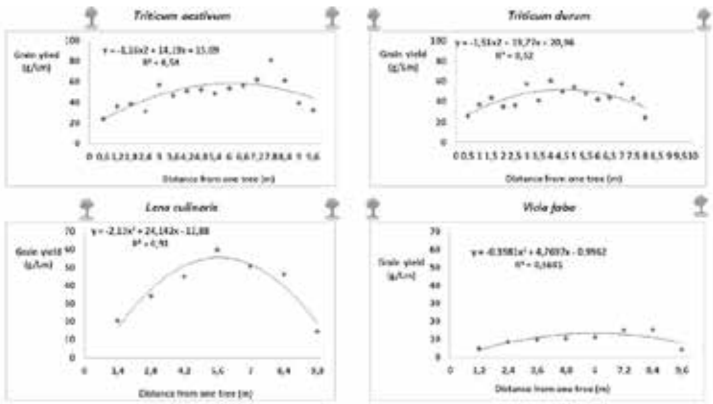


Figure 1. Productivity (g per linear meter) and productivity trends of cereals and legumes crops between two olive tree rows

Keywords: Olive, Triticum aestivum, Triticum durum, Vicia faba, Lens culinaris.

L18.P.09

Conventional AF : an oxymoron for the planet! - Organic AF: an oxymoron for crop breeding?… Towards OrgAgroforestry

Desclaux D. (dominique.desclaux@inra.fr)

INRA, Mauguio, France

Agroforestry (AF) is often define as “an ecologically-based land management system, that maintains ecosystem diversity and processes contributing to long-term sustainability and environmental quality”. But surprisingly in Europe and especially in France, AF is mainly implemented by conventional farmers, using chemical herbicides, pesticides and mineral fertilizers. Therefore, although «sold» as enhancing biodiversity of plants and insects, AF is managed by intensive methods known to kill such biodiversity!

This paradox interrogates the capacity of organic farming to well address stakes of agroforestry.

In France, organic AF knows a shy development and concerns mainly systems mixing fruit trees and vegetables or crops. Therefore, the understorey crops must be adapted to organic conditions and also to fruit trees association. But nowadays, there is no variety, registered in the french or european catalogue, cumulating these two criteria. For arable crops, to be register, a variety must be distinct, uniform and stable and is generally evaluated, for its value for cultivation and use, in conventional environments. In France, there are only 3 varieties bred in and for organic farming and registered (1 durum wheat and 2 soft wheat).

The demand for varieties presenting traits well adapted both to organic and to AF is increasing. But the question is : «Is-it the same ideotype that is required for both? «

Because herbicides and fungicides are prohibited and organic fertilizers are expensive, organic farming requires varieties adapted to weed competition (e.g. for cereals: early sowing to tolerate mechanical weed control, emergence seedling vigor, numerous tillers, high plant height, competitive roots), diseases resistance, and resources (water, N, P) use efficiency (deep roots).

In Agroforestry systems, the presence of trees imposes to consider others important traits like the duration of the cycle, namely to be compatible with the fruit tree phenology (for instance cereals can be sown in olive orchards only after olive harvesting, so late sowing is targeted), the tolerance to shade (horizontal leaf orientation, low leaf area index), the underground competition (superficial roots to avoid competition with tree roots), the ability to bear some adverse conditions like excess of humidity.

Some of the traits are common between organic and agroforestry needs but some others like phenology, roots architecture, etc. may differ. These differences must be seen as highly challenging for plant breeding. The proposal is to focus on a new merging concept : OrgAgroforestry (a contraction of Organic Agroforestry) that will strengthen the sustainability of AF and will help to reconsider ecological plant breeding through participatory approaches (Ecobreeding). The involvement of a great diversity of actors (farmers, processors, consumers, researchers, etc) to breed adapted varieties will renew the way to envision agroforestry and definitely enhance biodiversity.

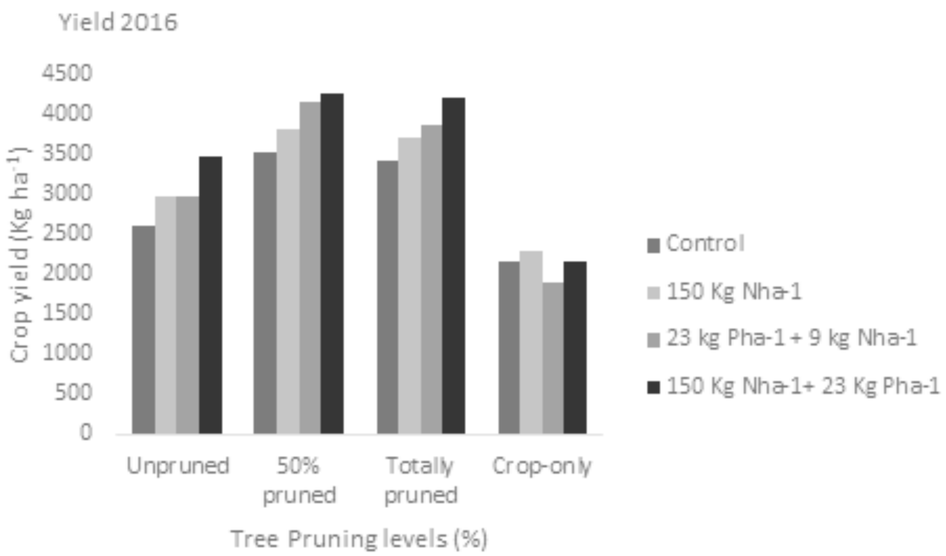
L18.P.10

Faidherbia albida improves maize productivity and carbon sequestration in a parkland agroforestry system in Ethiopia

Dilla A.[1] (amdilla@utas.edu.au), Smethurst P.[2], Barry K.[3], Parsons D.[4], Denboba M.[5]

[1] *University of Tasmania, Hobart, Tasmania, Australia*; [2] *CSIRO, Private Bag 12, Hobart TAS 7001, Hobart, Tasmania, Australia*; [3] *Tasmanian Institute of Agriculture, Hobart, Tasmania, Australia*; [4] *Swedish University of Agricultural Scien, Umeå, Sweden*; [5] *Addis Ababa University, Addis Ababa, Ethiopia*

Faidherbia albida is an important tree species in the parkland agroforestry system of Ethiopia, as it can improve carbon (C) sequestration and crop production. However, C sequestration and the effects of tree pruning and fertiliser on crop growth, have not been extensively studied in these parklands. Carbon sequestration in this system was estimated by harvesting *F. albida* trees above-ground and by taking soil samples under and beyond the tree canopies. A field experiment containing three levels of tree pruning as main plots, and application of recommended rates of N and P fertilisers as sub-plots, was conducted for two years (Dilla et al. 2019 Agroforestry Systems, in press). Trees stored about 2 t C ha-1 in their above-ground biomass and 34 t C ha-1 more in soil (0–80 cm depth) under trees than in crop-only areas. Carbon storage in trees was low due to sparse tree density (5.80 ha-1) but could be increased by encouraging farmers to protect planted seedlings or natural regeneration.
Biomass and yield of maize were higher (56%) under the 2-6 m radius of tree canopies compared to crop-only plots in both growing seasons, regardless of pruning and fertiliser levels. Fertilisation further increased yields (14.8%) under tree canopies compared to crop-only plots both years, but more so in 2016 (Fig). Maize production, C sequestration and profitability could be improved by partial pruning, and by preferentially applying fertilisers in normal and wet years.



Keywords: Biomass, Carbon, Maize, Soil, Yield.

References:

1. Dilla et al.
2. 2017
3. Agroforestry Systems
4. 1-11

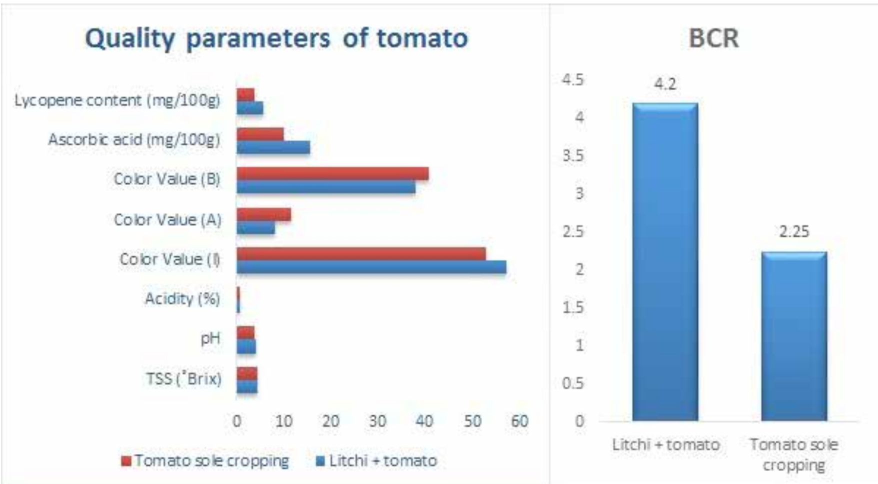
L18.P.11

Alley cropping of tomato improves fruit quality and profitability: experience from plain land ecosystem of Bangladesh

Hanif M. A.[1] (hanif_hstu@yahoo.com), Abdullahi Omar M.[2], Sarker M.[3], Bari M. S.[4]

[1] *South China Botanical Garden, Guangzhou, Guangdong, Bangladesh*; [2] *Benadir University, Mogadishu, Somalia*; [3] *Food Process and Preservation, Hajee Mohammad Denesh Sci. &Tech. Univ., Dinajpur, Bangladesh*; [4] *Agroforestry and Environment, Hajee Mohammad Denesh Sci. &Tech. Univ., Dinajpur, Bangladesh*

A central goal of agroforestry practices is to ensure productivity, profitability while maintaining ecosystems sustainability. Alley cropping is one of the most popular agroforestry system practiced around the world for triumphing ecological and economic benefits. Traditionally smallholder farmers of Bangladesh grow vegetables in between the alleys of fruit and timber yielding trees for income generation. Previous researches focused on identifying tree-crop combination only in terms of production but the profitability of the system along with the nutritional quality of the crops produced remain unknown. We conducted field experiments in the alleys of eight years old litchi orchard and recorded data of different parameters. The results revealed that the fruit yield of tomato was significantly higher in sole cropping (27.08 t/ha) than of alley cropping (15.33 t/ha). But benefit-cost ratio (BCR) of litchi tomato based alley cropping system (4.20) was maximum than sole cropping (2.25). In case of quality parameters, total soluble solids (TSS), ascorbic acid and lycopene content was significantly higher in alley cropping while pH and color values of fruit were higher in sole cropping. In alley cropping, tomato plants received 40-50% total light which indicates partial shade improved fruit quality. The findings from this study are valuable for the farmers and policymakers as litchi-tomato alley cropping system ensures production upholding nutritional quality and profitability.



Keywords: Alley cropping, productivity, profitability, fruit quality, Bangladesh.

References:

1. Dumus et al., 2003, Journal of the Science of Food and Agriculure, 369-382; 10.1002/jsfa.1370.
2. Hossain et al., 2014, International Journal of Agricultural Research, Innovation and Technol, 61-69.
3. Luedeling et al., 2014, Current Opinion in Environmental Sustainability, 1-7; 10.1016/j.cosust.2013.
4. Wang Feijuan and Zhu Cheng, 2012, African Journal of Agricultural Research, 4408-4415; 10.5897/AJAR1
5. Wolz and DeLucia, 2018, Agriculture, Ecosystems and Environment, 61-68; 10.1016/j.agee.2017.10.005.

L18.P.12

Yields of triticale in black locust stands based on different spatial arrangement of the trees

Honfy V.[1] (honfyv@erti.hu), Bácskai I.[2], Borovics A.[3], Füredi M.[4], Keserű Z.[5]

[1] *Department of Plantation Forestry, NARIC ERTI, Budapest, Hungary*; [2] *NARIC MGI, Gödöllő, Hungary*; [3] *Department of Tree Breeding, NARIC ERTI, Sárvár, Hungary*; [4] *Plant Protection Institute, Szent István University, Gödöllő, Hungary*; [5] *Department of Plantation Forestry, NARIC ERTI, Püspökladány, Hungary*

In 2014, the first national research project on agroforestry was launched in Hungary, at the Forest Research Institute (ERTI) of the National Agricultural Research and Innovation Centre (NARIC). The project aims to develop agroforestry technologies and management and disseminate knowledge on agroforestry systems.
A former experimental energy plantation was converted to a demonstration site of an alley cropping system in 2016 by removing certain tree rows and trees in the rows, creating 9 different spacings, which act as treatments of the intercropped cereal.
The site is located in an undulating area, eroded, and mainly characterized by Arenosol. The tree species is balck locust (Robinia pseudoacacia) and the crop is triticale (x Triticosecale) Maros GK which has been bred in Hungary, a hybrid of wheat and rye, a drought tolerant cereal. It is in commercial use for human consumption since 2015, and is assumed to be the future's organic cereal.
In this study we wish to announce the first results based on the yields of triticale in 2018. Data processing is in progress.
There was no pesticide use nor fertilizing on the site since 2012, and the latter fact makes the site appropriate to investigate nutrient cycle in the future. Balck locust is a nitrogen-fixing tree, therefore it could play an outstading role in sustainable agriculture in Europe, especially in the context of climate change. Eventually, we wish to provide an alternative land-use management in the region.

The alley cropping demonstration site in Hungary (Photo: Veronika Honfy)

Keywords: alley cropping, black locust, triticale, yield, tree spacing.

L18.P.13

Nitrogen-fixing tree hedges to fertilize crops on acid tropical soil

Kadir W. R.[1] (rashidah@frim.gov.my), Zaharah A. R.[2]

[1] *Forest Plantation Programme, Forest Research Institute Malaysia, Kepong, Selangor, Malaysia*; [2] *Soil Management, Universiti Putra Malaysia, Serdang, Selangor, Malaysia*

Traditional low input farming system relies on trees and shrubs to sustain soil fertility. One of the approaches is to adopt hedgerow tree planting, having trees of certain attributes capable of giving benefits to the cash (in our study *Zea mays*) or targeted crops. Trees with nitrogen fixing ability and fast returning biomass are of beneficial. Six nitrogen fixing trees i.e. *Gliricidia sepium*, *Parkia speciosa*, *Azadirachta excelsa*, *Paraserianthes falcataria*, *Acacia mangium* and *Leucaena leucocephala* were screened for their potentials to fix nitrogen and to produce high biomass. Stable isotope nitrogen technique was adopted with two reference non-fixing trees which were *Hopea odorata* and *Khaya ivorensis*. Each tree was planted within a plastic sheet lined inside 6m by 6m trench with 1m ditch and covered back with the same soil. ^{15}N was applied as labelled ammonium sulphate of 10% atom excess. Data collection was concluded at 30 months. For evaluating hedgerow trees contribution, *G. sepium* was selected based on its proven ability to withstand frequent pruning. Results show that *A. mangium* and *P. falcataria* were able to fix above 80% N. These two species also contributed high biomass (Table 1). We did not find significant improvement in soil fertility from N-fixing tree planting but corn yield (cash crop) was significantly improved by having hedgerow N-fixing tree and applied with its pruning and root biomass. The significant increase in yield was also seen in the second corn crop.

Table 1. Biomass fraction, nitrogen yield and biological nitrogen fixation of potential hedgerow trees

Species	Tree biomass (g tree^{-1})		Nitrogen yield (g tree^{-1})		Nitrogen from fixation (g tree^{-1})	
	Leaves	Stem	Leaves	Stem	Leaves	Stem
P. falcataria	4,073 a	61,043 a	138.6 a	423.1 a	122.3 a	196.0 a
L. leucocephala	175 c	2,554 c	7.2 d	26.3 c	4.7 c	6.9 c
G. sepium	200 c	3,281 c	8.4 d	34.2 c	1.6 c	0.0 d
A. mangium	2,389 b	18,247 b	75.7 b	118.8 b	62.1 b	59.1 b
A. excelsa	832 c	2,168 c	25.6 c	13.9 c	7.2 c	1.7 d
P. speciosa	Not harvested due to very low biomass				-	-

Keywords: Alley cropping, Green mulch, Low input, Nitrogen transfer, Weathered soil.

References:

1. Kang BT, Akinnifest FK & Lapido Do. 1994. J. Trop. For. Sci. 7(2): 303-312
2. Chintu R., Zaharah A. R. & Wan Rasidah Kadir. 2005. Agroforestry Systems 63(1): 45-52
3. Mercer DE. 2004, Agroforestry Systems 61(1–3): 311–328

L18.P.14

Evaluation of *Colocasia esculenta* L. germplasm under poplar based agroforestry system

Kukreti A.[1] (akshitkukreti1@gmail.com), Singh R.[2], Lavania S.[3]

[1] *Silviculture and FM Division, Forest Research Institute, DEHRADUN, Uttarakhand, India*; [2] *Agroforestry, GB Pant University, US Nagar, Uttarakhand, India*; [3] *Agronomy, GB Pant University, US Nagar, Uttarakhand, India*

Colocasia esculenta L. Schott (taro) plant is basically a collection of long-stemmed leaves which grows from the swollen stem/corm underground. It is the fourteenth most consumed vegetable worldwide. The most important feature of taro is its good adaptability, resistant to different diseases and high productivity in different areas. Taro plant can fit well with different tree crops and agroforestry systems. Taro in an agroforestry system will not only increase the supply of vegetable crops but also raise the green cover. The present study focus on the vegetative growth and yield of *Colocasia esculenta* under poplar based agroforestry system and open condition. Comparative performance of ten *Colocasia esculenta* germplasm, i.e., PA-12, PA-16, PA-18, PA-29, PA-33, PA-49, PA-56, PA-60, PA-63 and PA-73 were evaluated using Factorial Randomized Block Design with three replications. The results of the study revealed that germplasm PA-16 performed well under poplar based agroforestry system and gave highest yield (262.34 g/plant) per plant and (145.74 q/ha) per hectare. Whereas, germplasm PA-12 performed well in open system and gave highest yield (655.19 g/plant) per plant and (364.10 q/ha) per hectare. The physico-chemical property of soil for pH, electrical conductivity, organic carbon, available soil nitrogen, available soil phosphorus and available soil potassium were also analyzed, which were better under poplar based agroforestry system as compared to open farming system.

Table-1: Yield of Colocasia esculenta under open condition and poplar based agroforestry system

Treatment	Growing Condition (GC)			
	Yield per plant (g/plant)		Yield per area unit (q/ha)	
	Poplar	Open	Poplar	Open
PA-12	196.23	655.19	109.01	364.10
PA-16	262.34	484.49	145.74	269.16
PA-18	252.95	360.31	140.53	200.17
PA-29	125.74	337.48	69.86	187.49
PA-33	144.64	230.15	80.35	127.86
PA-49	215.42	299.06	119.68	166.15
PA-56	88.30	472.35	49.05	262.42
PA-60	78.28	439.47	43.19	244.15
PA-63	206.48	642.66	114.71	357.03
PA-73	95.35	490.44	52.97	272.47
Mean	166.57	441.16	92.54	245.08
	GC	Taro germplasm	GC	Taro germplasm
SEm±	2.94	1.31	0.73	1.63
SEm± (GC x germplasm)	4.15		2.31	
CD (5%)	8.44	3.77	2.10	4.69
CD (5%) (GC x germplasm)	11.93		6.63	
CV (%)	4.23		4.24	

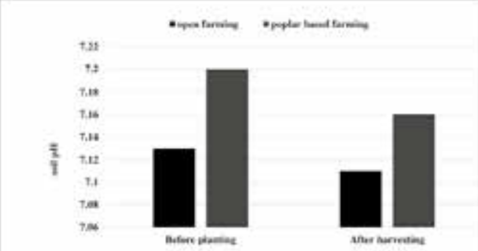


Fig. 1: pH content in soil before planting and after harvesting of taro

Table-1: Yield of Colocasia esculenta under open condition and poplar based agroforestry system.
Fig. 1: pH content in soil before planting and after harvesting of taro

Keywords: Agroforestry, Colocasia esculenta, Poplar, Soil, Yield.

References:

1. Bainbrdge, R., Evans, G.C. & Rackham, O. (1968). Journal of Plant Science, 46: 299-315.
2. Bhardwaj, S.D., Panwar, P. & Gautam, S. (2001). Indian forester, 23(4): 722-730.
3. Bidyut C. D. (2013). Indian Journal of Hill Farming, 26(2):16-20.
4. Chandra, J.P. (2011). Indian Journal of Ecology, 38: 11-14.
5. Dwivedi, A.K. and Sen, H. (1998). Horticultural Journal. 11(1): 83-89.

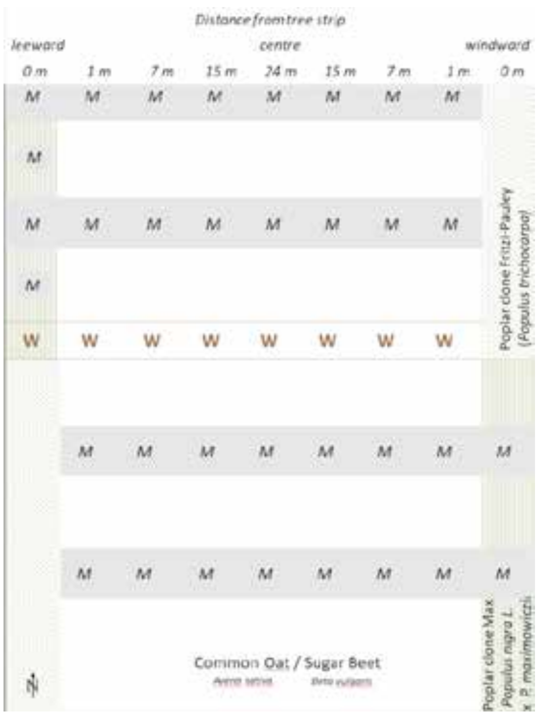
L18.P.16

Effects of agroforestry systems on microclimate and water availability as determinants for sustainable soil productivity

Majaura M. (majaura@b-tu.de), Böhm C., Freese D.

Soil Protection and Recultivation, BTU Cottbus-Senftenberg, Cottbus, Germany

Recent studies have shown that hedgerows in short rotation alley cropping systems (SRACS) can improve the microclimate in adjacent crop alleys through, e.g., a reduction of daytime temperature, wind speed and evaporation (Kanzler et al. 2018). Improved microclimatic conditions may positively affect crop yields by increasing the availability of water for the crop. However, studies that examine the interdependencies between microclimate changes caused by hedgerows in SRACS, water availability and crop yields are rare.
In a poplar SRACS, we investigate with high spatial and temporal resolution if changes in microclimate affect water availability for two crops and crop yields. For this purpose, we use stationary weather stations installed in a transect and mobile sensors in four strips running parallel to the stationary transect at different distances from tree strips (Fig. 1) and in a monoculture. At all measuring points air temperature, air humidity and Piché evaporation will be continuously determined. In addition, wind speed, global radiation and precipitation will be measured at the stationary weather stations. Furthermore, transpiration of crops will be determined at different times close to all microclimate points. Subsequent crop yield sampling will then enable us to determine the degree to which tree strips in ACS influence microclimate and water availability for crops at different distances from tree strips and how these relate to small-scale changes in crop yield.



Design of field experiment. Tree strips of poplar clones Max 1 (Populus nigra L. x P. maximowiczii) and Fritzi-Pauley (Populus trichocarpa) intercropped with Common oat Avena sativa and sugar beet Beta vulgaris, respectively. W: stationary weather stations, M: mobile weather stations.

Keywords: Alley cropping, Short-rotation coppice, Poplar, crop yields, Piché evaporation.

References:

1. Kanzler, M. et al. (2018), Agroforest Syst, in press, https://doi.org/10.1007/s10457-018-0289-4

L18.P.17

Soybean yield and feed value in a SRC poplar alley-cropping system: preliminary results from a field trial in Italy

Mantino A.[1] (alberto.mantino@santannapisa.it), Pecchioni G.[1], Volpi I.[1], Bosco S.[1], Dragoni F.[1], Giannini V.[1], Micci M.[2], Cappucci A.[3], Mele M.[3], Ragaglini G.[1]

[1] *Institute of Life Sciences, Sant'Anna School of Advanced Studies, Pisa, Italy*; [2] *Department of agricultural sciences, University of Perugia, Perugia, Italy*; [3] *Department of agriculture, University of Pisa, Pisa, Italy*

Silvoarable systems can reduce impacts of agricultural practice and increase agroecosystems services in the Mediterranean [1]. Nonetheless, farmers are reluctant to implement agroforestry systems because of the potential loss of gross production due to: (i) the reduction of arable surface and (ii) the risk of lower crop yield due to the competition for resources with trees [2]. The aims of this study are: (i) to assess the productivity of soybean in an alley-cropping system (AF) and (ii) to determine soybean productivity and feed value according to the position in the alley (A-West, B-MidWest, C-Centre, D-MidEast, E-East). The experiment is located in Pisa (Italy) 3 m a.s.l. on a loam to clay-loam soil with 7.6 pH. Rows of short rotation coppice (2yrs cut cycle) poplar are spaced 13,5m and N-S oriented. Soybean was sown the 12 June 2018 with 50 seed m-2. During the soybean growth period, rainfall was 90 mm and the mean temperature was 22.9 °C.

The harvest biomass and grain yield of soybean were higher in C respect all the other positions in the alley. The grain yield ranged from A to C (55 and 247 g m-2). Overall, the yield components declined according to the tree distance and light availability, showing a higher reduction in A and B position respect to D and E (Fig.1). The harvest index ranged from 0.40 to 0.47 in A and D respectively. Further analysis will assess the effect of tree presence as light availability and soil water competition on crop yield and nutritive value.

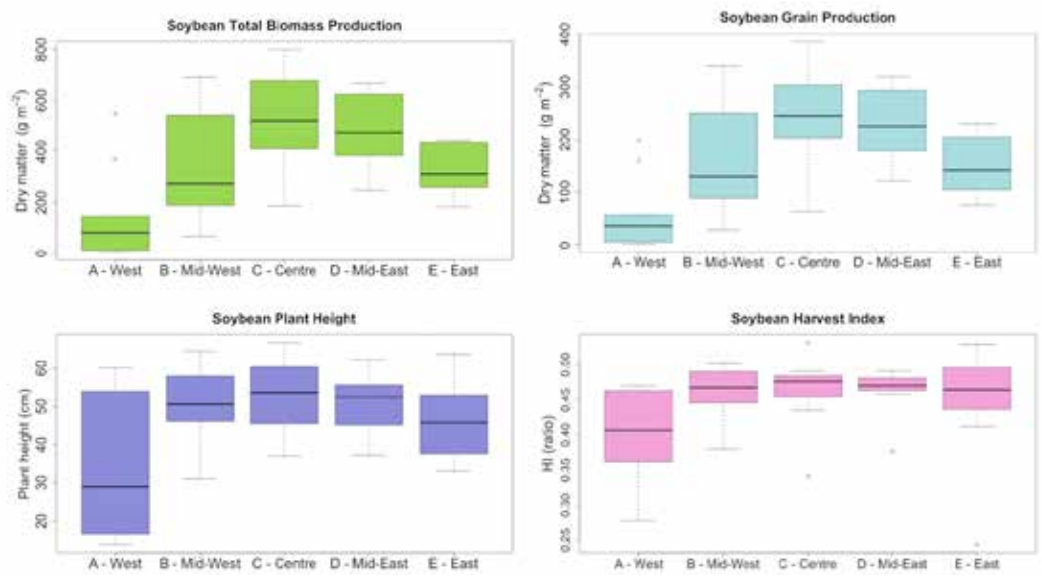


Fig.1 – Yield component data of soybean cultivated in an alley cropping system.

References:

1. Tsonkova et al., 2012, Agroforest Syst, 85: 133–152; doi: 10.1007/s10457-012-9494-8
2. Nasielski et al., 2015, Agron. Sustain. Dev., 35:1541–1549; doi: 10.1007/s13593-015-0330-1

L18.P.18

Trade-off of trees conservation and crops production on agroforestry parklands in Burkina Faso

Neya T.[1] (neyatiga@gmail.com), A. Abungyewa A.[2], Neya O.[3], Callo-Concha D.[4]

[1] *Civil Engineering, KNUST, Ouagadougou, Burkina Faso*; [2] *Agroforestry, KNUST, Kumasi, Ghana*; [3] *Competance center (escosystem service), WASCAL, Ouagadougou, Burkina Faso*; [4] *ZEF, University of Bonn, Bonn, Germany*

The rapid population growth couple with food demand makes land for agriculture more scarce. Farmers therefore, make use of any available piece of land at their disposal for crop production. The trade-off between crop production and tree conservation in the farm was assessed in Bouroum-Bourmoum, Sapouy and Ouahigouya municipalities in Burkina Faso. More than 3000 trees made up of 1154 trees at Bouroum-Bourom, 884 trees at Ouahigouya and 1054 trees at Sapouy were used. The mean tree canopy cover and tree cover in the farms were calculated. The three principal crops (millet, red sorghum and white sorghum) yield were used to estimate the trade-off using the mean tree canopy cover as the potential no cropping area. The results revealed a tree canopy cover of 66.25 m2at Bouroum-Bourom, 59.92 m2 at Sapouy and 42.1 m2 at Ouahigouya . The average tree cover was 23.99% at Bouroum-Bouroum, 18.23% at Sapouy and 14.88% at Ouahigouya. This represents a loss in grain production of 109.5 kg/ha at Bouroum-Bouroum, 247.6 kg/ha at Sapouy and 252.8kg/ha at Ouahigouya. A higher tree cover implies a higher trade-off in the agroforestry parkland and suggests reduction in tree density. There is urgent need to work out the balance between smallholders' farmer continuous requirement for increase food crop production and the need to maintain tree diversity in the farm for carbon credit payment promotion.

Keywords: smallholders, Trade-off, tree conservation, crop production, conopy cover.

L18.P.19

Climatic variability and the role of trees in influencing maize productivity in semi-arid Kenya

Njoroge J.[1] (juliusmnjoroge@gmail.com), Muthuri C.[1], Kuya S.[2], Nyaga J.[1], Sinclair F.[1]

[1] *Systems Science, ICRAF, Nairobi, Kenya*; [2] *Botany, JKUAT, Nairobi, Kenya*

The influence of mixed-species agroforestry systems in contrast to monocultures on crop productivity has not been widely examined in semi-arid Kenya. Pilot trials have to account for yield gaps as influenced by variability in rainfall and temperature. We evaluated performance of agroforestry trees (*Acacia seyal*, *Acacia xanthophloea*, *Cordia africana*, *Faidherbia albida* and *Grevillea robusta*) in sole and mixed species treatments in an on-station experiment at Jomo Kenyatta University of Agriculture and Technology farm and their influence on associated maize crops. Light interception was measured as above-ground interaction component. The trial was laid out in Randomized Complete Block Design covering 3.2-hectares. Tree growth was observed to vary with rainfall patterns while flowering in *C. africana* and *A. seyal* was influenced by changes in temperature. Rainfall distribution rather than intensity was also observed to be most critical for maize productivity and was evident in 2014/15 season where 93% of rainfall was received in one month resulting in crop failure. Average maize yields were higher (P<0.001) in 2013/14 (4.2 t ha-1) season compared with 2012/13 (2.6 t ha-1) and 2015/16 (1.4 t ha-1). Overall, *G. robusta* had the largest mean height (3.8m) and annual growth rate (1.3m yr-1); *F. albida* was slowest with corresponding values of 1.9m and 0.6m yr-1 respectively. Yields in agroforestry treatments consisting of *C. africana* and mixed species were 28% and 13% higher relative to control during the 2015/16 season. Canopy transmittance was higher in mixed-species (24%) compared to *C. africana* treatment (18%) while *F. albida* canopy was still developing. This study presents new information on the combined influence of differing canopies and suggest potential synergistic complementarity in mixed-species systems. Modeling below and above-ground interactions is considered the way forward in advancing the call for mixed-species systems and therefore a good basis for scaling within similar agro-ecologies.

Keywords: Agricultural productivity, Agroforestry, Mixed-species, Light interception, Climatic variability.

L18.P.20

Soil fertility variation under dominant agroforestry practices common to smallholder farms in Rift valley, Kenya

Nyaga J. (J.Nyaga@cgiar.org), Barrios E., Muthuri C., Öborn I., Sinclair F.

World Agroforestry Centre, Nairobi, Kenya

In sub-Saharan Africa, smallholder farmers remain the dominant source of food production and over the past years, integration of tree into cropping systems has become a common practice. A major constraint that is associated with such practice is on how to minimize competition and favor complementarities plus facilitative interactions among trees and associated crops in these simultaneous agroforestry systems. To overcome this constraint, our study evaluated the effect of spatial arrangement of dominant tree species (*Calliandra calothyrsus*, *Sesbania sesban*, *Grevillea robusta*, *Eucalyptus spp, Croton macrostachyus* and *Markhamia lutea*) on soil nutrient availability and whether this differential impact explains maize productivity in smallholder farms. Results showed that both *S. sesban* and *C. macrostachyus* have highest turnover rate of plant residues while *Eucalyptus spp* and *G. robusta* recorded lowest rate compared to the rest of evaluated tree species. The nutrient concentrations decreased with an increase in distance from tree trunk and increase in soil depth under *S. sesban*. The amount of total carbon (Total C), total nitrogen (Total N), exchangeable bases (ExBas), calcium (Ca), potassium (K), phosphorus sorption index (PSI) and available phosphorus (available P) in the soil decreased with an increase in depth into soil under all dominant tree species. The observation was attributed to direct inputs of soil nutrients under the tree from aboveground residues and possible depletion from uptake by tree roots. However, soil pH significantly increased with increase in soil depth under *C. calothyrsus* and *G. robusta.* Maize production was found to be adapted to Zone B (zone of root and light competition) under *C. calothyrsus* which the study attributed to improved soil nutrient under the tree as a result of leguminous nature. Maize production under *Eucalyptus* spp treatments was higher at Zone D (open cropped areas that are relatively free from the interference of trees) which highlights high competition for nutrients, water and light under the tree. In conclusion, dominant tree species in smallholder farms were found to differently influence the spatial distribution of soil nutrient which explains their differential impact on maize yield.

Keywords: Tree species, Nutrient availability, Maize productivity, Agroforestry systems, smallholders farms.

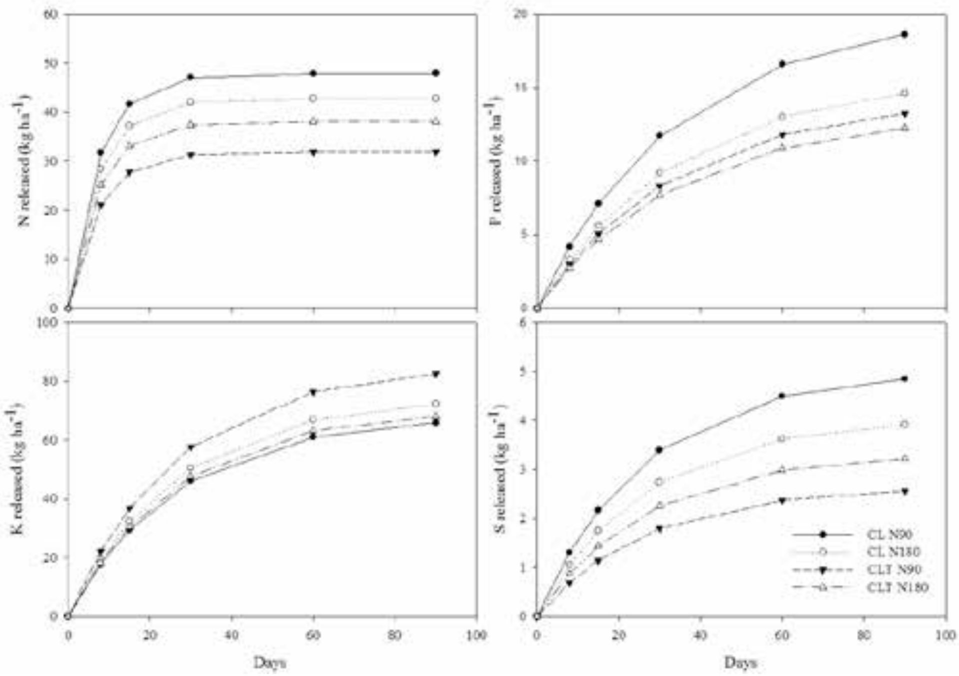
L18.P.21

Decomposition and nutrient release of corn litter in integrated crop-livestock systems

Pontes L. D. S.[1] (laisepontes@iapar.br), Oliveira F.[2], Santos B. R. C. D.[3], Carpinelli S.[2], Assmann T. S.[4], Fonseca A. F. D.[2]

[1] *Agronomic Institute of Paraná, Ponta Grossa, Paraná, Brazil*; [2] *State University of Ponta Grossa, Ponta Grossa, Paraná, Brazil*; [3] *Federal University of Paraíba, Areia, Paraíba, Brazil*; [4] *Technological Federal University of PR, Pato Branco, Paraná, Brazil*

Calculations of nutrient fluxes in integrated crop-livestock systems (ICLS) can furnish basic information about sustainability of those systems (Carvalho et al., 2010). We evaluated the influence of two levels of N fertilization (90 and 180 kg N ha-1) and two ICLS, with (159 trees ha-1, *Eucalyptus dunnii* + *Grevillea robusta*) and without trees, on the release rate of N-P-K-S from decomposing corn straw. Both ICLS integrated corn during the warm season and beef cattle grazing on pasture during the cool season. The experimental design was a randomized complete block with three replicates and with four treatments (i.e. two ICLS crossed with two N levels). Litter decomposition and nutrient release were assessed with litter bags placed at the soil surface during the subsequent growth of black oat/ryegrass pasture. During 90 days of decomposition, no changes in N-P-K-S release dynamics (i.e. on the decomposition rates and active fractions) were observed between treatments. However, total N-P-K-S released from summer residues (Figure 1) and potentially available to the subsequent pasture depended on the initial N-P-K-S level of residues and on the quantity of plant residues, which was significantly (P<0.10) reduced under 7-year-old trees (-26%). Silvicultural interventions need to be intensified to reduce the shading level to below 41% and avoid losses to soil cover, which in turn will maximize benefits from nutrient cycling, since important amounts of N-P-K-S are cycled (Figure 1).



Total Nitrogen (N), Phosphorus (P), Potassium (K) and Sulfur (S) released from corn straw to Lolium multiflorum + Avena strigosa pasture, as affected by treatments, during litter-bag exposure in a field experiment. CL, crop-livestock and CLT, crop-livestock-trees systems; 90 and 180 kg N/ha, N90 and N180, respectively.

Keywords: corn, Eucalyptus dunnii, litter bag, no tillage, subtropic.

References:

1. Carvalho, et al., 2010. Nutrient Cycling in Agroecosystems, 88, 259-273, DOI 10.1007/s10705-010-9360

L18.P.22

Effect of *Populus deltoides* windbreak on productivity of wheat and soil nutrients in semi-arid ecosystem of India

Sirohi C. (chhavisirohi22dec@gmail.com), Bangarwa K. S., Dhillon R. S., Chavan S. B.

Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana, India

Windbreaks under agroforestry systems (AFS) are considered to be a sustainable agricultural practice, as they bring an ample range of environmental services (ES) while upholding prime agricultural production. To optimize the efficiency of AFS, the suggestion is to develop well modified tree-crop integration by limiting competition for resources and capitalize on the coactions. However, yield data of various wheat varieties in AFS are inadequate, in particular for *Populus deltoides* windbreak at a age of seven and eight year old plantation. Here we focused on winter wheat varieties (WH-1105, WH-542, HD-2967, HD-943 and DPW-621-50) during two consecutive years (2013-2015) comprising delimited by a row of deciduous poplar trees in East-West and North-South directions (E-W tree line divide farmlands into two aspects i.e. Northern and Southern and N-S treeline divide into Eastern and western aspect). While effects on crop production were limited for all wheat varieties with the increasing distance from tree line, however, considerable yield reductions were found near tree line at a distance of 2 m, for all the wheat varieties. The highest available soil N (365.2 kg ha–1), P (19.7 kg ha–1) and K (357.3 kg ha–1) were recorded near tree line at a distance of 2 m. To optimize the provisioning service of poplar windbreak AFS, the cultivation of highly shade tolerant wheat variety HD-2967 may be advisable over other wheat varieties towards the end of the rotation of poplar windbreak AFS.

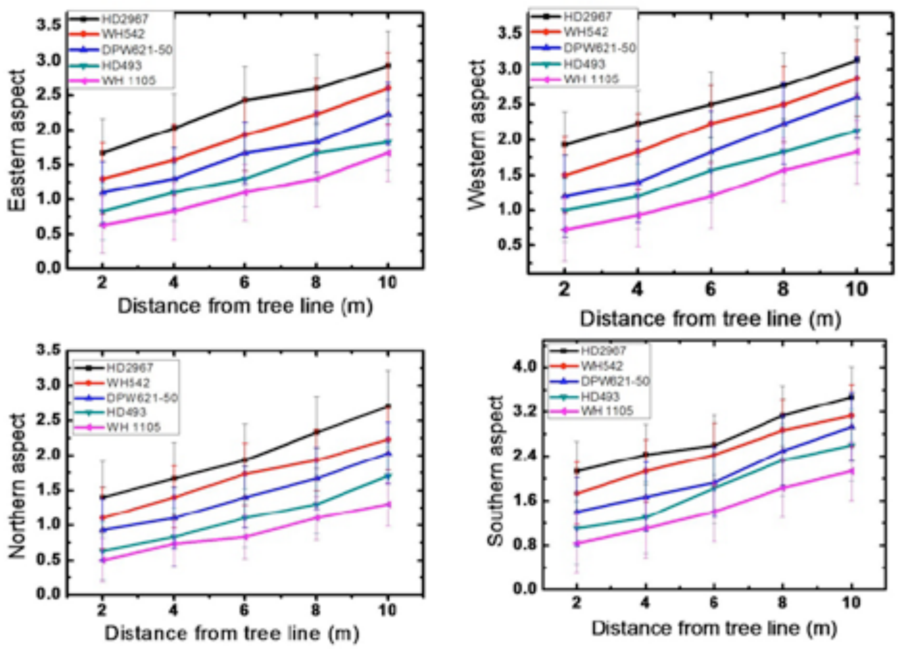


Figure 1: Effect of East-West and North-South bund plantation and different distances from the tree line of poplar on grain yield (t/ha) in wheat varieties (pooled data) of 2013-14 and 2014-15.

Keywords: Agroforestry, Poplar, Productivity, Windbreak, Wheat.

L18.P.23

Pollarding *Faidherbia albida* tree reduces complementarily benefits of understorey wheat: Experience from Mojo, Ethiopia

Toib A. A.[1] (awol.assefa@aau.edu.et), Muthuri C.[2], Gebrekirstos A.[3], Meles Hadgu K.[4], Sinclair F.[5], Fetene M.[1]

[1] *Plant Biology & Biodiversity Management, Addis Ababa University, Addis Ababa, Ethiopia*; [2] *Ecophysiology, World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [3] *Ecophysiology/Dendrochronology, World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [4] *World Agroforestry Centre, Addis Ababa, Ethiopia*; [5] *Bangor University, Bangor, Wales*

Faidherbia albida is an important agroforestry tree species known for its reverse phenology which makes it compatible with most crops. The management of F. albida varies from region to region; some retain part of the branches and some pollard full canopy, the later is common in Mojo for fencing purpose. The study was conducted in Mojo, Ethiopia from 2016 to 2017. The area is known for its erratic rainfall and frequent drought which adversely affect crop productivity. The main objective of this study was to investigate the impact of pollarding F. albida on water relation of the tree and wheat productivity under non-pollarded and pollarded trees. Six trees with similar size were selected of which three trees were pollarded as per farmers' practice and the other three were kept un-pollarded. Tree sap volume was measured using heat ratio method (ICT International Pvt. Ltd, Australia). Cambial growth was measured using electronic dendrometer (Ecomatik Muenchner, Munich, Germany), soil moisture was measured using profile probe (PR2 Delta-T device, Cambridge, England) from different depth classes (10-100cm); wheat aboveground biomass and grain yield were recorded under non-pollarded and pollarded F. albida. For most of the parameters, there were significant differences between the two tree managements. Sap volume declined when the tree was pollarded and during leaf shading from non-pollarded one mainly around the onset of the main rainy season (June-July). The highest monthly sap volume was 4590L (153L day^{-1}) for non-pollarded compared to 403L (13.4L day^{-1}) for pollarded F. albida, during the dry season (January-March) in each year. Cambial dynamics of pollarded trees reduced up to 96% due to pollarding effect compared to non-pollarded ones. As a result, pollarding reduces the tree annual trunk growth up to 78%. The average soil moisture percentage under non- pollarded F. albida was higher compared to under pollarded trees across similar depth classes. The highest aboveground biomass was 4.1 t ha^{-1} and 3.5 t ha^{-1} at 1m distance under non-pollarded and pollarded F. albida tree respectively. Similarly the highest grain yield obtained under non-pollarded and pollarded F. albida was 4 t ha^{-1} and 2.3 t ha^{-1} respectively. Despite higher sap volume and sap flow rate was recorded from non-pollarded F. albida, aboveground biomass and grain yield obtained under pollarded F. albida decreased by 14% and 42%, respectively. The study indicates pollarding the branches of F. albida not only reduced the cambium increment but also reduces complementarily effect of tree-crop interaction. To optimize the benefits of F. albida - wheat interactions, the study suggests to raise awareness of farmers and motivate them to reduce pollarding. To meet the fencing and fuel wood demands in this area, research should enhance informed policy and decision makings through supporting design, testing and adoption of best-fit and climate smart agroforestry options in Ethiopia and beyond.

Keywords: Faidherbia albida, Mojo, Reverse phenology, Sap volume, Water relation.

L18.P.24

The effect of distance from olive row on soil fertility in olive orchards with different intercropping crops in Morocco

Zayani I.[1] (zayaniinass@gmail.com), Bouhafa K.[2], Ammari M.[1], Ben Allal L.[1]

[1] *Chemistry, Faculty of Sciences and Techniques, Tangier, Morocco*; [2] *soil, plant and water, INRA, Meknes, Morocco*

Agroforestry is a set of agricultural practices whose coherence is based on the use of ecological processes and the valorization of agro-biodiversity. It is often a question of combining one or more woody species with annual crops to obtain a mixed farming system, managed in the long term to produce and protect the environment. These cropping systems are an integral part of traditional Mediterranean and also Moroccan agriculture including systems based on olive trees. This work aims to study the effect of distance from the olive tree on soil fertility at different intercrops in comparison with the olive tree in monoculture.
The study was done in an olive orchard conducted in rainfed conditions owned by a farmer in the Saiss region of Morocco. The orchard is planted at a density of 12*10 m^2 where the trees (Moroccan picholine) are old than 22 years. Three annual crops (fababean, spring chickpea and lentil) are cultivated as intercropping crops with olive tree in the study area. Soil samples were taken from the 0-30 cm layer in the different plots in the olive orchard. These samples were the subject of soil physico-chemical characterization. After harvesting annual crops in June 2018, soil samples were taken from the 0-30 cm layer at different distances from the olive rows (0, 1, 2, 6, 10, 11, 12m). These samples were subjected to chemical analyzes to determine their fertility levels.
The soils studied are calcareous with neutral pH and electrical conductivity. According to the distances studied the results showed that in the different annual crops parcels the soil organic matter content was important near the olive trees (0 and 12m) but it decreased in the uncultivated band (between 0-2m and 10-12m) then it increases inside the plot until reaching a high value at the mid-distance of the olive row. The results of this study are in agreement with several studies that contribute to the increase of soil organic matter returns to intercropping systems, due to the above-ground biomass residues of associated trees and intercrops and the in situ decomposition of their roots. For nitrate levels in the fababean and lentil plots, initial soil characterization recorded higher values than post-harvest analyzes. This may be due to the character of atmospheric nitrogen fixation related to legumes that have already been installed during the first sampling period. The results of variance analyzes, performed by the SPSS software, showed that soil parameters, have not been affected by the distance from the olive row for all the systems studied. On the other hand, for the olive tree in monoculture, the distance from the olive row affected the soil phosphorus contents.
The soil parameters measured in the different intercropping systems give different results relating to the effect of the distance studied.

Keywords: agroforestry, olive tree, soil fertility, legume, Morocco.

ABSTRACTS

Specific agroforestry systems

Let's drill down: the amazing varieties of agroforestry

- L19 -

Silvopastoral system: promoting rural development by increasing tree-animal-pasture relationships

When the trees and livestock dance together:
getting a rural renaissance through sylvopastoralism

Silvopastoral systems were and still are common all around the world. While traditional ones dominate large agricultural landscapes in less productive soils and/or climate, different new silvopastoral schemes emerged in the last decades to improve the forage autonomy of extensive pastures and to cope different environmental issues associated to livestock farming. The selection of the abstracts for this session will try to cover this geographical distribution and to demonstrate the relevance of these systems for livestock farmers and the provision of public ecosystem services. Both fundamental and applied research results are encouraged to be presented. The abstracts submitted for oral presentation should refer to work carried out in topics dealing to one or more of the following elements: tree, animal or pasture, and their interactions. Works dealing with environmental benefit and economic advantages of planting/maintaining trees (and/or shrubs) on pastures are also welcome. Abstracts dealing specifically to the description of silvopastoral systems are encourage to be proposed for a poster presentation, although the description of innovative silvopastoral systems and practices can be also proposed for oral presentation. Results should be clearly stated in the abstract submitted. Some examples of topics of interest are: tree-pasture management and interaction, improved pastures for shading conditions, woody forage banks, animal carrying capacity, evaluation of the benefit of tree shelter for animal production and welfare, tree regeneration monitoring and promotion, control of nutrient leaching and greenhouse gases emission, carbon sequestration, silvopastoralism for the adaptation and mitigation of climate change.

L19_O.01

Microclimatic effects of oak trees on California rangelands: implications for cattle heat stress in a changing climate

Kerr A. (ackerr@ucdavis.edu)

Agricultural Sustainability Institute, University of California, Davis, California, USA

Oak savannahs are a cultural icon of California and the most important rangeland type in California's $4 billion beef cattle industry. In past decades, California ranchers have often removed or ignored oak trees on their rangeland (Huntsinger et al. 2010), but they are now increasingly recognizing the need to actively manage oaks for multiple benefits (Oviedo et al. 2017). One benefit of mature trees is reducing cattle heat stress by providing shade. Studies in tropical Latin America (e.g., Mitloehner and Laube 2003) have quantified this benefit, but few field studies have been conducted in the US (Sharrow 2000), and none have been done in California to our knowledge.

The issue of cattle heat stress becomes more pressing under climate change. By 2040-2069, daily maximum temperatures in California's inland foothills are predicted to increase by 3°C (5.4°F). We conducted this field study (29 Aug – 3 Oct 2018) to investigate whether oak canopy cover could be an important climate adaptation tool in California rangelands.

Our study sites were three grazed regional parks (Vargas, Pleasanton Ridge, and Brushy Peak) along a 50-km transect (121.8W, 37.6N). We designated three plots per park, and in each plot, we used a pair of radiation-shielded loggers (Hobo 8K Pendant Temp, Onset Corp) at 1 m height to measure air temperature under a large mature live oak (*Quercus agrifolia*) and in an open field 20 m away. We also collected temperature data with a pair of "black globes" (hollow black metal balls with sensors inside) that incorporate effects of solar radiation and wind, as a proxy for animal heat stress.

Our paired sensors showed that *Q. agrifolia* canopies have a major cooling effect. Midday (10a to 4p) air temperatures averaged 4.5°C (8.2°F) cooler under the canopies. The effect varied between our nine plots (range: 3.1 to 6.3°C), with higher wind speeds reducing the canopy/field difference while tree size had no effect. Midday black globe temperatures showed an even larger difference of 10.2°C (18.3°F). We translated these data into a livestock heat stress index (Dahlen and Stoltenow 2012), assuming 30% RH. Compared to under an oak canopy, open fields were 2.4 times more likely to reach the "Alert" threshold (29.4°C / 85°F) and 12.7 times more likely to reach the "Danger" threshold (32.8°C / 91°F). Open fields reached the "Emergency" threshold (37.8°C / 100°F) for an average of 1 hour per day, whereas this threshold was never reached under any tree canopy.

These results suggest that maintaining and increasing mature oak trees on open rangeland could help California ranchers protect their herds from climate variability and future warming. Future work could examine a wider geographical area, more species of oaks, and animal behavior. It is already clear that cattle "vote with their feet," congregating under trees on hot days. Quantifying this important benefit of oaks can help inform management strategies in grazed oak woodlands.

Keywords: shade, cattle, heat stress, climate change, rangelands.

References:

1. Huntsinger, L., et al. (2010). Rangel. Ecol. Manage. 63:324-334.
2. Oviedo, J., et al. (2017). Rangel. Ecol. Manag. 70:518-528.
3. Mitloehner, F., and Laube, R. (2003). J. Anim. Vet. Adv. 2(12):654-659.
4. Sharrow, S. (2000). Temperate Agroforester 8:1.
5. Dahlen, C., and Stoltenow, C. (2012). NDSU Extension Brief AS1615 (ag.ndsu.edu).

L19_O.02

First high-density protein banks, based on *Morus alba* and *Leucaena leucocephala*, for livestock feeding in Western Africa

Sib O.[1] (sibollo84@yahoo.fr), González-García E.[2], Bougouma-Yaméogo V.[3], Blanchard M.[4], Navarro M.[5], Vall E.[6]

[1] *CIRDES, Bobo-Dioulasso, Burkina Faso*; [2] *INRA, Montpellier, France*; [3] *University Nazi Boni, Bobo-Dioulasso, Burkina Faso*; [4] *CIRAD, Hanoi, Vietnam*; [5] *University of Matanzas, Matanzas, Cuba*; [6] *CIRAD, Montpellier, France*

To feed dairy cattle in West African farms, livestock keepers usually combine the availability of natural resources, crops residues and other more or less locally available alternative feed resources. However, despite such strategies the herds nutritional requirements are rarely covered. Among the consequences of such often and unpredictable feeding unbalances are the low production level and calvings seasonality. Thus, this study was intended to design, in partnership with livestock keepers, an innovative forage system that has never been tested under the West African context. The proposed low-input intensive forage production technology, rely on establishing high-density Woody forage banks (WFB). The potentialities of WFB for sustainable forage production, as well as the establishment feasibility under real farm conditions and the effects on the dairy cows production performance was also evaluated. During 18 consecutive months, we monitored the agronomic performance of two widely recognized woody fodder species (one leguminous: leucaena, *Leucaena leucocephala*; and one non-leguminous: mulberry, *Morus alba*), planted at high-density (20000 plants/ha) for the first time in 3 different sites of western Burkina Faso for intensive forage production. Three WFB have been established in 2016 using the «step-by-step» co-design method (Vall et al., 2016). At the first standardization cut, 13 months after planting date (PD), the heights of leucaena and mulberry plants were respectively 183.4±20.4 cm and 153±5.3 cm and lower than reported results ranging from 200 to 300 cm (Wencomo et al., 2009; Martín et al., 2014). These performances were affected by soil quality, termite attacks, drought and agronomic practices such as mulching, shallower planting bed. The high forage yield per ha as well as the nutritional values (crude protein=28 and 19 % for leucaena and mulberry, respectively) confirmed the potential interest of this forage technology for contribution to the farm forage authonomy in this region while improving animal performance. However, special attention must be deserved for adjusting agronomic practices to factors like soil properties, drought, termite attack and fires. The cumulative biomass production over 3 harvests (PD+13, PD+15 and PD+18 months) was 8.2±2.6 t DM/ha and 1.8±2.3 t DM/ha respectively for leucaena and mulberry versus 15 t DM/ha and 10-12 t DM/ha for leucaena and mulberry respectively reported (González-García et al., 2009; Martín et al., 2014). The economic feasibility indicated that production cost of 1 kg of forage has been estimated at 152 franc of the African financial community (FCFA), which could be more competitive if the forage bank is «self-made» (46 FCFA). These results demonstrated the potentialities and feasibility of establishing, with a low-input approach, high-density WFB under the harsh conditions of Burkina Faso, a potential alternative to enhance farms forage autonomy and dairy production for livestock keepers.

Keywords: Forage technology, Woody forage banks, Ruminant feeding, Dairy production, West Africa.

References:

1. González-García E. et al., 2009, Agroforestry System., 77: 131–141, DOI: 10.1007/s10457-008-9188-4.
2. Martín G.J. et al., 2014, Revista Cubana de Ciencia Agrícola, 48(1):73-78, www.redalyc.org/pdf/1930
3. Vall E. et al., 2016, Cahiers Agricultures, 25: 1500 (1-7), http://dx.doi.org/10.1051/cagri/2016001.
4. Wencomo H.B. et Ortiz R., 2009, Pastos y Forrajes, 33(3): 1-17, http//scielo.php?script=s-ciarttex.

L19_O.04

Improving pastures for shading conditions: adaptive responses of legume species in a Mediterranean silvopastoral system

Franca A. (antonio.franca@cnr.it), Dettori D., Nieddu D., Sanna F.

CNR ISPAAM, Sassari, Sardinia, Italy

Background
Silvopastoral stakeholders need to ensure the system resilience through the increasing of pasture availability and the assessing of appropriate stocking rate (Camilli et al., 2018). Annual legumes are a key feature for the improvement of low quality native pastures in these systems. One of the most critical factor controlling silvopasture productivity, along with other factors (competition for soil resources, different microbiota, higher mineral N in the soil beneath trees, ets.), is the competition for light, and light interception affects the growth and development of understorey herbaceous vegetation in various ways.
Aims
The main objective was to assess the adaptability and the factors responsible for better adaptation to shade of different legume species in a Mediterranean silvopastoral system.
Materials and methods
The experimental site was located within a scattered tree cork oak silvopastoral systems at Monti, North-East of Sardinia, Italy. Three pasture types were compared (pasture oversown with Fertiprado commercial legume mixture; pasture oversown with ISPAAM mixture based on native pasture species; and native pasture) under and outside of the tree canopy. The composition of mixtures was as follows:
ISPAAM - 40% *Trifolium subterraneum* cv Campeda, 40% *Medicago polymorpha* cv Anglona, 20 % *Lolium rigidum* cv Nurra.
FERTIPRADO - *T. subterraneum* (60.6%), *T. michelianum* var balansae (4.5%), *T. vesiculosum* (3%), *T. resupinatum* (3%), *T. incarnatum* (6.1%). *T. isthmocarpum* (1.5%), *T. glanduliferum* (1.5%), *Ornithopus sativus* (19.7%).
The plot size was 5 m x 3 m, with three replicates. Measurements regarding plant morphology and mixture productivity were taken during 2015 and 2016.
Results
Shading did not affect seedling establishment, whether for sown mixtures and native pasture. Only *T. subterraneum* and *T. vesiculosum* have significantly elongated the stems under shading. Leaf area was significantly influenced by shading only in *T. vesiculosum* plants. Shading negatively affected the dry matter yield in both the ISPAAM and Fertiprado mixtures. In the spring of the second year, after the first self-reseeding, the ISPAAM mixture showed high contribution of *L. rigidum* and *T. subterraneum* cv Campeda to floristical composition. Among Fertiprado legumes, only *O. sativus* showed a high coverage in the second year probably because of its very low level of hardseededness.
Conclusions
The openness of scattered trees in the studied silvopastoral system restricted the difference in the levels of light transmission between shaded plots and not shaded plots. However, the most shade-adapted species for the use in legume-rich pastures were *T. subterraneum* cv Campeda (ISPAAM mixture), *T. vesiculosum* and *O. sativus* (Fertiprado mixture) and shading reduced the productivity of the legume-rich mixtures of 70%-90%.

Keywords: legumes, silvopasture, shading, adaptation.

References:

1. Camilli F. et al, 2018, Agroforestry Systems, 92, 4, SI, 849-862

L19_O.05

Silvopasture as an approach to restoring productivity of unmanaged woodland grazing in the Upper Midwest, USA

Zamora D. (zamor015@umn.edu)

Extension, University of Minnesota, St. Paul, Minnesota, United States

Unmanaged woodland grazing is a common practice among livestock producers in the upper Midwest, USA. It is a practice that is suboptimal for grazing animals, degrades potentially productive trees, reduces species diversity, and increases soil erosion resulting in reduced water quality. Woodland grazing without proper management is estimated to occur on 268,000 hectares in Minnesota, USA. As a beneficial alternative to unmanaged woodland grazing, silvopasture can be employed to increase forage growth, increase tree and livestock health and productivity, increase soil health, and improve water quality on those lands. This project had two major objectives: 1) to assess the impacts of silvopasture as an alternative to unmanaged woodland grazing practices, and 2) to increase awareness and adoption of silvopasture practices through outreach activities, such as the development of a Silvopasture Learning Network (SLN). The purpose of this network is to facilitate farmer-to-farmer learning, promotion, and information sharing to expand natural resource conservation practices. We established three research sites to measure the impacts of silvopasture on water quality as influenced by infiltration rate, plant species diversity, forage production and quality, and livestock weight gain. These parameters were compared among three established systems in each research site: 1) conventional open pasture, 2) traditional unmanaged woodland grazing, and 3) silvopasture. Results show that silvopasture can influence water quality, soil health, species diversity, forage availability, and livestock health. Silvopasture promotion and adoption are without any challenges. At this presentation, we will share an innovative approach of scaling up silvopasture through the development of a SLN. Understanding the benefits of silvopasture and increased networking opportunities may be the links that encourage producers to convert marginal unmanaged woodland grazing to silvopasture and thus allowing for a higher level of productivity and environmental benefits.

Keywords: Woodland Grazing, Water Quality, Species Diversity, Livestock Health, Soil Health.

References:

1. Diomy Zamora, University of Minnesota Extension, 55108, St. Paul, Minnesota, USA
2. Maddie Ford, Dean Current, Joe Magner, University of Minnesota, CFANS, 55108, St. Paul, MN USA
3. Sophia Vaughan, Minnesota Pollution Control Agency, 55155, St. Paul, Minnesota, USA
4. Gary Wyatt, University of Minnesota Extension, 56001, Mankato, Minnesota, USA.
5. Dusty Walter, University of Missouri, CAFNR, 65211, Columbia, Missouri, USA

L19_O.06

Trees and pastures: building integrated production systems in Amazonia

Olival A.[1] (aolival@unemat.br), Morais J.[2], Olveira R.[2], Souza S.[3]

[1] *NAFA, Universidade do Estado de Mato Grosso, Alta Floresta, Mato Grosso, Brazil*; [2] *Universidade Federal de São Carlos, Araras, São Paulo, Brazil*; [3] *Instituto Ouro Verde, Alta Floresta, Mato Grosso, Brazil*

Pastures are among the main land use types in the world. In Brazil they occupy 20% of productive area, although half of them are somehow degraded. In "Portal da Amazonia" Territory (MT) the implementation of agroforestry systems (AFS) has been encouraged by social movements and NGOs, with support of universities and research centers. In the past decade, more than 1,000 families have adopted AFS and, among them, silvopastoral systems (SPS). The Family Agriculture Resilience Research Program was structured in 2015 to support these projects, having SPS among their research lines. Research projects and governance structure were supported by Instituto Ouro Verde using resources from the Amazon Fund/ BNDES and University of Exeter. We have been working with participatory mapping to locate tree species of interest to farmers that can be incorporated into production systems, aiming to improve the quality of soil and forage, to identify species which leaves or fruits can be used as nutritional supplements and propose arrangements with different species that guarantee greater biodiversity and financial return in the short and long term. Research lines are updated every year, including new species and discussing results with communities for adjustments to existing production systems and planning new ones. So far, results have shown that among desirable characteristics for the species, according to farmers, are tree growth and their potential uses in the property, absence of toxicity or danger to animals and positive influence on pastures, especially in the dry season. Among the species indicated by farmers, *Handroanthus serratifolius* contributed to higher protein contents of forage plants, raising crude protein level from 3% to 5%. *Apeiba tibourbou* Aubl influenced soil fertility in shaded areas, especially increasing potassium levels from 116 to 298 mg dm-3. Main effects of trees on pasture were observed in the dry period, while the effects on soil fertility were potentialized in the rainy period. Fruits of *Samanea tubulosa,* leaves of *Maclura tinctoria* and different *Inga* species showed high percentage of crude protein (15,9%, 12,0% and 12,3%, respectively), being able to be used as supplements for dairy cows. Studies have also assessed the behavior of these animals in shaded pastures, showing that they respond positively to shading conditions when there is good distribution of forage supply, increasing rumination period and reducing laziness. However, when shading is not well distributed this effect can be reduced or even eliminated. We emphasize the importance of the articulation between research, extension and support for SPS planting, with the direct involvement of family farmers in this process. This experience shows that research can be used as a tool for innovation and transformation of production systems in different scales of action, thus paving the way for enhancing resilience of family farming in an Amazonian agricultural frontier

Keywords: Amazonia, participatory research, family farmer, pasture.

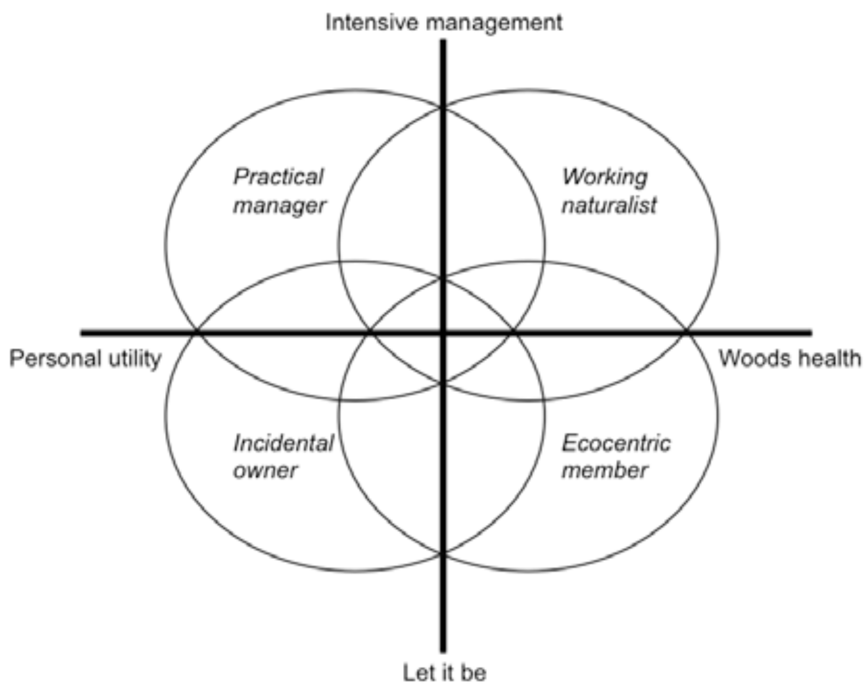
L19_O.07

Advancing silvopasture in temperate oak ecosystems via social, observational, and experimental approaches

Keeley K.[1] (keefekeeley@gmail.com), Galleguillos N.[2], Ventura S.[3]

[1] *Savanna Institute, Madison, Wisconsin, United States*; [2] *Gestión Ambiental Consultores, Santiago, Chile*; [3] *Soil Science, UW-Madison Nelson Institute, Ma, Wisconsin, United States*

Unmanaged woodland grazing can cause timber degradation, diminished regeneration, habitat loss, soil erosion and water quality impacts. Nevertheless, farmers in Wisconsin, USA use woodlands for grazing to meet management objectives, and for property tax benefits. To evaluate promise of silvopasture in this landscape, we conducted three related studies:
First, we interviewed 18 farmers about how they use and value their woodlands. Interviewees commonly valued woodlands for pasture, timber, fuel, hunting, aesthetics, and lifestyle benefits. Diverse perspectives emerged regarding management motivations and objectives, which suggested four types of perspectives toward farm woodlands: incidental owner, practical manager, working naturalist, and ecocentric member. We distinguished these types via instrumental or intrinsic values, as well as active or passive management of woodlands.
Second, we measured soil compaction and vegetation biodiversity across a gradient of cattle grazing intensities, confirming the direct relation between intensity and negative impacts on woodland ecology, but pointing out potential management strategies to reduce impacts.
Third, we established silvopasture via overstory and brush thinning in degraded oak woodland on three farms. In paired experiments with/out rotational beef grazing, preliminary results indicate that canopy thinning and broadcast seeding improved forages, native understory establishment was poor, and adaptive management improved outcomes.



A typology of perspectives on use and value of farm woods in the Driftless Area of Wisconsin. Perspectives were defined via qualitative analysis of in-depth interviews. The overlapping ovals represent the indiscrete nature of perspectives.

L19_O.08

Intake and digestibility of diets for creole lambs containing foliage of tropical trees

Gutiérrez-Oviedo F.[1] (fagutierrezo@ut.edu.co), Pardo-Guzman J.[2], Guevara-Muñeton L.[1], Velez-Giraldo A.[1], Castro-Vargas R.[1], Sandoval-Lozano E.[1], Diaz-Cristancho M.[1], Cediel-Devia D.[1], Lozano-Morales P.[1], Castañeda-Serrano R.[1]

[1] *Departamento de Producción Pecuaria, University of Tolima, Ibague, Tolima, Colombia*; [2] *Departamento de Producción Pecuaria, University of Tolima, Ibagué, Tolima, Colombia*

Colombian sheep production is carried out in extensive pastures with low percentage of protein and high fiber levels that lead to low weight gains (Vega et al, 2017).The aim of this study was to evaluate the intake and digestibility of diets based on *Dichanthium aristatum* with partial replacement of *Samanea saman* and *Cordia dentata* foliage. The experiment was carried out at University of Tolima-Colombia. 12 creole lambs of 6 months old and 20.5±1.7 Kg of body weight were housed individually in 4x4 Latin square design. Each period consisted with 12 days of adaptation and 5 days of sample collection.The feeding treatments were T1:100% *D. aristatum*, T2:80% *D. aristatum*, 20% *S. saman*, T3= 80% *D. aristatum*, 20% *C. dentata*, T4: 80% *D. aristatum* 10% *S. saman* 10% *C. dentata*. The method used to determine digestibility was the total collection of feces, feeds and orts in the collection period and analyzed for composition in dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF) and ether extract (EE). Data were analyzed using the PROC MIXED of SAS software. The results indicate that nutrients intake were positively affected by the supplementing (p <0.005). The digestibility of the nutrients was superior in the treatments with foliage trees (p <0.005) except for ether extract (p= 0.44). In conclusion, the partial replacement of hay by *S. saman* and *C. dentata* foliage improves the consumption of the nutrients and digestibility of DM, OM, CP and NDF.

	Variable	Treatments*				SEM	P value
		T1	T2	T3	T4		
DM	Intake, g/day	437,41^{a}	635,23^{b}	633,80^{b}	698,78^{b}	17,7	<0,05
	Dig, %	37,12^{a}	61,44^{b}	55,31^{b}	63,46^{b}	2,1	<0,05
OM	Intake, g/day	406,38^{a}	596,90^{b}	574,83^{b}	643,38	16,28	<0,05
	Dig, %	40,39^{a}	64,25^{b}	57,45^{b}	65,26^{b}	2,0	<0,05
CP	Intake, g/day	13,04^{a}	51,54^{c}	34,55^{b}	45,83^{c}	2,27	<0,05
	Dig, %	20,22^{a}	64,54^{d}	36,23^{b}	50,11^{c}	2,8	<0,05
NDF	Intake, g/day	316,33^{a}	436,22^{b}	451,88^{bc}	502,55^{c}	12,98	<0,05
	Dig, %	37,30a	63,81b	60,72b	67,01b	2,4	<0,05
EE	Intake, g/day	6,33a	8,70b	8,20b	8,71b	0,22	<0,05
	Dig, %	50,02	59,82	55,88	50,50	2,4	0,44

*T1: *Dichanthium* spp, T2 *Dichanthium* spp, 20% *Samanea. Saman*, T3:80% *Dichanthium* spp, 20% *Cordia. dentata*, T4: 80% *Dichanthium* spp, 10% *Samanea. saman*, 10% *Cordia. dentata*.

Values followed by different superscript letters indicate statistically significant differences according to ANOVA (p<0.05) in the comparison among diets at the same experimental time.

Table 1: Intake and in vivo digestibility of the DM, OM, CP, NDF and EE in lambs fed with diets containing foliage tropical trees.

Keywords: Small ruminants, Colombian hair sheep, Tropical dry forest, Silvopastoral systems.

References:

1. Vega-Pérez, et al, 2017,Orinoquia, 64-72.

L19_O.09

Silvopastoral agroforestry for off-setting greenhouse gas emissions from cattle farming systems in Costa Rica

Brook R.[1] (r.m.brook@bangor.ac.uk), Forster E.[2], Addis J.[2], Styles D.[2], Mancebo-Mazetto A.[2]

[1] *Agriculture, livestock and agroforestry, Bangor University / CATIE, Turrialba, Cartago, Costa Rica*; [2] *School of Natural Sciences, Bangor University, Bangor, Gwynedd, United Kingdom*

There is concern about greenhouse gas emissions from cattle farming systems, particularly methane from enteric fermentation and nitrous oxide from excessive application of nitrogenous fertilizers. Latin America produces 28% of the world's total live cattle, yielding 15% of milk and 25% of beef meat, globally. Costa Rica has >37,000 livestock farms with 1.4 million head, occupying one-third of the land area; ruminant methane production and N fertiliser use account for 69% of agricultural GHG emissions (CO2e). There have been several studies of the potential of trees to sequester carbon in silvopastoral systems but only as a standing stock and none linked to a life cycle analysis (LCA).

In September-October 2016 all the fences of the commercial dairy farm at CATIE, Costa Rica, were surveyed. In February-March 2018 a further two fields of the beef part of the enterprise were surveyed. On the dairy farm there were 33.1 km of fences, of which 22.4 km were live fences, ranging from simple pollarded stumps (2.2. km) to complex, multi-storey structures (5.2 km), and 119 individual trees not in fences. The area of the dairy farm was 62.1 ha, of which 42.0 ha were silvopastoral. The dominant tree species were *Erythrina fusca*, *Tricanthera gigantea* and *Gliricidia sepium.* The dominant grass species were tanner grass (*Brachiaria arrecta*) and gramalote (*B. mutica*). Using the model developed by Brown & Iverson (1992), the above ground C stock in trees was 12.3 t/ha on the silvopastoral part of the farm. The trees will be remeasured in February 2019 to calculate a rate of sequestration of C, which has hitherto never been included in a tropical dairy LCA. In the two beef paddocks, living fences were more mature and C stock was calculated as 30 t/ha, indicating a significant potential rate of sequestration. Soil C stock (15-30 cm stratum) was 72 t/ha under the steady state beef cattle pastures.

An attributional LCA was carried out on the milk production system. Enteric fermentation was found to be the largest contributor to global warming potential (56%), followed by imported feed (20%). The environmental burden per litre of milk was calculated to be 1.08 kg CO2e/L; quite low because most of the electricity is generated from an anaerobic digester that also reduces manure management emissions. A second, hypothetical attributional LCA was carried out to approximate the environmental impact of the system without live fences – i.e. where it was assumed that reduced shading may increase heat stress in animals and thus reduce milk yield by 11%, based on a previous study (Villanueva et al. 2014). Live fences were found to have a positive effect, reducing environmental burdens by 8% to 9% per litre of milk produced. The LCA will be recalculated once all sampled living fences have been remeasured to allow for off-setting due to rate of C sequestration.

Keywords: Dairy, Living fences, Life cycle analysis, C off-setting.

References:

1. Brown, S. & Iverson, L., 1992. Biomass estimates for tropical forests. World. Res. Rev., 4(3), pp. 3
2. Villanueva, C., et al. 2014. http://repositorio.bibliotecaorton.catie.ac.cr/handle/11554/7826

L19_O.10

Nutritional potential of fodder trees: the effect of tree species, soil type and seasonal variation

Luske B. (b.luske@louisbolk.nl), van Eekeren N.

Louis Bolk Institute, Bunnik, Netherlands

Introduction

In temperate regions, farmers often report that free ranging cows use trees as fodder. Available literature shows that different tree species are very interesting in terms of nutritional value for ruminants because of high levels of protein and especially macro and micro elements (Rahmann 2004; Luske et al. 2017). The objective of this study was to investigate the effect of soil type (clay and sand) and seasonal variation on the nutritional quality of three common tree species in the Netherlands.

Materials and methods

At 10 Dutch organic dairy farms (five on sandy and five on clay soils) tree leaf samples were collected from *Fraxinus excelsior,* alder *Alnus glutinosa* and basket willow *Salix viminalis* in June, July and September of 2013. The samples were analysed in the laboratory for a set of parameters. The data was analysed with a split-split plot design (Genstat 13.3) to test for differences in nutritional values (Table 1).

Results [insert Table 1]

Discussion and conclusion

Tree species is the most important factor to take into account when introducing three dimensional grazing with fodder trees or shrubs (Luske & van Eekeren 2017). *A. glutinosa* is interesting because of high CP and Cu concentrations in the leaves. *F. excelsior* leaves had the highest digestibility (DOMD) and Ca concentration. *S. viminalis* is very interesting for livestock when there is a shortage of micro elements like Zn and Se but less when there is a shortage of Cu.

		DOMD	Crude protein	Ca	P	S	Zn	Cu	Se
	Unit	%	$g\ kg\ DM^{-1}$	$g\ kg\ DM^{-1}$	$g\ kg\ DM^{-1}$	$g\ kg\ DM^{-1}$	$mg\ kg\ DM^{-1}$	$mg\ kg\ DM^{-1}$	$\mu g\ kg\ DM^{-1}$
Tree species	Ash (F. excelsior)	71.3 ± 0.88 b	171.5 ± 3.47 a	23.9 ± 1.77 c	2.5 ± 0.14 a	4.0 ± 0.20 b	32.5 ± 2.81 a	9.4 ± 0.65	79.3 ± 8.14 a
	Alder (A. glutinosa)	61.3 ± 1.25 a	203.0 ± 4.34 b	11.1 ± 0.59 a	3.0 ± 0.08 a	2.3 ± 0.08 a	74.6 ± 6.80 a	13.2 ± 0.62	43.2 ± 3.93 a
	Willow (S. viminalis)	61.5 ± 1.48 a	189.8 ± 6.87 ab	15.7 ± 1.06 b	3.3 ± 0.20 b	5.3 ± 0.21 c	227.4 ± 26.48 b	8.7 ± 0.32	193.1 ± 42.05 b
	P	**	*	**	**	**	**	ns	*
Sampling period	June	66.3 ± 0.93	204.1 ± 6.28 b	12.2 ± 0.92 a	3.0 ± 0.19 b	3.2 ± 0.25	109.1 ± 18.74	15.8 ± 0.57 b	87.7 ± 18.89 a
	July	63.2 ± 1.61	178.7 ± 4.67 a	17.5 ± 1.40 b	2.3 ± 0.14 a	4.0 ± 0.30	104.2 ± 19.09	9.3 ± 0.5 a	93.6 ± 21.51 a
	Sept	64.8 ± 1.77	179.0 ± 5.77 a	20.1 ± 1.93 c	2.6 ± 0.19 a	3.8 ± 0.31	121.2 ± 27.01	9.2 ± 0.83 a	134.2 ± 38.55 b
	P		**	**	**	ns	ns	*	*

Table 1. Nutritional values of tree leaves per species and measured at three sampling periods. The average values are displayed ± SEM. Significant effects are indicated by * ($P < 0.05$) or ** ($P < 0.01$). Group differences based on the LSD's are indicated with a, b and c's. Significant interactions were found between species, sampling period and/or soil type for DOMD, Ca, S, Zn and Se.

Keywords: Leaves, Digestibility, Protein, Macro elements, Micro elements.

References:

1. Luske et al., 2017, Online fodder tree database for Europe. www.voederbomen.nl/nutritional-values/
2. Luske, 2017, Agroforestry Systems, DOI: 10.1007/s10457-017-0180-8
3. Rahmann, 2004, Landbouforschung Völkenrode Sonderheft 272: 29

L19.P.01

Breeder's perceptions of potential development of livestock units within agroforestry systems in Guadeloupe

Alexandre G.[1] (gisele.alexandre@inra.fr), Cheval A.[1], Apatout M.[2], Barlagne C.[3], Diman J.-L.[4], Larade A.[5], Latchman C.[6], Vinglassalon A.[2]

[1] *URZ, INRA, Petit-Bourg, France, Guadeloupe*; [2] *Syaprovag, Petit-Bourg, France, Guadeloupe*; [3] *James Hutton Institute, Aberdeen, UK, Scotland*; [4] *UE Peyi, INRA, Petit-Bourg, France, Guadeloupe*; [5] *Parc National Guadeloupe, St-Claude, France, Guadeloupe*; [6] *GDA Ecobio, Petit-Bourg, France, Guadeloupe*

The Valab project (Integrated Ecosystemic value-enhancement of the Guadeloupian Forest Agrobiodiversity) is a participatory action research, that has developed at the initiative of the Agricultural Union of Vanilla Producers of Guadeloupe (Syaprovag) and within the framework of a European Innovation Partnership. In the exploratory phase of the project, we studied the constraints or motivations to setting up livestock units within agroforestry systems in the private forests of Guadeloupe. This aims to identify the locks that might hinder the development of this activity, or on the contrary the potential to be encouraged. To establish a diagnosis of the current situation and practices, 70 stakeholders (among them 48 farmers) were interviewed.

All the breeders interviewed (37) mention **economic** motivations for sales and/or self-consumption. The valuation of their land is another reason given, so animals are used to limit the bushes while fertilizing the soil. However, in 25% of cases, they are concerned about production costs and question the profitability of this animal sub-activity. Many breeders (36%) give importance to their activity in the construction of their **identity**, whether it is through a desire to perpetuate traditions or to maintain family activities. A strong commitment is observed for «**body involvement**» among 44% of breeders who like to spend time taking care of their animals or for physical activity. At the opposite, 36% report that this occupation is difficult and hard. For 44% of the informants the development of his breeding activity also depends on the **relationships** they have with their colleagues and family or even on the links between them and their animals. Finally 31 % of them reported how they suffer from dog's attacks from the vicinity as well as from praedial larceny.

The main constraints identified are **natural** constraints (61% of cases), including topography, climate and predators. On the other hand, 28% notify their motivations for environmental protection. The second most important constraint is of a **technical** nature for 44% of farmers. Very often, this is associated with the complexity of their work schedule resulting from the mixed nature of those farming systems that count with multiple units. Others ask for more technical references or support services. Regulation and the role of **institutions** are also among the obstacles identified by 36% of the farmers who felt constrained by norms or disappointed by state organizations.

Further development of this work involves the analysis of the set of actors within this very complex socio-technical system of agricultural activities within the Guadeloupian undergrowth.

Keywords: constraints, motivation, livestock farming, agroforestry, humid tropic.

L19.P.02

Local Agroforestory tree leaves for parasitic control in sheep of hilly areas in Jammu and Kashmir, Ind

Azad M. S.[1] (mandeepsinghazad@gmail.com), Arora R. K.[2], Kour K.[3]

[1] *Animal Sciences, SKUAST-Jammu, Jammu, Jammu and Kashmir, India*; [2] *Directorate of Extension, SKUAST-Jammu, Jammu, Jammu and Kashmir, India*; [3] *Animal Physiology, SKUAST-Jammu, Jammu, Jammu and Kashmir, India*

The local tree leaves found In hilly areas of Jammu and Kashmir,India have high condensend tanin content. Locally available tree leaves like Neem (Azadirachta indica) Guava (Psidium guajava),Mango(Magniferra indica),Jamun (Syzygium Cuminii) and Amla (Emblica officinalis), can be used as leaf meals in complete feed block making to meet the protein deficiency as well as control the parasitic load in sheep. Crude Protien content of these leaves are 20.00 ±0.44,10.58±0.54,11.02±0.11,25.56±0.48,10.62±0.57 respectively. 24 sheep were randomly divided into three groups (C, T1 and T2) of 8 animals each in a completely randomized block design for a period of 3 months. T1 group was supplemented with complete feed blocks without any leaf meal mixture whereas T2 group was supplemented with leaf meal mixture at 1.5%. Body weights were recorded at 0th day and then 15th day's interval for a period of 90 days to access feed intake and body weight changes. The faecal samples were collected at 0th, 7th, 15th day and thereafter at 15 days intervals for a period of 3 months for the assessment of H. contortus loads. The study showed that feed intake and weight gain was almost similar in both the treatment groups T1 and T2 but were comparatively better than the controlled group C with normal feeding. The mean fecal egg counts was significantly ($P < 0.001$) higher in T1 group as compared to T2 group. ,

Keywords: Azadirachta indica, Psidium guajava, Syzygium Cuminii, Emblica officinalis, Haemonchus contortus.

References:

1. Shelu R. S.2017 International Journal of Livestock Research ,209
2. PRIYA, M. N (2014) Life Sciences International Research Journal Volume 1 Issue 1
3. Sawleha Qadir 2010, Veterinary World, Vol.3(11):515-518
4. Tyrell Kahan 2008,Florida Cooperative Extension Service, Institute of Food
5. B.R. Joshi,2010 2010 Elsevier

L19.P.03

Grazing forests ecosystems in Poland – will cattle grazing add to the destruction of forest by wild game?

Borek R.[1,2] (rborek@iung.pulawy.pl), Wawer R.[2]

[1]*Dpt. of Bioeconomy and Systems Analysis, IUNG-PIB, Pulawy, Lubelskie, Poland;* [2]*Institute of Soil Science and Plant Cultivation – State Research Institute, 24-100, Puławy, Poland*

Forestry ecosystems are mostly managed in the direction of wood production, providing many other ecosystem services like tourism, non-timber/food production. Traditionally in many countries forest has served as grazing areas for cattle, pigs and sheep. The practices were abandoned as being too difficult and labour intensive. In some countries, eg. Poland, grazing in state-owned forest (here approx. 80% of forests) is forbidden by law (Polish Act of Forests). The reason for the ban on grazing is mostly based upon the high losses wildlife does to forests, especially red deer and moose. The current numbers of wildlife in Poland overexceed the capacity of forest ecosystems up to 4-fold. The question we want to rise with this paper is whether cattle presents same risk as wild game for the forest. Some data for private forests suggest that this is not the case. We present two case studies of livestock farms including grasslands and forests where wood production is facilitated due to improving accesibility to trees to be cut off by cattle grazing understory of mature tree stand. Keeping beef cattle on wooded grasslands and private forests can be seriously considered as a good practice improving biodiversity, forest management efficiency and restoring marginal non-used land for agricultural production, in the same time providing good-quality beef.

Grazing private forest by cattle in Beskid mountains of South Poland

Keywords: Silvopasture, forest grazing, forest capacity, wild game, forest management.

L19.P.04

Cattle seed dispersal services and perspectives for management in a high biodiversity Mediterranean silvopastoral system

Bueno R. (rafael.dasilveirabueno@unipa.it), La Mantia T.

Agricultural, Food and Forest Sciences, University of Palermo, Palermo, Italy

In Mediterranean traditional silvopastoral systems are composed mostly with oaks, with an overall lack of fleshy-fruited species, key elements in Mediterranean flora. A mixed composition may enhance biodiversity and diversify fodder for livestock, and at the same time guarantee higher resistance, resilience and a richer network of ecological interactions. Here we investigated the interactions of cattle and native fleshy-fruited species in a high biodiversity silvopastoral system inside the last large forest remnant in western Sicily, Italy. Along two fruiting seasons we used sampling transects covering the gradient from the forest to the pastureland and analyzed 132 cattle dungs, of which 47.7% contained an average of 67.2 (± 40.3) *Pyrus amygdaliformis* seeds. Just 2.1% were predated, resulting in a density of 238 seeds/ha. *Pyrus* is the most abundant tree in the pastureland, and cattle, other than retrieving nutritional rewards from the fruits, is effectively promoting its seed dispersal. This interaction is contributing to create a dynamic and self-regenerating alternative silvopastoral system, where the presence of other fleshy-fruited species extends the resource availability for other native animals. However, in the past 24 years woody vegetation increased more than 68%, so we shed perspectives on whether leave secondary succession or actively manage vegetation expansion to maintain this fruit-rich alternative silvopastoral system.

Location of the study site, pastureland with expanding fleshy fruited trees and shrubs, Pyrus amygdaliformis tree full with fruits and its seeds in cattle feces

Keywords: diversification, frugivory, mutualistic interactions, active management, secondary succession.

L19.P.05

Tree-species effect on forage and microclimate in a silvopasture system of the Southeast USA

Castillo M.[1] (mscastil@ncsu.edu), Tiezzi F.[2]

[1] *Crop & Soil Sciences, North Carolina State University, Raleigh, NC, United States*; [2] *Animal Science, North Carolina State University, Raleigh, NC, United States*

Silvopastures provide distinct ecosystems services and are a multiple-income enterprise for land managers benefiting from the integration of trees, livestock, and forages. The objectives were to: 1) characterize light environment and forage productivity, and 2) determine a mitigation (MIT) parameter [ability to reduce air temperature and thermal-humidity index (THI)], as a function of tree-species in silvopasture vs. open-pasture. The silvopasture, established in 2007 as an alley-cropping system, consisted of three tree-species (*Pinus palustris,* PP; *Pinus taeda,* PT; and *Quercus pagoda,* QP) and two alley-widths (Fig. 1). Understory forage was a mixture of big bluestem (*Andropogon gerardi)*, gamagrass (*Tripsacum dactyloides*), indiangrass (*Sorghastrum nutants*), and switchgrass (*Pannicum virgatum*). Light environment under the trees was ~40% compared to the alley pasture and it was not different among tree-species during summer but different during winter. Forage dry matter yield was lower by ~35% for QP and PT (~5 Mg ha-1) at the 3.5-m south sampling location compared to PP (8 Mg ha-1) but there was no difference at the center of the alley (~11 Mg ha-1). All the tree species were able to provide a significant MIT during daylight hours with greater impact during summer months (June, July and August). The three different species showed a different ability in MIT; QP showed the strongest MIT, which was significantly larger compared to PP and PT, which in turn showed similar values.

Fig. 1. Field layout of trees (PP = Pinus palustris; PT = Pinus taeda; QP = Quercus pagoda), alleys, silvopasture and open-pasture, and sensors (temperature and humidity) for the agroforestry site in Goldsboro, NC, USA.

Keywords: silvopasture, thermal-humidity index, forage, light environment, temperature.

References:

1. Amrstrong DV, 1994, J. Dairy Sci., 2044.
2. Cubbage et al., 2012, Agroforestry Syst,, 323.
3. Kallenbach et al., 2006, Agroforestry Syst., 43
4. Pent et al., 2018, Agroforestry Syst., doi:.org/10.1007/s10457-018-0221-y

L19.P.08

Ruminal degradability of leaves of *Morus alba* and *Fraxinus excelsior* managed as pollards or high stem trees

Delagarde R.[1] (remy.delagarde@inra.fr), Lamberton P.[1], Novak S.[2], Emile J.-C.[2]

[1] *Pegase, INRA, Saint-Gilles, France*; [2] *FERLus, INRA, Lusignan, France*

The effect of tree management (pollard *vs* high stem tree) on ruminal effective degradability of dry matter (DM) and nitrogen (N), for common ash (*Fraxinus excelsior*) and white mulberry (*Morus alba*), was studied. Leaves of common ash were collected in Lusignan (France), and leaves of white mulberry were collected in Le Pradel (France), in August 2016. Trees were pollarded since 2 years in Lusignan (1 m height) and 12 years in Le Pradel (0.8 m height). Duplicate leaves samples were collected from three trees, dried (60°C) and ground (0.8 mm sieve). Fractional rate kd (%/h) and ruminal effective degradability (ED) were determined for DM and N, from *in situ* leaves degradation in 3-g nylon bags samples, replicated on 3 dry cows, after 2 to 48 h of incubation (INRA, 2018). Leaves CP concentration ranged from 129 to 177 g/kg DM. There was no species by management interaction for kd or ED. The kd(DM) was unaffected by tree species or management, while ED(DM) was greater by 5.1 points on white mulberry than on common ash, and greater by 4.3 points for high stem trees than for pollards (Table 1). The kd(N) was greater by 0.015 for high stem trees than for pollards. Finally, ED(N) was greater by 6.5 points for white mulberry compared to common ash, and greater by 4.3 points for high stem trees compared to pollards. It is concluded that leaves of both species have a good protein nutritive value. Unexpectedly, ruminal degradability was lower for the leaves of the pollarded trees.

Table 1 : Effect of tree species and management on fractional rate (kd, in %/h) and ruminal effective degradability (ED, in %) of DM and N in fresh leaves collected in summer.

Sp	White mulberry		Common ash		RSD	Effects (P <)		
Ma	High stem	Pollard	High stem	Pollard		Sp	Ma	Sp×Ma
kd (DM)	0.118	0.114	0.137	0.099	0.0369	ns	ns	ns
ED (DM)	75.8	70.8	70.0	66.3	1.54	***	***	ns
kd (N)	0.105	0.098	0.116	0.093	0.0173	ns	*	ns
ED (N)	66.1	61.5	59.2	55.4	2.56	***	**	ns

Sp : species ; Ma : management; RSD, residual standard deviation

Keywords: degradability, fodder tree, leave, pollard, high stem.

References:

1. INRA, 2018. INRA feeding system for ruminants. Wageningen Academic Publishers, Wageningen, 640 pp.

L19.P.09

Long-term monitoring of grafted honeylocust trees for the production of fodder pods

Dupraz C. (christian.dupraz@inra.fr), Dufour L., Bourdoncle J.-F., Sellier A.

UMR System, INRA, Montpellier, France

Bumper harvests of honeylocust (*Gleditsia triacanthos* L.) pods on some isolated trees often draw attention of farmers and researchers on the value of this tree as a potential fodder producer for ruminants (Detwiller 1947, Dupraz and Newmann, 1994). In vivo digestibility studies of the pods provided encouraging results with sheep (Foroughbakhch *et al*, 2006). In 1988, an orchard was established with 16 grafted varieties that were identified by a survey of honeylocust trees in Southern France. The orchard includes a variety selected in the USA (Millwood variety). Pod production was monitored since plantation. Alternate bearing is a distinctive trait of all cultivars, but high year production are not synchronised between all varieties. Growing a mixture of different cultivars would therefore allow a sustained pod production. Measured yields are small, as the local site conditions are harsh. The tree size has remained almost the same for the last 20 years, indicating a severe water shortage at the site. Better soil conditions could easily induce higher yields, but the extrapolation of extraordinary heavy harvest from isolated trees is definitely not advisable. The adoption of honeylocust fodder trees by farmers rely on the availability of grafted trees at a reasonable cost, and this proves to be the limiting factor for adoption at the moment.

The orchard of grafted honeylocust trees established in 1988 at Melgueil (Montpellier, France) was monitored for almost 30 years for pods production.

Keywords: fodder tree, alternate bearing, Gleditsia triacanthos, pod.

References:

1. Detwiler S.B., 1947, Notes on honey-locust. USDA, Washington DC (On Microfilm)
2. Dupraz C, Newman SM, 1997, Temperate agroforestry: the European way. CABI, pp 181-236
3. Foroughbakhch R, Dupraz C, et al, 2006. Journal of Applied Animal Research 41-46.

L19.P.10

Enhancing livestock farms resiliency and forage autonomy through silvopastoralism in the Pyrenean mountains

Etienne L.[1] (laura.etienne@idele.fr), Bounab M.[2], Launay F.[1], Broux S.[2]

[1] *Institut de l'Elevage, Montpellier, France*; [2] *Chambre d'Agriculture de l'Ariège, Foix, France*

In the hills and mountains of the Pyrenees, more than 50% of the surface are woodlands, and 63% of extensive livestock farms. Agrosyl OG EIP project implement innovative solutions to develop agro-silvo-pastoralism in these mountain livestock systems, increasing both their capacity of adaptation to climate change, and the skills of technicians and farmers. Silvopastoral experiments are conducted among 3 diverse livestock farms (2 sheep farms and 1 beef farm), as a partnership with the farmers, with a comprehensive demarche to understand each system. On each farm 3 experimental blocks of 0.25ha were defined, with 9 measurement plots for grass monitoring and 9 others for tree monitoring. There are 3 modalities for each block: control; 40% thinning; 40% thinning with 10% more on the 2nd year of experimentation. Temperature and humidity are also monitored and compared with a grazing plot nearby. Different managements were chosen, depending on vegetation and farmers' objectives for silvopastoralism. 2 pilots had a selective thinning on adult oak (*Quercus Pubescens*) population and one pilot had a clearing on a young common ash (*Fraxinus excelsior*) and black locust (*Robinia pseudoacacia*) population. The vegetation dynamic (herbaceous, mosses, lianas, woody plants, and tree conformation and eventual hurts) is monitored every year, before and after pruning in May, and before and after grazing. As the vegetation dynamic is quite slow, we won't have any significant results before 2020.

The experimental sites with silvopastoralism certainly make it possible to follow up on the evolution of the vegetation, but also on the production of acorns (see the nets) and make it possible to organize technical days for the breeders and technicians.

Keywords: silvopastoralism, forage autonomy, codesign.

References:

1. Bounab et al, 2018, Actes des 24èmes Rencontres Recherches Ruminants 2018 (à paraître)
2. Launay et al, 2009, Restitution du Casdar Sylvopastoralisme

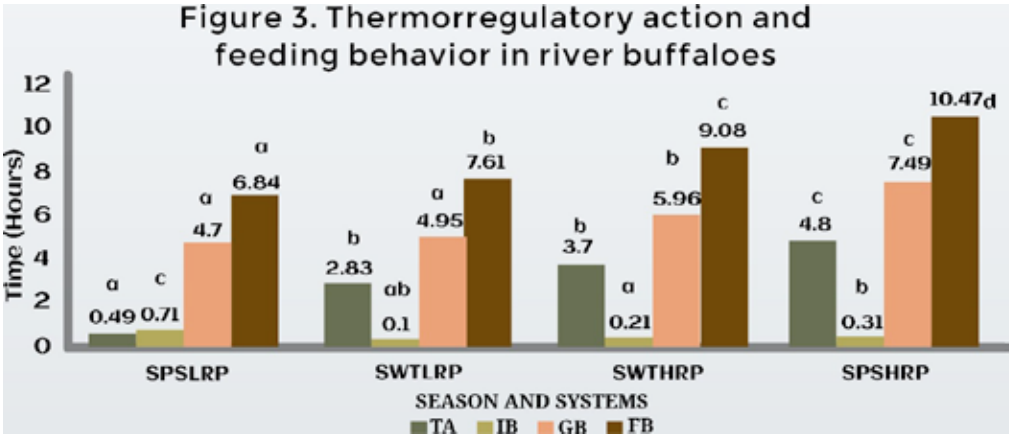
L19.P.11

Can trees replace the need for wallowing in river buffalo *(Bubalus bubalis)* in the tropics?. Preliminary results.

Galloso Hernández M. A.[1] (z62gahea@uco.es), Rodriguez- Estevez V.[1], Simon-Guelmes L.[2], Soca-Perez M.[2], Alvarez-Diaz C. A.[3], Dublin D.[4], Gonzalez-Garcia E.[5]

[1] *Animal Production, Cordoba University, CORDOBA, Spain*; [2] *Silvopastoral Systems, EEPF:Indio Hatuey, Perico, Matanzas, Cuba*; [3] *Universidad Tecnica de Machala, Machala, El Oro, Ecuador*; [4] *Conservation International, Tokyo, Japan*; [5] *INRA-SupAgro, Montpellier, France*

The production systems of river buffaloes (Bubalus bubalis) are receiving increasing attention in the tropics. The incorporation of trees in pastures (silvopastoral systems) can improve production conditions and animal welfare. The objective of this study was to characterize the behavior of buffaloes in a silvopastoral (SP) system with Leucahena Leucocephala 600 trees per hectare and a system without trees (WT), at the heavy rain (HR) period and the light rain (LR) period in Cuba, in order to assess whether the inclusion of trees in pastures affects buffaloes thermorregulatory behavior, the following activities were recorded observing 9 animals of 90 kg for 12 days during the daylight period, between 6:00-18:00 hours, at 10 minute intervals: grazing, ingestion from the tree leaves, rumination, water intake, walking, lying, standing, positioned in the shade of trees and wallowing. The sum of positioned in the shade of trees+ wallowing was considered as thermorregulatory behavior (TB) was diferent in both systems and season (P<0.05) represented 3,70 hours in WT and 4,80 hours in SP in the Heavy Rain Period. In the Light Rain Period was SP 0,49 hours and WT showed 2,83 hours dedicated. The wallowing showed differences (P<0.05) in the Heavy Rain Season with 0.62hours in WT and 0,64 hours in the SP. These results describe the behavior the buffaloes and indicate the importance of Silvopastoral systems as a technological alternative of friendly to the animals welfare.



TA: Thermorregulatory Action; IB: Ingestion of Branches; GB: Grazing Behavior; FB: Feeding Behavior. (a, b, c) Averages with same colors and different superscripts differ significantly for the level. (P<0.05) (Duncan, 1955).

Keywords: buffaloes, silvopastoral systems, animal welfare, behavior, thermorregulatory behavior.

References:

1. Simón, L. Galloso. M. 2008. Pastos y Forrajes. 31-2. Pp:173-179.
2. Simón, L. Galloso. M. 2011. Pastos y forrajes. 34-1. Pp: 3-20
3. Pentón, G. & Blanco, F. 1997. Pastos y Forrajes. 20. Pp:101–110
4. Yadav, et al. 2016. Journal of Animal Science and Technology. 58:2
5. Moraes Júnior R.J. et al. 2010. Acta Amazonica. 40:4. Pp.629–640.

L19.P.12

Intensification of animal production in tradicional agroforestry systems

Hanisch A. L.[1] (analucia@epagri.sc.gov.br), Negrelle R. R. B.[2], Pinotti L. C. A.[2]

[1] *Canoinhas Experimental Station, EPAGRI, Canoinhas, Santa Catarina, Brazil*; [2] *Agricultural Sciences Sector, Federal University of Paraná, Curitiba, Parana, Brazil*

Large forest areas were conserved in private properties through use as traditional agroforestry systems (AFS). An example are the caívas in the south of Brazil. In these, the maintenance of the forest is combined with the extraction of yerba-mate and livestock. The animal production in traditional caívas is low (~0.4 animal units per ha). Due to this, the *caívas* have been threatened, being their areas replaced by agricultural activities of greater economic income. Strategies to intensify pasture use has indicated that it is possible to promote increased animal production without compromising the environmental benefits of these systems. The use of ½ of the recommended dose of fertilizer in two annual applications, associated with rotational grazing and the introduction of more productive forages (*Lolium* sp., *Trifolium* sp., *Vicia* sp. and *Axonopus catharinensis* Valls) allowed the increase from for 2,0 animal units per ha in caívas (Figure 1). This result is highly promising, since it was reached in a system with more than 350 adult trees per ha of Native Araucarian Forest. The forest regeneration was monitored annually. There was no difference in the regeneration between the *caívas* with and without intensification. These results confirm that it is possible to increase productivity in traditional AFS. It is hoped that this result may support the economic valuation of this system, which combines income generation and conservation of biodiversity in forest remnants used AFS.

Traditional agroforestry systems – caívas – in southern Brazil with use of strategies to intensify the use of pasture.

Keywords: silvopastoral system, caívas, pasture, Ilex paraguariensis, Araucarian Forest.

L19.P.15

Estimating total and browsed leaf area of fodder trees using a photographic gap fraction method

Mahieu S.[1] (stephanie.mahieu@inra.fr), Dupuy S.[1], Frak E.[2], Roy E.[2], Combes D.[2], Novak S.[1], Emile J.-C.[1]

[1] *FERlus, INRA, 86600 Lusignan, France*; [2] *UR4, URP3F, INRA, 86600 Lusignan, France*

The software Tree Analyser (TA) was developed to estimate total leaf area of isolated trees from digital photography (Phattaralerphong and Sinoquet, 2005). Estimations are based on gap fraction inversion. Our objective was to test and adapt this method to estimate total and browsed leaf area of three tree species grown in an agroforestry system for livestock feeding. Experiment was conducted on common ash, white mulberry and italian alder 4 years old. Two branches were collected on 4 trees per species in June and August. Photographs were implemented on branches and trees. The method was tested by comparison with direct estimation of leaf area using the image processing software ImageJ. In parallel branches and leaves were measured, weighted and counted to establish allometric relationships. Reliable allometric relationships were obtained between the leaf area and the total length of shoot axes ($r^2>0.9$) and the leaves dry and fresh weight ($r^2>0.9$) and between the total length of shoot axes and the number of leaves ($r^2>0.9$) for all species. Estimated leaf area with TA was sensitive to the camera calibration, picture discretization, individual leaf size and leaf inclination distribution. Reliable estimations of leaf area using TA were obtained on branches for italian alder ($r^2=0.69$), common ash ($r^2=0.96$) and white mulberry ($r^2=0.79$). The average error in estimating a difference from the analysis of tree crown pictures taken before and after removal of branches were 24%, 86% and 73% for italian alder, common ash and white mulberry, respectively. The method allows fast and non-destructive monitoring of leaf area of trees grown in an agroforestry system. Taking into account the potential to improve accuracy of measurements TA is a promising tool to study the browsing of fodder trees by ruminants.

Keywords: Tree Analyser software, leaf area, allometric relationships, fodder trees.

References:

1. Phattaralerphong J., Sinoquet H. (2005). Tree Physiology 25: 1229–1242.

L19.P.16

Diversity in the nutritive value of tree leaves within and between botanical families

Mahieu S.[1] (stephanie.mahieu@inra.fr), Barre P.[2], Delagarde R.[3], Novak S.[1], Emile J.-C.[1]

[1] *FERlus, INRA, 86600 Lusignan, France*; [2] *UR4, URP3F, INRA, 86600 Lusignan, France*; [3] *Pegase, INRA-Agrocampus Ouest, 35590 Saint-Gilles, France*

Plant species are classified into families on the basis of common morphological characteristics. The objective was to describe the diversity of leaves biochemical characteristics in woody species within and between botanical families. Leaves crude protein (CP) content and enzymatic digestibility of dry matter (ED, Aufrère, 1982, adapted to the DAISY Incubator) were determined on 153 leaves samples from 30 tree species belonging to 7 families (Emile et al., 2017), with at least 2 species per family. The relationship between ED and CP content (Figure 1) shows a wide diversity within and between botanical families. The variability of ED and CP within families was dependent on the family. Species belonging to the *Moraceae, Betulaceae*, *Fabaceae* and *Caprifoliacea* families exhibited high leaves CP content, with mean values of 171, 168, 164 and 160 g kg-1 DM, respectively. ED was highest for *Moraceae* and *Caprifofoliaceae* (min of 74%) and lowest for *Fabaceae* (max of 60%). ED of *Betulaceae* varied widely, from 41 to 77%. Most of the species belonging to *Rosaceae*, *Oleaceae* and *Fagaceae* exhibited moderate leaves CP content with mean values around 130 g kg-1 DM. ED was rather good for *Rosaceae* and *Oleaceae* (62 to 87%) and varied in a large extent for *Fagaceae* (43 to 76%). The results revealed clear leaves biochemical characteristics similarities across species within the same botanical family.

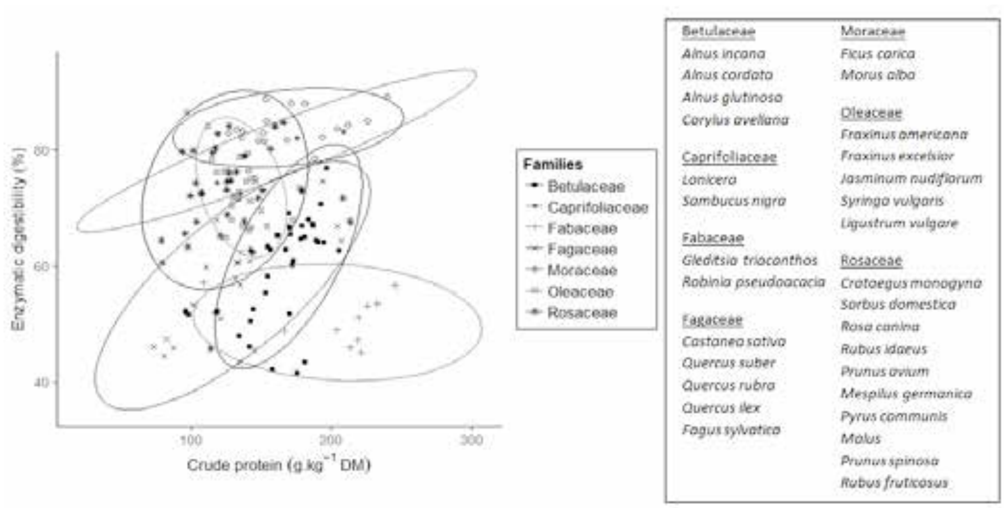


Figure 1 Relationship between the enzymatic digestibility of dry matter (%) and crude protein content (g kg-1 DM) in the leaves of 30 woody species collected in August aggregated into botanical families.

Keywords: nutritive value, fodder trees, botanical families, biodiversity.

References:

1. Aufrère J., 1982 Annales de Zootechnie 31, 111-130
2. Emile et al., 2017 Fourrages 230, 155-160

L19.P.17

Effect of species, season and management practice on the nutritive value of fodder tree leaves

Mahieu S.[1] (stephanie.mahieu@inra.fr), Emile J. C.[1], Barre P.[2], Delagarde R.[3], Novak S.[1]

[1] *FERLus, INRA, 86600 Lusignan, France*; [2] *UR4, URP3F, INRA, 86600 Lusignan, France*; [3] *Pegase, INRA-Agrocampus Ouest, 35590 Saint Gilles, France*

A better understanding of tree pruning and pollarding on the fodder quality of woody leaves may be helpful for the conception and the management of livestock agroforestry systems (Dufour *et al*., 2018; Emile *et al.*, 2017). In this study we compared the nutritive value of pollard and high stem tree leaves across seasons in three species (common ash, white mulberry and paulownia). Leaves were collected on high stem and winter pollard trees grown on the same site. All samples were analysed for 1/ ash, crude protein (CP), and fibre (NDF) contents, and 2/ enzymatic digestibility (Aufrère, 1982, adapted to the DAISY Incubator). The three-way ANOVA shows a significant effect of species, season and management on all the variables. Common ash and white mulberry exhibit a better fodder quality than Paulownia: higher leaves CP content, digestibility and lower NDF content. Leaves ash content was 50% and 30% higher for white mulberry than for common ash and paulownia, respectively. There was a strong interaction species by management for all variables but particularly high for CP and ash content. Leaves CP content decreased from June to October (146 to 131 g kg-1 DM). In conclusion, the three species have a sufficient digestibility and CP content to be including in the diet of ruminants whatever the season and the tree management.

			Dry matter ($g\ kg^{-1}$)		Crude protein ($g\ kg^{-1}$ DM)		NDF ($g\ kg^{-1}$ DM)		Enzymatic digestibility (%)		Ash ($g\ kg^{-1}$ DM)	
		n	H.st.	Pollard	H.st.	Pollard	H.st.	Pollard	H.st.	Pollard	H.st.	Pollard
Common ash	June	7	299	278	167	197	366	382	73.0	72.4	75	58
	August	7	400	359	138	184	352	375	70.8	70.2	88	82
	October	7	402	391	118	147	300	319	73.8	73.3	92	82
White mulberry	June	3	225	268	219	153	258	242	84.6	90.1	123	123
	August	3	322	324	151	121	266	259	83.2	84.3	156	191
	October	3	346	373	164	114	257	286	82.6	82.3	164	196
Paulownia	June	3	283	201	152	196	481	450	57.7	69.3	80	101
	August	3	267	228	134	149	483	469	53.5	61.6	88	113
	October	3	318	260	127	117	440	448	57.8	60.6	81	116
LSD			10.8		6.9		9.0		13.8		4.9	
Three-way ANOVA												
Mgt		DF=1	F= 9.3**		F=6.5*		F=1.9		F=4.6*		F=2.8+	
Sp.		2	62.1***		2.7*		275.7***		173.8***		199.9***	
Season		2	65.6***		42.3***		15.4***		4.9*		27.4***	
Sp. x Mgt		2	8.3***		28.5***		2.3+		6.7**		15.3***	
Mgt x Season		2	0.5		1.6		1.1		1.1		2.2	
Sp. x Season		4	4.5**		1.7		6.5***		1.7		5.9***	
Sp. x Mgt x Season		4	0.8		1.7		0.5		0.8		0.7	

Sp : species ; Mgt : management ; H.st. : High stem; +P<0.10, *P<0.05, **P<0.01, ***P<0.001; LSD : Least significant difference

Table 1 : Effect of tree species, season and management (pollard vs high stem) on leaves dry matter, crude protein, neutral detergent fibre (NDF) and ash content and enzymatic digestibility.

Keywords: nutritive value, fodder trees, pollard trees, agroforestry, ruminants.

References:

1. Aufrère J., 1982 Annales de Zootechnie 31, 111-130
2. Dufour et al., In : Proceedings of the 4th European Agroforestry Conference, Agroforestry as Sustain
3. Emile et al., 2017 Fourrages (230), 155-160

L19.P.18

Biomass of tree legumes in silvopastoral system with signal grass in the Northeastern region of Brazil

Mello A.[1] (alexandre.lmello@ufrpe.br), Herrera A.[2], Apolinário V.[3], Dubeux Jr. J.[4], Cunha M.[2], Santos M.[2]

[1] *Animal Science Department, Federal Rural University of Pernambuco, Recife, Pernambuco, Brasil*; [2] *Animal Science Department, UFRPE, Recife, Pernambuco, Brasil*; [3] *Animal Science Department, State University of Maranhão, São Luis, Maranhão, Brasil*; [4] *Animal Science Department, University of Florida, Marianna, Florida, United States*

Silvopastoral systems allow efficient use of natural resources by following principles of sustainable production. *Gliricidia sepium* (Jacq.) Steud (Gliricídia) and *Mimosa caesalpiniifolia* Benth (Sabiá) are important local options for livestock production. There are drought tolerant, N fixers and provide protein for livestock. Sabiá has value as timber used locally. This work was conducted at the Brazilian Northeastern, located at 7°23'S and 35°10'W, evaluating the legume fractions biomass in silvopastures intercropped with *Brachiaria decumbens* Stapf. (Signalgrass, SG). Plots were distributed in randomized complete block design (three replicates, one ha each), and consisted of SG + Sabiá and SG + Gliricídia, with steers (200 kg BW) in continuous stocking and variable stocking rate. Two evaluations were carried out, being in dry (Oct-17) and rainy season (Apr-18), harvesting 11 trees per plot by season. Fractions were classified in branches: fine (<13 cm), intermediate (13-20 cm), and thick (>20 cm); leaves up to 1.5 m and total leaf biomass; and total tree biomass. Differences were observed between legumes species in all fractions, with greatest biomass for Sabiá (except leaves up to 1.5 m). Species and season interaction was observed in leaf total biomass, with greater values for Sabiá at rainy season (Table 1). The contribution of aerial biomass of the local species was superior, favoring the potential of commercialization of wood and nutrient cycling, in consortium with SG.

Table 1. Arboreal biomass of Gliricidia and Sabiá in silvopastoral system in the Brazilian tropic

Branches (Mg DM·ha^{-1})	Gliricídia	Sabiá	EP	P-value
Fine (<13 cm)	5.60 B	14.74 A	1.11	0.0043
Intermediated (13-20 cm)	7.37 B	14.77 A	0.61	0.0010
Thick (>20 cm)	17.05 B	44.98 A	3.22	0.0036
Leaf biomass (kg DM·ha^{-1})	**Gliricídia**	**Sabiá**	**EP**	**P-value**
Leaves up to 1.5 m	82.19 A	10.08 B	10.65	0.0087
Total*	2246.59 B	3949.67 A	330.77	0.0020
Total tree biomass (Mg DM·ha^{-1})	32.35 B	78.45 A	4.69	0.0023

* Significant interaction Treatment x Season (P= 0.0020)

Keywords: Gliricidia sepium, branches biomass, leaf biomass, Brachiaria decumbens, Mimosa caesalpiniifolia.

L19.P.19

Impact of pig activity in soil compaction of oak forests under silvopastoralism (Álava, Northern Spain)

Mendarte S. (smendarte@neiker.eus), Lizarralde J., Albizu I.

Conservation of Natural Resources, NEIKER-Tecnalia, Derio, Bizkaia, Spain

Silvopastoralism is an activity that integrates silvicultural production and animal production, based on grazing, on the same land. In this study, we evaluated the effects of pig activity in a natural forest of *Quercus faginea* (Vitoria-Gasteiz, Northern Spain). A stocking rate of 8 pigs/ha with two different pig breeds (an autochthonous and endangered Euskal Txerria breed, and a mixed breed) were considered. The experimental design consisted of three plots divided according to the breeds (1 ha) and three control plots without animals (0.5 ha). The experiment lasted two productive cycles of approximately five months each (June17-October17 and December17-April18) and samplings were taken at the beginning and at the end of both cycles. Each subplot was set up for proper animal management with shelters, water points and feeders, all which became points of concentration for pig activity. Soil compaction, one of the most damaging effects of grazing, was closely analysed. Twenty sampling points were defined in each subplot and control plots. As an indicator of soil compaction, resistance to soil penetration was measured with a digital penetrometer (0-60 cm). Two replicas were recorded and averaged with 0-10; 10-20; 20-30; 30-40; 40-50 and 50-60 cm depth ranges. ANOVAs were applied, taking into account the effect of treatments of pig breeds and controls. In addition, in relation to distance to points of concentration of pig activity, transects of 16 points each were defined to measure resistance to soil penetration with a manual penetrometer (0-10 cm) after the first and second pig cycle. In general, the observed values do not exceed the critical thresholds that suppose a limitation in the development of plants (< 3000 kPa) regardless of the time the samples were taken in the cycle. No differences were detected at the level of soil compaction at the end of the second cycle between the two different breeds, or with the control. Although, in the duration of this study, the effect of resistance to soil penetration was not significant a tendency of greater soil compaction was observed in the plots with pig activity. The effect of pig activity showed spatial variability within the plots while the distance to points of concentration to pig activity was also a significant effect, higher compaction and bare soil coverage were both observed with less distance. High values were eventually recorded with manual penetrometer (0-10 cm) near activity points, after two pig cycles. The obtained results show a complex production system that requires an adequate and adaptive management plan in order to guarantee the sustainability of pig activity under trees of natural forest.

Keywords: resistance to soil penetration, grazing, endangered breeds, Quercus faginea, natural forests.

L19.P.20

Cattle productivity and carbon stock in silvopastoral systems with Leucaena in the Colombian Dry Caribbean

Mojica Rodriguez J. E.[1] (jmojica@agrosavia.co), Rivera Rojas M.[1], Lombo Ortiz D. F.[1], Zambrano Ortiz J. R.[1], Arias Rojas J. A.[1], Ospina Hernández S. D.[2]

[1] *Dirección de Investigación, Agrosavia, Valledupar, Cesar, Colombia*; [2] *Dirección de Investigación, Agrosavia, Palmira, Valle del Cauca, Colombia*

Dual purpose cattle systems in Valle del Cesar are based on grazing of grasses and grasslands. The integration of shrubs and wood trees in grazing areas is still occasional adopted by farmers. Milk yield and composition (total solids, fat and protein content) for cows Zebu x Swiss brown at the early (experiment 1) and mid lactation stage (experiment 2) were evaluated for silvopastoral systems that integrated *Eucalyptus camaldulensis* and *Leucaena leucocephala* with Brachiaria hybrid Mulato II (T1), *Brachiaria brizantha* cv. Toledo (T2), *Brachiaria brizantha* cv. Marandú (T3) and *Megathyrsus maximus* cv. Tanzania (T4). Wood measurement variables for carbon stock in aerial biomass from *E. camaldulensis* were determined. The crop or harvest period for Leucaena and grasses was 49 and 32 days in the experiments, 1 and 2, respectively. The initial establishing density of *E. camaldulensis* was 500 trees per hectare with harvest projection for fencing post at six years and final plot density of 300 trees per hectare. A simple crossover design was used to analyse the variables of each experiment. In experiment 1, the saleable milk yield was higher (P<0,05) with the integration of Leucaena - Mulato II (T1) (8,4 l/v/d), however the total solids (12,0%) and fat (3,3%) were lower (P<0,05) than for Leucaena – Tanzania (T4) (7,4 l/v/d; 12,8 and 3,9% for total solids and fat, respectively). In experiment 2 the saleable milk yield per cow was higher (P<0,05) in the integrations with Tanzania (T4) (3,8 l/v/d) and with Mulato II (T1) (3,8 l/v/d) while the total solids was higher (P<0,05) in T4 (14%). The total and the commercial timber volume of *E. camaldulensis* was 59,2 and 31,2 m3, respectively when considering 16,1 m and 14,4 cm as total height and diameter at breast height, respectively. According to commercial volume information it can be expected among 900 and 1200 wooden poles for fencing (2,1 m length) for different uses in the farms or between farm sells. For carbon stock aerial biomass, the reserve was estimated as 12,6 tC/ha with fixation rates of 2,1 tC/ha/yr. Tanzania - Leucaena – *E. camaldulensis* was identified as a silvopastoril system that increase the saleable yield, and the total solids of milk compared with the predominant open grass (*Bothriochloa pertusa*) in the colombian dry caribbean region, that has shown a milk production of 4,4 y 3,9 l/v/d and total solids of 12.2 y 12.9% at the early and mid lactation stage for dual purpose cows, respectively. This system also represents an opportunity to contribute to mitigation from carbon fixation rates of 2, 10 tC/ha/yr at the cattle production system and farm level.

Keywords: Feeding cows, forages, silvopastoral systems, Leucaena, Colombian Caribbean Region.

L19.P.21

Allometric equations and reforestation guidelines of *Maclura tinctoria*, an important multi-purpose tree of Latin America

Montes I.[1] (irene.montes@12tree.de), Montagnini F.[2], Ashton M.[2]

[1] *1-2-Tree Finance, Panama, Panama*; [2] *Yale University, New Haven, CT, United States*

As reforestation and restoration processes gain momentum across the world native tree species are being established for production, conservation and restoration purposes in agricultural landscapes. One such tree with promise is dinde [*Maclura tinctoria* (L.) D. Don ex Steud]; a multi-purpose, Neotropical tree species that is being widely introduced on to silvo-pastoral farms of the coffee axis region in the Latin American Andes. No formal studies have been made that examine its potential for reforestation. Unlike exotic species, technology for the introduction of native species in ranchlands is scarce, and markets and wood-processing techniques are often insufficient. It has therefore become imperative to generate information and disseminate appropriate management practices for native species that can be integrated into reforestation and rehabilitation strategies across Latin American landscapes (Piotto et al. 2004; Calle et al. 2012). In this study we aim to measure and define the relationships between age, bole size (dbh), tree height, and crown size of planted dinde trees for the development of spacing guidelines at time of planting and for thinning. We also sought to identify whether tree growth is influenced by various measures of soil fertility. We studied these relationships on dinde trees planted at twelve silvo-pastoral farms in the central Andean foothills of Colombia. Our results are the first to show dinde has comparable growth to other native and exotic trees used for reforestation in Latin America. Strong relationships exist for tree age and diameter at breast height (DBH) with crown size and height. Based on these relationships we developed spacing and thinning guidelines for timber production in plantation and silvo-pastoral circumstances. Soils were generally fertile but varied between farms. Growth varied with soil primarily related to pH and calcium, and secondly to soil nitrogen and organic matter. Our results provide preliminary information for the forester and/or the farmer on expected growth and size relationships for given ages in relation to soil fertility for planted trees. As more trees are planted on a wider array of soils and providing a greater diversity of ages further studies are necessary for refining guidelines.

Keywords: Silvo-pastoral systems, Native species restoration, Spacing, Thinning guidelines, Colombia.

References:

1. Calle Z, Murgueitio E, Chara J, 2012, Unasylva 239, 31–40
2. Piotto D, Vıquez E, Montagnini F, Kanninend M, 2004, For Ecol Manag 190, 359–372

L19.P.22

Agroforestry for ruminants in Northern Europe: recent studies to address challenges expressed by stakeholders

Novak S.[1] (sandra.novak@inra.fr), Smith J.[2], Luske B.[3]

[1] *UE FERLUS, INRA, Lusignan, Vienne, France*; [2] *Organic Research Center, Newbury, RG20 0HR, United Kingdom*; [3] *Louis Bolk Institute, Bunnik, 3981 AJ, Netherlands*

Agroforestry could play several functions in ruminant production systems, but at present it constitutes only a minor part of ruminant husbandry in Northern Europe. Ruminant livestock farmers need more scientific and practical knowledge for the implementation of agroforestry systems. During meetings held in France, the Netherlands and UK in 2014 in the framework of the AgForward project, the expectations and questions of farmers related to agroforestry were collected. They identified the need for more data on the nutritive value of tree leaves, as well as information on methods to protect young trees from ruminants and on the spatial arrangement of trees in the paddock. Other demands were more country-specific. In the Netherlands for example, dairy farmers were preferentially interested in the health benefits for cows and the effect on soil.
To answer these multiple demands, several studies were implemented in these three countries (Table 1) and gave first promising results. However, to promote agroforestry in ruminant production systems several knowledge gaps still remain, such as the proportion that tree biomass could play in the diet, the presence of antinutritional compounds, the effects of nutritive value of tree leaves on the health and production, and the role of trees on ruminant welfare, especially in the case of climate change.

Country	France	The Netherlands	UK
General aims of the studies	integrating agroforestry into dairy cattle systems	fodder trees for cattle and goats	combining organic livestock and bioenergy production
Authors	Novak *et al.* (2017)	Luske *et al.* (2017)	Smith *et al.* (2017)
Specific studies conducted in each country			
Nutritive value of tree fodder	Analyses comparing tree species, management modes, seasons (Emile *et al.*, 2017)	Analyses of macro and micronutrients of three tree species on two soils at three periods (Luske & van Eekeren, 2018)	Analyses comparing five tree species
Spatial organization of the trees in the paddock	Test of multipurpose trees (fodder, timber, litter, fuelwood)		
Tree protection from cattle	Test of seven types of protection		
Use of tree leaves as conserved fodder			Test of air-drying three tree species and analyses of dried material
Effect of trees on soil properties		Effect of two tree species on soil organic matter and earthworm biomass	
Self-medicative behaviour of dairy cows		Preliminary case study	

Table 1: Studies implemented in three European countries to answer questions of farmers expressed in the framework of the EU FP7 AgForward project (2014-17)

Keywords: silvopastoral, ruminants, innovations.

References:

1. Emile JC et al., 2017, Grassland Science in Europe, 548-550
2. Luske B et al., 2017, Deliverable 5.14 for AgForward, 16 pp. https://www.agforward.eu/
3. Luske B et al., 2018, Agroforestry Systems, 975-986;DOI 10.1007/s10457-017-0180-8
4. Novak S et al., 2017, Deliverable 5.14 for AgForward, 23 pp. https://www.agforward.eu
5. Smith J et al., 2017, Deliverable 5.14 for AgForward, 20 pp. https://www.agforward.eu

L19.P.23

Integrating multipurpose trees in a paddock grazed by cattle: first results of the co-designed layouts

Novak S.[1] (sandra.novak@inra.fr), Emile J.-C.[1], Chargelègue F.[1], Liagre F.[2], Fichet S.[3]

[1] *UE FERLUS, INRA, Lusignan, France*; [2] *Agroof, Anduze, France*; [3] *Prom'haies en Nouvelle Aquitaine, Montalembert, France*

Introduction

Despite the multiple functions offered by trees to livestock farmers (*e.g.* source of forage, animal welfare, litter, fuel wood, timber), agroforestry systems constitute a minor part of ruminant husbandry in Northern Europe. Before adopting agroforestry, farmers need more information on the methods to protect young trees from ruminants, and on the spatial organization of trees to address multiple purposes.

To answer these demands, an agroforestry paddock was co-designed with farmers, researchers, technical institute engineers and extension agents in 2014. This paper presents the agroforestry paddock and gives its first results.

Materials and methods

The agroforestry paddock (3 ha) was implemented in February 2015 on the innovative mixed crop – dairy cattle system of INRA in Lusignan (Vienne, France), which integrates also other agroforestry practices (Novak et al., 2016). To save fossil energy and water, forage resources are preferentially grazed.

Fodder trees were planted to be browsed by cattle but also to provide wood chips. Two types of pruning techniques will be tested: pollards of *Morus alba* and *Alnus cordata*, and coppices of *Salix caprea*, *Ulmus minor*, *Robinia pseudoacacia* and *Alnus incana*. High stem trees (*Pyrus communis, Gleditsia triacanthos, Sorbus domestica*) were also planted, mixed in various layouts with pollards and coppices. Three spatial organizations of trees are tested with single, double or triple-row sets, with an inter-row spacing of 20 m. To restrict the browsing of the young trees by cattle, seven types of tree protections were compared: single or double line of electric fence, electric fencing tape, metal or plastic fences, olfactory repellents and a barrier tape. Another option was to exclude the paddock from grazing and to mow the grassland during the first years.

Major results

After two years, the most efficient protections were the following: electric fence, electric fencing tape and metal fence. Electric fence and electric fencing tape are quickly installed and facilitate the mechanical control of the vegetation although they are relatively expensive. Metal fence is cheaper and offers the opportunity to be used as trellis for climbing fodder plants. However, it needs more time to be installed and it complicates the control of the vegetation on the tree rows. The olfactory repellents did not work.

When considered relative to the number of tree seedlings, double and triple row sets are more economical and time saving for their implementation and maintenance. They also open more opportunities for different tree uses compared to single rows. However, the available grazing area is more reduced, and will only be recovered when the trees will be browsed.

Conclusion

The collaborative design gave promising layouts for integrating multipurpose trees in a paddock grazed by cattle, and for using them as an aerial browsed fodder.

We acknowledge the support of EU through the AGFORWARD FP7 research project (contract 613520).

Keywords: tree fodder; cattle; collaborative design; silvopastoral system; multipurpose trees.

References:

1. Novak S., et al., 2016, 3rd European Agroforestry Conference, Montpellier, 396-398.

L19.P.24

Ecological, silicultural and management characteristics of a valonia oak silvopastoral system in W. Greece

Pantera A.[1] (pantera@teiste.gr), Mosquera-Losada R.[2], Papadopoulos A.[1]

[1] *Forestry & NEM, AUA, Karpenissi, Greece*; [2] *Crop production, USC, Lugo, Spain*

The valonia oak forest in Western Greece is one of the biggest and oldest in the Balkan Peninsula. It is mostly used nowadays for livestock raising of freely grazing sheep and less goats, rending it an important silvopastoral system. Under the framework of the AGFORWARD project, we investigated this system. The area can be characterized as hilly to semi-mountainous with trees extending from an altitude of 0-580 m, mostly on shallow to very shallow soil of limestone origin. The climate of the region is typical Mediterranean with mean participation of 938.5 mm and mean annual temperature 16.8°C. Even if the environmental conditions are favorable for organic matter accumulation and decomposition, soil litter is absent due to wind and water erosion. *Quercus ithaburensis* subsp *macrolepis* dominate in the area with old aged trees of 500 years old (mean age 200-250 years) and 4 m bh diameter, mean height ranging from 6.4-11.5 m at a density of 32-204 trees/ha. Most stands are uneven aged even if they appear as evenaged due to the old age of the trees, from a silvicultural point of view. A major problem is the lack of a management scheme applied in the area. This resulted to intense illegal logging and land use switch to agriculture or brush encroachment, and other problems caused by humans. The system provides numerous ecosystem services such as eco-friendly dyes, high quality dairy products, medicinal plants and contributes to biodiversity with its diverse flora and fauna species.

View of a valonia oak silvopastoral system

Keywords: agroforestry, Quercus ithaburensis subsp. macrolepis, ecosystem services, management, forest.

References:

1. Papadopoulos et al, 2018, Agroforestry Systems, DOI: 10.1007/s10457-018-0220-z
2. Zianis et al, 2017.Agroforest Syst, doi 10.1007/s10457-016-0060-7

L19.P.25

An innovative, farmer initiative of silvopastoral restoration in a degraded semiarid Caatinga region of Brazil

Pinheiro F. M.[1] (felipinheirorj@gmail.com), Nair P.K. R.[2], Paulson S.[3], Nair V. D.[4], DeVore J.[5], Tonucci R. G.[6]

[1] *School of Natural Resources and Envir., University of Florida, Gainesville, Florida, United States*; [2] *School of Forest Resources & Conserv., University of Florida, Gainesville, Florida, United States*; [3] *Center for Latin American Studies, University of Florida, Gainesville, Florida, United States*; [4] *Soil and Water Sciences, University of Florida, Gainesville, Florida, United States*; [5] *Anthropology and Latin American Studies, Miami University, Oxford, Ohio, United States*; [6] *EMBRAPA Sheep and Goats, Sobral, Ceara, Brazil*

Planting and managing native fodder trees and shrubs on degraded lands offers a promising approach to establishing resilient silvopastoral systems (SPS) in the semiarid Caatinga region of Brazil (Pinheiro & Nair, 2018). Although several examples of such successful smallholder initiatives are available, their experience is seldom known or recognized by outsiders. The objective of the present work is to describe such a success story of a progressive smallholder farmer, Eduardo Emídio, in his 24 ha-farm in the municipality of Barreiros, in *Bacia do Jacuípe* region, Bahia state, Brazil, and assess the extent of improvements brought about in land-quality and productivity through his innovation. His initiatives included high-density planting of cactus (*Opuntia ficus-indica*) and enclosing the area to keep off animals, broadcasting seeds of native fodder trees (mainly *Caesalpinia pyramidalis*) and adding a few tree seedlings, and managing the buffelgrass (*Pennisetum ciliare* (L.) Link syn. *Cenchrus ciliaris* (L.)) covers. Manure was applied at the rate of ca. 1kg per m^2 annually. By replicating this SPS model in plots six times on the 24-ha farm, the farmer could maintain a total herd of 110 goats and 40 cows, and substantially increase his profitability, such that it was hailed as a model farm by the local farmers and organizations. We collected some on-farm biophysical productivity data from a non-recovered area, an extensively degraded pasture (DP), and two closed SPS areas, one with 3-year-old trees (SPS 3) and the other with 17-year-old trees. The DP and the SPS were compared in terms of percent soil cover, mulch cover on land, and stand density and species composition of trees; total biomass productivity and the biophysical water storage in SPS 17 were also estimated. The DP, which the farmer described as the least deforested area on the farm, had a shrub/tree density of 462 per ha and a total of 18 tree species, compared with the corresponding values of 1,867 & 2,154 and 20 & 30 tree species for SPS 3 and SPS 17, respectively. The soil cover values in the dry season were 48% for both SPS systems and 12% for DP. The average mulch cover values (g m^{-2}) ranged from less than 100 in DP to 420 in SPS 3 and 1,200 in SPS 17. For SPS 17, the annual dry matter productivity (cactus+grass+trees) was estimated as 40 Mg ha^{-1} and the annual biophysical water storage in cactus (assessed as 85% of fresh weight) was 215 Mg ha^{-1}. Costs and profits associated with this innovative SPS indicated fast (one year) returns on cactus investment. Through a series of interviews, the farmer's views on factors influencing adoption of the system by other producers were evaluated. Main constraints to adoption included pressure from local deforestation and extensive grazing practices. The study clearly indicates the promising potential of innovative SPS for recovery and rehabilitation of degraded areas, which deserves serious consideration by development and research agencies.

Keywords: Agroforestry, Reforestation, Desertification, Biodiversity, Arid regions.

References:

1. Pinheiro & Nair, 2018, Forest Systems, 27: 1-16, doi. org/10.5424/fs/2018271-12267.

L19.P.26

Meriagos wooded grasslands: the main type of agrosilvopastoral systems of Sardinia

Pulina G.[1] (gpulina@uniss.it), Patteri G.[2], Piras G.[3], Mele S.[4], Manca M.[4], Carroni A. M.[5]

[1] *Animal science, University of Sassari, Sassari, Italy*; [2] *FoReSTAS - Sardinia Agency of Forestry, Cagliari, Italy*; [3] *FoReSTAS - Sardinia Agency of Forestry, Oristano, Italy*; [4] *FoReSTAS - Sardinia Agency of Forestry, Nuoro, Italy*; [5] *CREA - FoReSTAS, Nuoro, Italy*

Sardinia is the second largest Island in the Mediterranean Sea (24.090 square kilometers). This region has a high degree of natural environments and it is the richest in woodlands. Here, the management practice of agroforestry shaped a mosaic of agricultural and forest landscapes by the action of livestock farming systems, characterized by almost 4 million of sheep, goats, cattle and pigs (*ISTAT 2014-2016*).
Sardinian landscapes have evolved through millennia as a response to the environmental conditions and are associated with a long history of deforestation, periodical fires and grazing as strategies to maximize production of multiple goods and ecosystem services (*Zapata et al., 2014*). Cereal and fodder crops or semi-natural grass-herbs communities are mixed with a sparse tree cover mostly dominated by oak trees such as *holm oak*, *cork oak*, *downy oak*. These landscapes are common in Spain and Portugal, where they are respectively called *Dehesa* and *Montado*, but are also spread in other areas such as Sardinia in Italy, where they cover about 113.000 ha, 4.7% of the regional surface and 9.8% of the total agricultural land (*Camarda et al.*, 2015).
Sardinian *Meriagos*, often tilled and sown with annual species for the grazing and hay production, are mainly dominated by cork oak or wild olive, with tree densities ranging from 7 to 250 ha^{-1} and are generally concentrated in the hilly areas of the North and the Center of Island. Others *agro-silvo-pastoral systems* of Sardinia are *Mediterranean maquis* with more or less dense shrubs and a combination of cereals, forage crops and natural pastures. Livestock graze usually for the whole year, sometimes in mixed grazing systems with sheep, goats and beef cattle, using different feed resources such as herbaceous species, shrubs and trees. The grazing activity involves private, public silvo-pastoral areas and common lands.
Meriagos wooded grasslands have emerged from a continuous selection of both the woody and grass vegetation operated by traditional agro-silvo-pastoral activities practiced over centuries. They are used as a forage suppliers and provide *ecosystem services* such as climate regulation, carbon sinks (*Seddaiu et al.,* 2013), control of water flow, soil erosion regulation and pollination (*Bagella et al*., 2013).
Scattered trees in Mediterranean's *Meriagos* significantly enhanced pasture plant biodiversity (*Seddaiu et al.*, 2018). Traditional land uses still persist in these agro-silvo-pastoral systems, but depopulation and consequent abandonment represent a real threat.

Keywords: Meriagos, Wooded grassland, Agro-silvo-pastoral system, Scattered trees, Biodiversity.

References:

1. Bagella S. et al., 2013, Plant Ecology, 214: 621-631
2. Seddaiu G.et al., 2013, Agric. Ecosyst. Environ., 167 : 1-11
3. Zapata V.M. et al., 2014, J. Nat. Cons. 22.2: 166-175
4. Camarda I. et al., 2015, ISPRA, Rapporti 222: 1-131
5. Seddaiu G. et al., 2018, Agroforestry System, 92: 893–908

L19.P.27

Light intensity affects N-fixation and forage performances of legume swards in a Mediterranean agroforestry system

Re G. A. (giovanniantonio.re@cnr.it), Piluzza G., Sanna F., Campesi G., Sassu M. M., Stangoni A. P., Dettori D., Sulas L.

ISPAAM, CNR, Sassari, Italy

Mediterranean agroforestry systems, which integrate perennial woody plants with livestock, pastures and/or forage crops benefit from legume establishment. The sown of biodiverse permanent pastures rich in legumes is recognized as an economically rational strategy to increase grassland productivity and sustainability. This study is aimed at evaluating the forage performances and N fixation ability of different legume based swards, which were subjected to variations in light intensity. The research was carried out in a cork oak Mediterranean agro-silvopastoral system in Sardinia, where open areas with full sunlight exposition (FS) and areas under tree canopy with partial shade conditions (PS), under a cork oak density of 450 trees ha-1 were identified. Light levels of photosynthetically active radiation were measured using a canopy analysis system. For both FS and PS plots, arranged in a completely randomized design with three replications, four legume based swards were compared: Fertiprado legume mixture (100% legume composition), CNR ISPAAM mixture (80%), Bladder clover pure sward and semi-natural pasture (60%).
Dry matter yield and botanic composition were determined on five sampling areas per plot and forage subsamples were analysed for bromatological composition. The N2 fixation was estimated by 15N isotopic dilution method (Unkovich et al. 2010), using barley as a non-fixing reference species.
Light interception by cork trees ranged from 85 to 70% in January and May, respectively, due to the different solar azimuth angle of the seasons. Beneath cork oak cover with a PS (70% of light interception), aboveground dry matter yield represented 41, 45, 46 and 52% compared to the corresponding values under FS of legume based swards under comparison, namely unsown semi natural pasture, CNR mixture, bladder clover pure sward and Fertiprado, respectively. Crude protein content significantly increased (up to 57%) in PS, whereas Neutral Detergent Fibre was not significantly affected by light intensity. Results pointed out that the rates on N derived from the atmosphere by the understory legumes, were about half than the corresponding values obtained under FS, except for semi-natural pasture. In fact, PS significantly increased shoot N percentage and atom% 15N excess of understory legume based swards but, in meantime, decreased their absolute rates of N fixation, compared to the same legume swards growing in FS. Moreover, PS led to longer shoots and wider plant leaf area in several legume species, whereas leaf chlorophyll contents were unaffected by light intensity. Photosystem efficiency ratio was also affected by light intensity. Research highlight relevant variations in legume plant biomass yield and traits and clear reductions in N derived from atmosphere rates caused by light interception under PS. Results could had been also affected by differences in nutrient competition, microbiota and mineral N in the soil beneath trees.

Keywords: agroforestry, understory legumes, %N derived from atmosphere, partial shade, full sunlight.

References:

1. Unkovich M.J. 2010. Plant Soil 329:75-89

L19.P.28

Bioactive compounds of legume based swards are affected by light intensity in a Mediterranean agroforestry system

Re G. A.[1] (giovanniantonio.re@cnr.it), Piluzza G.[1], Sanna F.[1], Molinu G. M.[2], Sassu M. M.[1], Stangoni A. P.[1], Dettori D.[1], Sulas L.[1]

[1] *ISPAAM, CNR, Sassari, Italy*; [2] *ISPA, CNR, Sassari, Italy*

In Mediterranean grazed woodlands, microclimate changes induced by trees influence the growth and development of the understory but very little is known about its phenolic composition in relation to the contrasting exposure to full sunlight or shade. Phenolic acids, flavonoids and tannins are the most important compounds for biological activities and especially antioxidant properties and related implications in animal nutrition and welfare. The research was carried out in a cork oak agrosilvopastoral system in Sardinia, where we investigated the bioactive compounds and antioxidant capacity of different legume-based swards subjected to variations in light intensity. Open areas with full sunlight exposition (FS) and areas under tree canopy with partial shade conditions (PS), under a cork oak (Quercus suber L.) density of 450 trees ha-1 were carefully identified. Light levels of photosynthetically active radiation were measured using a SunScan canopy analysis system (Delta-T Devices, Cambridge, UK). For both FS and PS, the following legume based swards were compared: Fertiprado commercial legume mixture, with 100% annual legume composition, CNR ISPAAM mixture, with 80% legume composition, Bladder clover, Trifolium spumosum L., elite Sardinian accession pure sward and semi natural pasture with 60% of legume composition. Total phenolics, total flavonoid and antioxidant capacity were determined and single phenolic compounds were identified. Light interception by cork trees was 85, 77 and 70% in January, April and May, respectively due to the different solar azimuth angle of the seasons. The antioxidant capacity, total phenolics and total flavonoid of the different legume-based swards were significantly affected by the contrasting conditions of light intensity, as well as by the type of legume-based sward. Compared to full sunlight, partial shade reduced antioxidant capacity values by 29 and 42%, and total phenolics content by 23 and 53% in Fertiprado and semi natural pasture. Twelve phenolic compounds were detected, verbascoside in bladder clover mixture was the most abundant in full sunlight and neochlorogenic acid and isorientin were abundant in partial shade in CNR ISPAAM mixture and in unsown semi-natural pasture respectively. As antioxidant capacity and the content of plant secondary metabolites ascertained in the legume-based swards could potentially affect the nutritional properties of forage, their variations caused by contrasting light intensities thus represent a particular benefit, which must be exploited as an additional service from agroforestry. Our results provide new insights into the effects of light intensity on plant secondary metabolites from legume based swards, underlining the important functions provided by agroforestry systems.

Keywords: understory, bioactive compounds, HPLC, sunlight, partial shade.

References:

1. Piluzza G. et al. 2011. Pharm Biol 49:240-247
2. Karimi E. et al. 2013. J Med Plants Res 7:290-297

L19.P.29

Genetic and morphological diversity of *Tithonia diversifolia* for use in silvopastoral systems of Latin America

Rivera J.[1] (jerivera@fun.cipav.org.co), Lopera J.[1], Chará J.[2], Gómez-Leyva J.[3], Barahona R.[4], Murgueitio E.[1]

[1] *Sustainable Livestock, CIPAV, Cali, Valle del Cauca, Colombia*; [2] *Aquatic systems, CIPAV, Cali, Valle del Cauca, Colombia*; [3] *Molecular biology laboratory, Instituto Tecnológico de Tlajomulco, Tlajomulco, Guadalajara, Mexico*; [4] *Animal production, Universidad Nacional de Colombia, Medellín, Antioquia, Colombia*

In plant species, genetic and morphological variability are considered the basis for their adaptation and ability to respond to challenges and threats (Govindaraj *et al*., 2015). *Tithonia diversifolia*, a shrub of the family Asteraceae, is considered a forage species of great importance due to its chemical composition, productive performance, and adaptation (Mauricio et al., 2017, Mauricio et al., 2018). According to different studies, silvopastoral systems with *T. diversifolia*can replace commercial feeds (15% DM basis) in a total mixed ration diet fed to dairy cows without any change in total intake (18.7 kg MS/ day), milk yield (22.9 kg/day) and composition; an alternative resource like *T. diversifolia* might can provide important economic saving for farmers (Ribeiro *et al.,*2016). On the other hand, comparing animal production in systems with *T. diversifolia*(5,000 shrubs/ha, alley crop) and monoculture systems whit Brachiaria or Urochloa, the daily milk production per cow is 8% higher than the conventional system, and the stocking rate and milk production (ha/year) are higher 32.1% and 36.6% respectively, in addition to greater production of solids in milk (Rivera *et al.,*2015). The objective of this work was to determine the diversity of *T. diversifolia* in Colombia and Mexico, as well as to recognize its social, productivity and economic potential for bovine systems. Molecular markers were used to determine genetic diversity, and chemical characteristics and morphologies were analyzed with multivariate statistics and non-parametric statistics were used to analyze the economic and social variables. The materials presented differences in their crude protein (CP) (29.4% ± 3.29), extract ether (EE) (1.6% ± 0.67), Calcium (Ca) (2.3%), acid detergent fiber (ADF) (44.99 ± 9.43) and neutral detergent fiber (NDF) (46.82 ± 12.52) contents ($p < 0.05$); differences were found in the total weight of the plant, leaf area, leaves per branch and plant height ($p < 0.05$), and a wide genetic diversity was determined with a Nei index of 0.281 and a Shannon index of 0.432. The inclusion of *T. diversifolia* in bovine systems increased the animal load and milk production ha-1 year-1 (3.7 ± 0.11 and 0.5 ± 0.1, and 6605 ± 293.3 l and 776 ± 338.7 l, respectively) ($p < 0.05$) In addition, in the economic aspect, the Internal Rate of Return, had values of 3.40 and -0.10 with a Benefit / Cost ratio of 3.20 and 0.74 ($p < 0.05$), favoring a higher level of employment generation (4.3 and 0.6, respectively). It is concluded that *T. diversifolia* has a wide phenotypic diversity and adaptation to different agroecological conditions, with high quality provenances that offer greater nutritional contributions for different species of domestic animals and potential to contribute to the income and welfare of livestock producers.

Keywords: economic efficiency, nutritional quality, silvopastoral systems, social impact.

References:

1. Govindaraj et al., 2015. Genet Res Int, 1- 14. http://dx.doi.org/10.1155/2015/431487
2. Mauricio et al., 2017. J Dairy Vet Anim Res 5(4): 00146. DOI: 10.15406/jdvar.2017.05.00146
3. Mauricio et al., 2018. In: - Reconciling contemporary agriculture. Academic Press, 287 – 297
4. Ribeiro et al., 2016. PLoS ONE, 11(12): e0165751
5. Rivera et al., 2015. Livestock Research for Rural Development, 27(10)

L19.P.31

Assessment of the resprouting capacity and forage biomass production of native shrubs in La Guajira, Colombia

Rua Bustamante C. (crua@agrosavia.co), Zambrano Ortiz J. R., Lombo D.

Investigación, Corporación Colombiana de investigación, Codazzi, Cesar, Colombia

Sheep and goats are one of the most important livelihood capitals of wayuu indigenous communities in La Guajira, Colombia. These populations are being affected by the effect of climatic variability on the availability of forage for animal feed. The present study assessed the biomass production and resprouting capacity of four native forage species during two contrasting periods (rain and drought). A total homogenization pruning at two meters of height was performed for individuals of the species *Prosopis juliflora, Tabebuia chrysanta*, *Phitecellobium dulce* and *Capparis odoratissima*; in trees with a diameter at breast height (DBH) between 5 and 20 cm. Monthly counting, marking and recording of sprouts was carried out during each contrasting period (three months for rain season and three months for drought season). At the end of each period the regrowths were harvested and divided into fractions: fine < 5 mm (thin leaves and stems) and thick > 5 mm (thick leaves and stems). In the rainy period *P. juliflora* and *T. chrysanta* had the highest sprouting capacity with 114.5 and 113 sprouting / tree respectively, followed by *P. dulce* and *C. odoratissima* with 86 and 3.5 sprouting / tree. However, the dry season influenced significantly the production of sprouts in these species, being the exception of *P. juliflora* with 214 sprouts / tree. There were differences in the production of edible biomass between the species. For the first period, the *T. chrysanta* and *P. juliflora* species showed higher value with 356.5 and 222.57 g/DM/tree respectively. while in the second period *P. juliflora* presented a better response to drought with a production of 503.7 g/DM/tree; followed by *T. chrysanta* with 7.63 g/MS/tree. With respect to the leaf - stem relationship, the species with the best relation correspond to *T. chrysanta* with 1.48, followed by *P. dulce* with 1.21 and *P. juliflora* 1.06. It was not possible to estimate this relationship for *C. odoratissima* due to the low production of sprouts during the development of the investigation. The fractionation analysis of the biomass in the thin and thick components showed that the *P. dulce* species assigns a percentage of total biomass for the edible biomass fraction with 98.27%, followed by *P. juliflora* and *T. chrysanta* with 95.21 % and 85.26% respectively, while for *C. odoratissima* the fine fraction of the leaf is the most important. As a conclusion it can be said that the species *P. juliflora* behaves in an effective way in its ability to regrow and produce biomass in relation to the other species of the study for the two assessed periods. In this sense, it is necessary further research about the effect of frequent pruning on the survival of *P. juliflora* and also to propose the inclusion of silviculture management practices, such as tree pruning, into the animal feeding strategies of wayuu communities. The species *C. odoratissima* showed the lowest capacity for regrowth and biomass production for the assessed periods.

Keywords: Animal nutrition, forages, small ruminants, dry topic.

L19.P.32

Digestibility and nutritional value of *Inga* species applied to tropical silvopastoral systems

Souza S.[1] (sauloexfs@gmail.com), Souza L.[2], Olival A.[3], Milliken W.[4], Dexter K.[5], Pennington T.[6]

[1] *Centro de Pesquisa em Agrofloresta, Instituto Ouro Verde, Alta Floresta, Mato Grosso, Brazil*; [2] *NAFA, Universidade do Estado de Mato Grosso, Alta Floresta, Mato Grosso, Brazil*; [3] *NAFA, Universidade do Estado de Mato Grosso, Alta Floresta, M, Brazil*; [4] *Royal Botanic Garden Kew, Richmond, United Kingdom*; [5] *School of GeoSciences, University of Edinburgh, Edinburgh, United Kingdom*; [6] *College of Life and Environmental Scienc, University of Exeter, Exeter, United Kingdom*

Agroforestry planning requires reliable information on the species to be used. Different tree species of *Inga* have been successfully employed in different agroforestry and silvopastoral systems because of their rapid growth, tolerance to poor soils and beneficial effects for soil fertility, as well as providing shade, firewood and food. Here we present results of digestibility and nutritional assessments of five *Inga* species used in agroforestry and silvopastoral systems in Northern Mato Grosso region, Brazil. These species were sampled in family farmers' properties that participate in the *Sementes do Portal* project, coordinated by Instituto Ouro Verde. Sampling the species (*I. edulis*, n = 30; *I. laurina*, n = 12; *I. macrophylla*, n = 10; *I. nobilis*, n = 11; *I. pilosula*, n = 10) was performed following farmers' indications for adult trees, avoiding sampling two trees less than 50 meters apart. These trees were planted in homegardens or agroforestry systems, except *I. nobilis*, which grows spontaneously in wet areas. For each tree, we measured the diameter at breast height (DBH), total height and crown area, and visually estimated crown density using a five-point scale. Leaves of each tree were collected for determining dry matter, mineral matter, ethereal extract, crude protein and fibers. All species exhibited basal branching, usually below 2 m, which is useful for direct feeding on trees. *I. edulis* and *I. laurina* were the largest, with average DBH of 61.1 and 33.2 cm and crown areas of 102.4 and 77.7 m2, respectively. Most of the trees had an intermediate crown density, which would allow the development of pasture under the canopy, except *I. macrophylla*, which provides deeper shade, and is therefore better suited to control weeds. All species have high protein content, exceeding 10% of dry mass. Despite the fiber content of *Inga* leaves was similar to other tropical forage plants, digestibility was much lower (ca. 20%).Nutritionally, *I. edulis* and *I. macrophylla* stand out, as values of mineral matter and crude protein are significantly superior to others and with significantly lower fiber content, yet still not ideal for animal nutrition. To confirm that the leaves of these species are not useful as forage, specific tests for lignin are still required. Regardless, fruits of these species have nutritional qualities for both animals and people, being the pulp rich in carbohydrates and the seeds valued as natural purgative. This study provides important information for agroforestry and silvo-pastoral system designs, such as size and crown density of adult trees for five *Inga* species, as well as the nutritional quality of the leaves, although future studies are still needed to confirm leaves digestibility and to incorporate the fruits of these species into analyses. Further silvicultural studies are also welcome, since few *Inga* species have been used yet in agroforestry or silvopastoral systems.

Keywords: alternative forage, family farming, native trees, leaves, legume.

References:

1. Gobbi et. al., 2010, Arch. Zoothec, 59(227):379-390.
2. Leblanc et al., 2005, Plant and soil, 275: 123–133, https://doi.org/10.1007/s11104-005-0808-8
3. Lojka et. al., 2010, Agricultura Tropical et Subtropical. 43(4): 352-359.

L19.P.33

Sheep in organic vineyards: landmarks for the risk of Chronic Copper Poisoning (CCP)

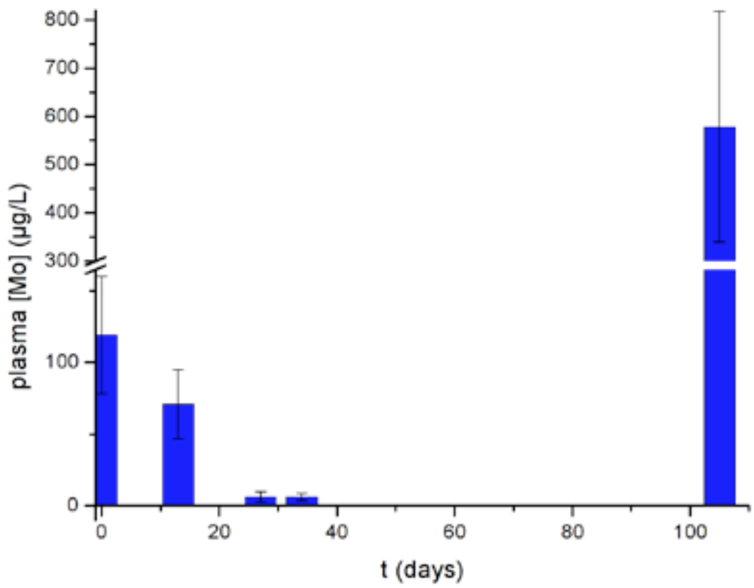
Trouillard M.[1] (martin.trouillard@fibl.org), Lèbre A.[1], Chevalier E.[2], Ferreyra S.[3], Groulard N.[4], Heckendorn F.[1]

[1] *Antenne FiBL France, Eurre, France*; [2] *Communauté de Communes du Val de Drôme, Eurre, France*; [3] *Syndicat de la Clairette de Die, Vercheny, France*; [4] *Fédération Départementale Ovine 26, Valence, France*

Sheep grazing in vineyards can provide free pasture resources to sheep breeders, and control of herb development for winegrowers; but it exposes sheep to a risk of Chronic Copper Poisoning (CCP) related to the use of copper-based fungicides for the control of downy mildew. The present study aimed at providing landmarks to estimate this risk under usual farm conditions. 16 lambs were allowed to graze on copper treated (>3 kg Cu/ha/year) organic vineyard plots in the winter 2017, during 2-4 weeks per plot. Soil and vegetation samples were collected for analysis of Cu and antagonist elements, such as molybdenum (Mo); blood analysis was performed on lambs on day 13, 27, 34 and 105, in order to identify potential harmful effect on the liver, via monitoring of Glutamate Dehydrogenase (GLDH) activity [1] and Mo and Fe levels in plasma.

Levels of Cu, Mo and S in the plants and soil were compatible with a moderate to high risk of CCP [2]. GLDH values did not provide clear evidence of hepatocyte damage, but a significant drop ($p<0,001$) of plasma Mo was observed between day 1 and 34, probably explained by its mobilization to prevent Cu storage in the liver. In contrast, the level of Mo in the plasma after the end of the grazing period raised very significantly ($p<0,001$), which may be interpreted as evidence of Cu detoxification.

Ongoing work focuses on the dynamics of Cu wash-off and/or uptake by the plants, and on extended monitoring of liver enzymes in blood. Results will be presented.



Molybdenum concentration in blood plasma of lambs grazing (from day 0 to day 34) in Cu-treated vineyards. Means of measurements performed on n=16 animals; error bars represent standard deviation.

Keywords: Copper, Sylvopastoralism, sheep, vineyard, organic.

References:

1. Humann-Ziehank et al., 2001, J. Vet. Med. Series a-Phys. Path. Clin. Med. 48(7): pp. 429-439.
2. Suttle, Copper in: Mineral Nutrition of Livestock, 2010 (4th edition), CABI; pp. 255-305.

ABSTRACTS

Biophysics of agroforestry systems

The wonders of agroforestry's biophysics

- L20 -

Agroforestry and agroecology: opportunities and challenges

Agroforestry and agroecology:
the key divisions in the growing Land Use Army

An agroforestry approach fits well with agroecological food production systems (organic, biodynamic, permaculture etc.), applying ecological principles and practices to the design and management of agroecosystems, and integrating the long-term protection of natural resources as an element of food, fuel and fibre production. Farmers of agroecological systems are familiar with managing more complex systems, relying on diversity within the system to deliver ecosystem services such as pest control and maintaining fertility. However, there are challenges to managing agroforestry systems with an agroecological approach, particularly with regards competition for limited resources such as nutrients, and weed control within the tree rows. This session will explore the opportunities and challenges that combining agroforestry and agroecological farming can generate.

L20_O.01

The 10 Elements of Agroecology: Guiding the transition to sustainable food and agricultural systems

Barrios E. (edmundo.barrios@fao.org), Bicksler A., Siliprandi E., Batello C., Brathwaite R.

Food and Agriculture Organization - FAO, Rome, Italy

Agroecology is an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems. It seeks to optimize the interactions between plants, animals, humans and the environment while considering the social aspects that need to be addressed for a sustainable and fair food system. Agroforestry is considered a realization of the promise of an agroecological approach. The 10 Elements of Agroecology emanated from a FAO consultative process, expert reviews and regional seminars, and include: diversity, co-creation and sharing of knowledge, synergies, efficiency, resilience, recycling, human and social values, culture and food traditions, responsible governance, circular and solidarity economy. As an analytical tool, the 10 Elements can help countries to operationalize agroecology and promote agroforestry by linking increased biodiversity and the use of local and co-created knowledge to build relevance, credibility and legitimacy, with agroecosystem redesign that enhances synergies, efficiencies and resilience, and helping to enhance governance while developing a circular and solidarity economy. By identifying important properties of agroecological systems and approaches, as well as key enabling environment conditions, the 10 Elements constitute a guide for policy makers, practitioners and stakeholders in planning and evaluating transitions aiming at sustainable food and agricultural systems.

The 10 Elements of Agroecology (FAO 2018)

Keywords: agroecology, agroforestry, co-creation, biodiversity, ecosystem services.

References:

1. FAO 2018. The 10 Elements of Agroecology http://www.fao.org/3/I9037EN/i9037en.pdf

L20_O.02

Agro-ecological evolution through agroforestry systemsin Uganda

Mbidde R.[1] (mbidrob@gmail.com), Kiviri S.[1], Luzinda L. M.[2], Namaganda P.[3], Nassuna A.[4]

[1] *Century Environmental Awareness Agency, Kibale, Uganda*; [2] *Council for Community Resilience, Wakiso, Uganda*; [3] *Makarere University, Kampala, Uganda*; [4] *Grassland Community Initiatives Uganda, Masaka, Uganda*

Agroforestry systems are recognized as important components in the history of human occupation in the tropical region of Uganda, and nowadays are growing in importance as sustainable options supported by Uganda's public policies focusing towards local, territorial and regional development. This study discussed some important agroforestry systems presently practiced in this region of Uganda, how they may be faced as outstanding components in many agro-ecological transition processes, and how they are directly or indirectly being contemplated by a growing number of public policies, either in national or local government level, as is the case of the Ugandan forest code. This analysis attempts also to understand the real importance of agroforestry systems in relevant current issues such as local and regional food sovereignty; water, carbon and nutrient cycling; integrated pest management, and additionally, to point to the need of considering a number of priorities in research, extension, communication, training/education, and policies formulation and implementation. The study raises the necessity of increasing the adoption of interdisciplinary and transdisciplinary approaches in agroforestry systems research. Five practices were identified and these range from Boundary marking, live fences, hedges, woodlots to home gardens. The most significant constraint was Pest and diseases followed by fire outbreak, Lack of labor, Drought, Shortage of land, and lack of seedlings and Theft. Boundary planting is the most widely adopted practice while woodlots were the least. Wives and children are the main farm labor providers and therefore farm labor is often available when the children are on holiday since most of them attend boarding schools.

Keywords: Agro-ecological evolution, Agroforestry systems, Tropical region, Uganda.

L20_O.03

An agroecology approach to improve production: Case of tropical agroforestry

Salazar-Diaz R. (risalazar@tec.ac.cr)

ITCR, Cartago, Costa Rica

Agroforestry systems in the Talamanca region in Costa Rica are particularly interesting because their vertical and horizontal organization is particularly diverse. Plant diversity was separated by different functional groups of the plant communities. This helped to better understanding the rules that govern the production in multi-strata systems. The aim of this study was to address the question, how plant diversity influences the global productivity of agroforestry systems? Plants in nine plots of 100 m² in each of 20 fields were classified into five groups (banana, cacao, other fruits, timber, and firewood), and diversity was assessed by the Shannon–Wiener index. A global evaluation of the productivity of these systems was possible with the estimation of the production of each plant during 1 year. This production was converted into income according to local market prices. While we observed a global positive effect of plant diversity on global income. When considering the functional group separately, there was a positive effect of plant diversity for higher strata groups (other fruits, firewood, and timber) and a negative effect for lower strata groups (banana and cacao). This suggested that complementarity between plants was stronger than competition for those plants occupying the higher strata of the canopy but that competition was stronger than complementarity for plants occupying the lower strata of the canopy.

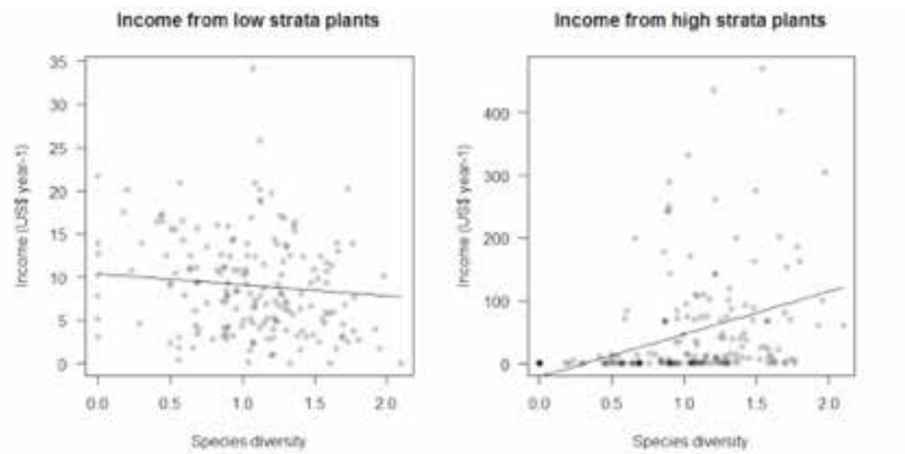


Figure 1. Total mean income (global income) for higher strata plant groups (timber wood and other fruit trees) and lower strata plant groups (banana and cacao) in response to plant species diversity in 20 agroforestry fields in Talamanca, Costa Rica. Diversity was assessed using the Shannon–Wiener index. Each circle indicates the mean value from one of the 180 plots. The lines show the prediction of the generalized linear model that included field as a random effect.

L20_O.04

Agroecological benefits realized by small farmers adopting tree-based farming on degraded lands in Maharashtra, India

Bedare G. (ganeshbedare@gmail.com), Daniel J., Sawant Y.

Agriculture, BAIF Development Research Foundation, Pune, Maharashtra, India

Trees are commonly found on farmland in India, but intensive agroforestry is not often practiced. BAIF Development Research Foundation, a non-government organization engaged in rural development, introduced tree-based farming among small farmers about 30 years ago. It has grown into a major land-based development programme over the years, covering about 80,000 ha in 11 states of India. The socio-economic benefits of this agroforestry model, locally known as the *wadi* system, are well documented (Sohani 2014, Indian Farming, ICAR, 33-35; Sawant *et al*, 2016, National conference on Forestry in India, HFRI, 26). It comprises of fruit trees, annual crops and fast-growing multi-purpose trees.
Besides the easily measured socio-economic gains such as farm income and reduced distress migration, the *wadi* system brings in many agroecological benefits. As these benefits have not yet been scientifically examined, the study reported here is an attempt towards understanding the agroecological aspects of this system. The location of this study is villages around Jawhar in Maharashtra state of India and the mango and cashew trees were about 15 years old. Information was collected by interviewing 30 farmers with a questionnaire.
The study revealed increased biological activity in the farms adopting the *wadi* system. This increase was seen in the biodiversity of birds and insect as well as soil organisms. Farmers attributed many ecological benefits to this increase in biodiversity, but it was not always possible to find direct relationships. Reduced pest incidence as a result of birds feeding on them was a major benefit, but some farmers also found the birds feeding on fruits and intercropped grain crops. More than 95% of the farmers felt the interaction among the birds, insects, reptiles and crops to be positive. A major ecological benefit of tree-based farming is the reduction in deforestation in the neighborhood of the farms in the study as fuelwood and fodder are produced in the farm itself. In some cases, this has resulted in moderated flow of rainwater and more ground water recharge. Reduction in soil erosion is another benefit that in turn improved biological activity of soil. In general, interventions aimed at building a sustainable farm production system resulted in a more favorable ecosystem on farms practicing *wadi* system.
Improved soil fertility and the favorable conditions under the tree canopies provided a better environment for weed growth. Plants that were few in number earlier have now become serious weeds and some new weeds have also been observed. Although the ecological benefits of the *wadi* system far outweigh the negatives, there are instances where farmers have not fully realized the potential because of unsustainable practices such as excessive use of water and agrochemicals. This emphasizes the need for adopting appropriate practices in order to sustain the gains.

Keywords: Wadi system, Agroecology, Biodiversity, Deforestation, Soil erosion.

References:

1. Sohani 2014, Indian Farming, ICAR, 33-35
2. Sawant et al, 2016, National conference on Forestry in India, HFRI, 26

L20_O.05

Agroforestry for a Better Mountain Futures

Xu J. (j.c.xu@cgiar.org)

East and Central Asia Regional Office, World Agroforestry Centre, Kunming, China

Mountains cover almost a quarter of the earth's surface. Both urban and rural areas depend on mountains for essential ecosystem services such as fresh water, crops and high-value products. Mountainscapes are storehouses of natural and cultural diversity; they are on the frontlines of global change, and can provide insights and solutions to global problems. Multi-functionality of mountainscapes depends on intertwined and interdependent five pillars of biological diversity which includes microbes, plants, fungi, invertebrates and vertebrates, which are the result of hundreds of millions of years of evolution. Agroforestry could be a potential innovative solution for addressing mountain challenges such as climate change and restoring functionality to mountain ecosystems, especially if we seek new, innovative ways of linking the use of trees with positive feedback models aimed at supporting the five pillars of diversity. Agroforestry is broadly defined by the FAO as the use of trees in agricultural systems, however, given the changes imposed on agricultural systems over the past two decades, perhaps it is time to redefine this concept. It is time to think about the goals and drivers behind the use of trees, what are the overall benefits to be gained by incorporating trees into a social-ecologicalsystem, beyond C capture or shading. Trees function as complex ecosystems, acting as reservoirs of biodiversity, providing feedback loops into the broader ecosystem, furthermore, these effects are unique to a given tree species. Therefore we need to first understand the complexities of a given tree species and the effects it has on the surrounding ecosystem before we decide on its use. An integrated approach towards agriculture is now more commonplace than in the past, and in light of this, we should rethink how trees fit into these integrated systems. What roles should the trees be playing, especially in environments where there remains a delicate balance between human activities and nature. With this in mind, I would like to propose the following steps for restoring mountainscapes for a better future: a) selecting superior species based on local social-ecological systems; b) developing vertical communities with tree-shrub-grass layers, as well as the above-below ground interaction of roots, mycorrhiza and soil microbes; c) Integrated system with tree-crop-livestock; and d) Biomass-based circular economy & society. The sustainability of agroforestry systems largely depends on incorporating business models that use new technologies to restore landscapes and recycle biomass, which benefit farming communities while generating sustainable profits and protecting the environment. We are carrying out research into new plants/crops/fungi that can thrive in the face of global change.

Keywords: Trees, mountainscapes, biological diversity, integrated system, circular economy.

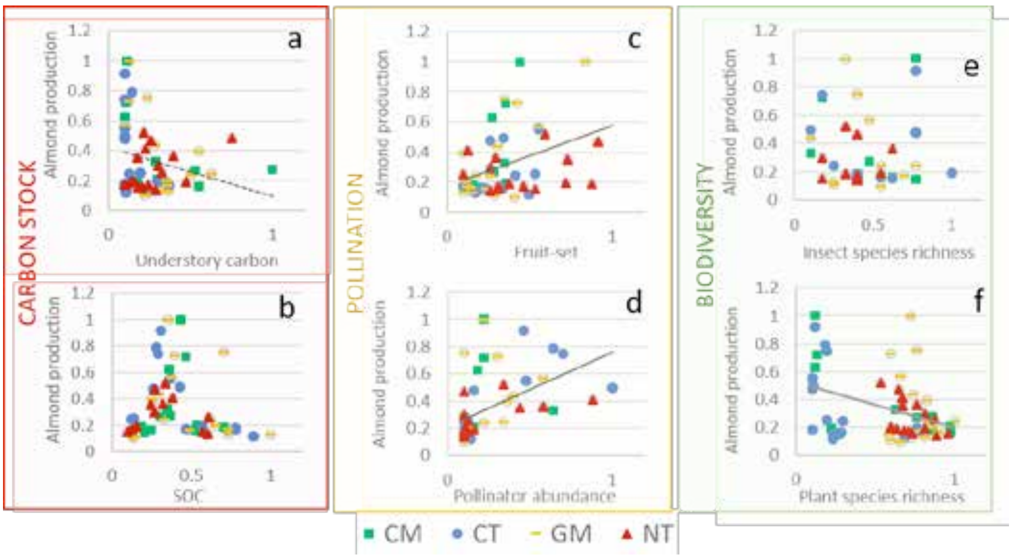
L20_O.06

Ecosystem service interactions under agroecological management transition in European almond orchards

Leijster V.[1] (v.deleijster@uu.nl), Santos M. J.[2], Ramos-Font M. E.[3], Robles-Cruz A. B.[3], Wassen M. J.[1], Verweij P. A.[1]

[1] *Sustainable Development, Utrecht University, Utrecht, The Netherlands*; [2] *Geography, University of Zürich, Zürich, Switzerland*; [3] *Estación Experimental del Zaidín, CSIC, Granada, Spain*

In this study we investigate trade-off and bundle formation among ecosystem services (ES) in Mediterranean woody crop systems. Therefore, we selected frequently tilled almond monocultures which are known to be associated to reduced ecosystem service potential. We experimentally applied conventional tillage (CT, n=6) and as agroecological treatments; green manure (GM, n=6), no-tillage (NT, n=6) and compost (CM, n=6), because of their presumed capacity to improve regulating and supporting ES. We measured indicators related to carbon stock, pollination and biodiversity and relate these to provisioning of almonds to assessed whether ES bundles or trade-offs emerge. We found that pollination indicators form an ES bundle with almond provisioning (Fig. 1 c-d). Plant species richness was significantly negatively correlated with almond provisioning (Fig. 1, f). This suggests that maintaining understory vegetation results in a trade-off for almond provisioning. Our results also suggest that trade-offs and synergies might be management specific, as GM was better capable of enhancing both food provisioning and understory plant diversity in comparison to the other treatments. Soil organic carbon (SOC) and insect species richness were not correlated to almond production. To conclude, this study shows that agroecological management in almond orchards may be an efficient tool to enhance carbon stock and biodiversity.



Keywords: Ecosystem services, trade-offs and bundles, Mediterranean, almonds, Spain.

L20_O.07

Role of field boundary habitats in agro-ecosystems health and productivity

Akhter F.[1] (fardausi.akhter@canada.ca), Bainard L.[2], Hodge K.[3], Leeson J.[4], May W.[1], Poppy L.[1], Sheffield C.[5], Soolanayakanahally R.[1], Ward T.[1]

[1] *Agriculture and Agri-Food Canada, Indian Head, SK, Canada*; [2] *Agriculture and Agri-Food Canada, Swift Current, SK, Canada*; [3] *Agriculture and Agri-Food Canada, Regina, SK, Canada*; [4] *Agriculture and Agri-Food Canada, Saskatoon, SK, Canada*; [5] *Royal Saskatchewan Museum, Regina, SK, Canada*

Canada contributes significantly to world food production, but this has not occurred without environmental costs. The fragmentations of the agro-ecosystem and associated habitat destruction for monoculture production have contributed to a loss of flora and fauna diversity. Producers often regard field boundary habitats as a non-productive land that potentially limits crop production. We hypothesized that non-crop areas provide a mixture of habitats that contributes to the diversity and dynamics of the agro-ecosystem, with net positive impacts on adjacent crops. To test this hypothesis we: 1. spatially analyzed the extent and distribution of field boundary habitat influences on in-field variability using precision agriculture approaches, such as micro scale in-field measurements of soil moisture, above- and below-ground bio-diversity, insect pests, pathogens and weeds, crop metrics from UAV-based sensors; and 2. quantified the benefits of conserving non-crop areas on crop yield and quality. We collected data from 15 sites representing one of two field boundary habitat types in the black soil zones of Saskatchewan, Canada: planted shelterbelt (Figure 1), natural hedgerow, and open field with no field boundary habitat. The data is currently being analyzed. The intent is to provide science-based information on the functioning and value of field boundary habitats and the extent of their influence into adjacent field crops.

Figure 1. Planted shelterbelt within the prairie agro-ecosystem in Canada

Keywords: prairie, shelterbelt, agro-ecosystem, resource competition, precision agriculture.

L20_O.08

Natural Assisted Regeneration of woody species in agrosystems of Senegal: agro ecological advantages and constraints

Mbaye G.[1] (mbaygora@hotmail.fr), Sanago D.[2], Niang Diop F.[3], Camara B. A.[2]

[1] *Agoecology, Enda Pronat, Dakar, Senegal, Senegal*; [2] *forestery, ISRA/CNRF, Dakar, Senegal, Senegal*; [3] *Environment, UCAD, Dakar, Senegal, Senegal*

Natural Assisted Regeneration (NAR) is one of the endogenous strategies used by some sahelian communities to regreen agro systems and fight against the effects of climate change. However, the conditions of its adoption remain insufficiently documented. The aim of this study is to identify the advantages and constraints of adopting NAR in the Fatick area of Senegal's Groundnut Basin. The methodology was to do perception surveys with 92 producers adopting NAR and 12 extension agents in the area. In terms of results, it appears that the conditions that favor the NAR in crops field are various: 55% of the producers spread organic manure, 37.3% pen the cattle in field crops before the rainy season in order to improve seed germination rate and 25% practice mulching so that to trap seeds against high winds. The perceived advantages of adopting NAR in household are also varied. At the agronomic field, 88% of producers practice NAR for soil fertilization and 12% for soil microbial diversity. Ecologically, 55.6% of producers practice NAR for conserving local biodiversity of species, 19% for improving microclimate and shade and 17% for adaptation and mitigation in climate change. The main constraints to the development of the NAR in the area are anthropic and natural. These are mainly abusive cuts (61.1% of producers), free-ranging animals (50% of producers), presence of termites (38.9% of producers) and land salinization (36. 1% of producers). This information may help decision-making in Sahel regreening programs.

Keywords: NAR, Adoption, regreening, Agroforestry.

References:

1. Badji M., al, 2015, International Journal. Biological Chememicals Sciences 12p
2. Bakhoum C., 2012,Journal of Asian Scientific Research, 14p
3. Bationi A B, 2012, World agroforestry Center, 32p
4. Niang Diop F., and al, 2011, Sécheresse 5p
5. Camara B A., and al, 2017, Journal of applied Biosciences, 10p

L20_O.09

Potential for using biochar in resource-limited agroforestry systems

Nair V. (vdn@ufl.edu), Nair P., Freitas A.

University of Florida, Gainesville, FL, United States

One of the major expectations from agroforestry systems (AFS) is to maximize the use of locally available and environment-friendly resources instead of harmful and resource-depleting chemical inputs. In this context, the use of biochar from locally available farm materials to substitute, and complement to some extent, the use of synthetic products holds promise. A meta-analysis of studies on biochar use in agriculture from 1850 to 2011 showed that 50% of cases reported positive effects, 20% no effect and 30% negative effects on crop yields (Maddox, 2013).
Wide differences in nutrient availability exist among biochar produced from plant- and animal-based materials (Table 1) and could result in variable crop-yields when biochar is used as a nutrient source. Biochar produced from mixed feedstocks (*feedstock* refers to the materials used for biochar production) would be an option to optimize the amount of biochar to be land-applied to maintain soil fertility (Nair et al., 2017). For example, both plant- and animal-based "waste products" are often available in AFS in many parts of the world. Application of biochar within tree-rows or its use as a nutrient source in other AFS is yet another, relatively unexplored opportunity. Developing appropriate techniques for biochar use will be a win-win situation in terms of crop-yield increase and waste disposal for smallholder farmers particularly in developing countries.

Table 1. Nutrient availability in biochar (in a Mehlich 3 soil test solution) from plant- and animal-based feedstocks. Units are in mg kg^{-1}

	TKN[†]	P	K	Ca	Mg	Zn	Mn	Cu	Fe	Ni
Plant-based feedstocks										
Hardwood	1010	480	4345	670	620	11	99	BDL[‡]	70	BDL
Pine	BDL	70	450	490	47	9	42	BDL	300	BDL
Animal-based feedstocks										
Poultry litter	31 400	3230	39 700	1690	2420	20	30	105	25	3
Biosolids[§]	50 700	7060	500	2330	5140	60	20	20	440	BDL

[†]TKN = Total Kjeldahl nitrogen
[‡]BDL = Below Detection Limit
[§]Biosolids vary greatly in composition based on their production process (Nair et al., 2018); results shown here are for biosolids obtained from Jacksonville-FL, USA that was converted to biochar.

Keywords: nutrients, feedstocks, environmental-friendly, crop yield, farm materials.

References:

1. Maddox N. 2013. CSA News. doi:10.2134/csa2013-58-9-1
2. Nair VD et al. 2018. Proceedings of the 4th European Agroforestry Conference. Nijmegen, Netherlands
3. Nair VD et al. 2017. Front Plant Sci 8. 2051 doi: 10.3389/fpls.2017.02051

L20_O.10

Multilayer agroforestry: the missing link

Torquebiau E. (emmanuel.torquebiau@cirad.fr)

CIRAD - UR AIDA, Univ Montpellier, Montpellier, France

Modern agroforestry emerged in the 70's as an answer to the disappearance of tropical rainforests. To improve land management, it was felt necessary to combine crops, trees and animals and apply management practices compatible with the cultural patterns of the local population. Yet, today's agroforestry relies often on simplified associations of one crop and one tree species. Such associations ignore the "forest dimension" of agroforestry and fail to restore forest-like ecosystems and promote local cultural values. I argue that between the 2 extremes of "forest gardening" and a simplified two-plant association, there is a continuum of multilayer agroforestry options with environmental attributes close to natural ecosystems, management features compatible with existing practices and productive qualities comparable if not better than simplified associations. I provide examples from Indonesia (multistrata agroforests in Sumatra), Egypt (multilayer agriculture in the Nile Delta), Cameroon (cocoa agroforests near Yaoundé) and Bangladesh (agroforestry gardens near Rajsahi). They show that multilayer agroforestry has a range of sustainability attributes and performs well for soil carbon sequestration and climate change mitigation. If agroforestry is to play its role to address environmental and climate change challenges and diversify land-based commodities, it needs to learn from complex agroforestry associations and recommend them as viable alternatives to industrial agriculture.

Multilayer agriculture near Rosetta in the Nile Delta (Egypt): from top to bottom:
Date palms, olive trees, citrus trees, tomatoes © E. Torquebiau, 2004

Keywords: complex agroforestry systems, ecosystem services, diversification, resilience, agroecology.

References:

1. Bene et al. 1977. Trees, Food and People: Land Management in the Tropics. IDRC-084e, Ottawa, Canada.
2. Torquebiau, 1992. Agriculture, Ecosystems and Environment, 189-207
3. Corbeels et al. 2018. Soil and Tillage Research, doi.org/10.1016/j.still.2018.02.015

L20.P.01

Contrasting water use patterns of two agroforestry tree species in Mt. Elgon region of Uganda: Implication on management

Buyinza J.[1] (joel.buyinza@adelaide.edu.au), Muthuri C.[2], Downey A.[3], Njoroge J.[2], Denton M.[1], Nuberg I.[1]

[1] *School of Agriculture, Food and Wine, University of Adelaide, Adelaide, South Australia, Australia*; [2] *World Agroforestry Centre, Nairobi, Kenya*; [3] *ICT International, Armidale, NSW, Australia*

Knowledge of tree water use can inform water requirements of interacting components and best bet management options for farmers. The objective of the study was to assess the daily water use patterns of mature *Cordia africana* and *Albizia coriaria* trees at different times of the year. This study deployed 6 sapflow meters on stems of 3 selected trees each of *C. africana* and *A. coriaria*. We measured the daily sapflow of these two species using the heat ratio method (HRM). The two species show contrasting patterns of seasonal water use across leaf shedding stages characterized by episodes of reverse flow in *A. coriaria*. This is an indication that the two species may have different water-use strategies. *C. africana* generally used 12% more water than *A. coriaria* on a standardized daily basis. There was a significant main effect of the interaction between tree species and season on daily water use. The consistent and predictable leaf fall in *A. coriaria* may be beneficial for planning farming activities among smallholders. This knowledge is useful in facilitating development of appropriate tree management regimes for optimal utilization of soil water. Managing on-farm trees can be a powerful means of controlling tree water use in agroforestry system. For example, canopy pruning can reduce the water demand of the tree component and may result in recharge in the crop-rooting zone, while prolonging the period of intercropping.

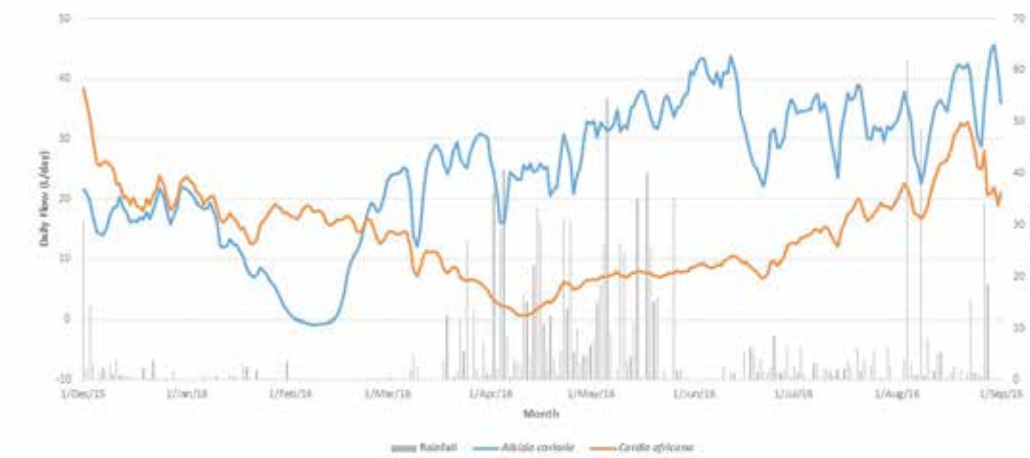


Fig. 1 Daily average sapflow in A. coriaria and C. africana over a 10 month period. Rainfall events indicate the early wet season (April to June) and the start of the late wet season (August to November)

Keywords: Sapflow, Cordia africana, Albizia coriaria, pruning.

References:

1. Burgess et al. 2001. Tree Physiology. 589-598. DOI: 10.1093/treephys/21.9.589
2. Descheemaeker et al. 2013. CAB International, 104-123
3. Pinho et al. 2012. Applied and Environmental Soil Science, 1-11. DOI: 10.1155/2012/616383

L20.P.02

Intraspecific leaf trait variation influences litter decomposition in a willow agroforestry system

Coleman B.[1] (colemanb@uoguelph.ca), Martin A.[2], Gordon A.[1], Thevathasan N.[1], Isaac M.[2]

[1] *School of Environmental Sciences, University of Guelph, Guelph, ON, Canada*; [2] *Dept Physical and Environmental Sciences, University of Toronto Scarborough, Toronto, ON, Canada*

Agroforestry systems enhance nutrient cycling in part through modifications to leaf litter quality and quantity, and subsequently, enhanced variability in decomposition rates (Jose 2009). However, the role of agroforestry management in moderating decomposition vis-à-vis leaf inputs is likely to vary widely, due to leaf functional trait plasticity across both temporal and spatial scales (Gagliardi et al. 2015; Quaye et al. 2015). Using a short-rotation willow (*Salix* spp.) temperate tree-based intercropping (TBI) system, this study examined effects of shade tree functional group (N_2-fixer, Non N_2-fixer, or monoculture) and distance from shade tree on i) willow leaf traits (namely leaf area, specific-leaf area (SLA), leaf nitrogen concentration (LNC)); we then explored ii) how intraspecific leaf trait variability influenced decomposition rates. Willow leaves within TBI systems exhibited greater leaf area, SLA, and LNC than leaves from willow in monoculture. Leaves from the N_2-fixer TBI system tended to decompose more quickly, averaging 77.50±0.43% (S.E.) remaining across sampling distances after a 56-day incubation, compared to the non-N_2-fixer treatment (78.38±0.77%) and monoculture (78.72±1.06%) (Figure 1). Willow litter in TBI systems provides soils with additional N, potentially reducing required fertilizer inputs. Our results indicate that intraspecific variation in leaf traits plays a key role in governing decomposition and ultimately nutrient availability in TBI systems.

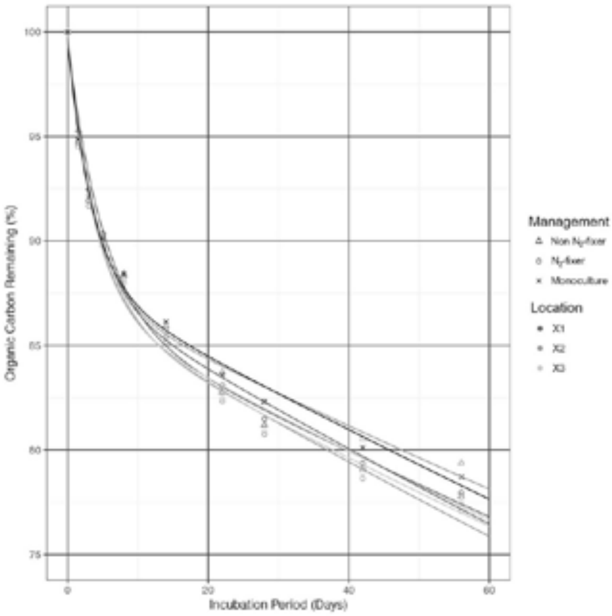


Figure 1: Organic C mineralization (%) of upper stratum willow leaves for all treatments and sampling distances during a 56-day incubation period. Lines represent the two-pooled kinetic decay models for each management system and location combination. Locations indicate willow stools on a single transect perpendicular to shade tree rows, where distances from shade trees are indicated in brackets for each location: X1 (2.25 m), X2 (4.50 m), and X3 (6.75 m). Each point represents the mean percentage of organic C remaining at each management-location combination (n=4).

Keywords: Agroecology, Decomposition, Intraspecific trait variation, Tree-based intercropping, Willow (Salix dasyclados).

References:

1. Jose, 2009, Agrofor Syst, 76(1), 1–10. https://doi.org/10.1007/s10457-009-9229-7
2. Gagliardi et al., 2015, Agric Ecosyst Environ, 151–160. https://doi.org/10.1016/j.agee.2014.11.014
3. Quaye et al., 2015, Appl Environ Soil Sci, 1–12. https://doi.org/10.1155/2015/471248

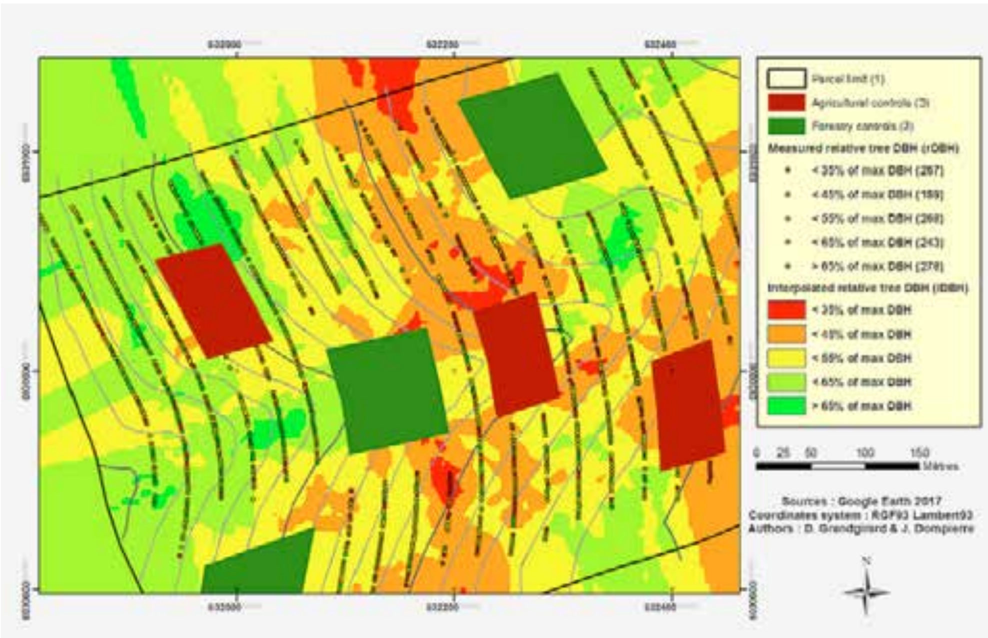
L20.P.03

Towards a zero net CO2 balance into an agroforestry cropping system - The SCA0PEST example

Grandgirard D.[1] (david.grandgirard@unilasalle.fr), Marraccini E.[1], Dompierre J.[1], Boulanger O.[1], Liagre F.[2], Dupraz C.[3], Mézière D.[3], Marin A.[2]

[1] *UniLaSalle Polytechnic Institute, Beauvais, France*; [2] *SCOP AGROOF, Anduze, France*; [3] *UMR système, INRA, Montpellier, France*

In low-forested agricultural areas where industrial crops dominate with the objective to maximize yield of every single hectare, setting up of Agroforestry systems (AFS) is often limited to less favoured soils. However, shift to a bioeconomy strategy in these territories expects new revenues from differentiating labels such as better net carbon balance of its agricultural raw materials. In order to produce useful references and ease the adoption of AFS, the SCA0PEST zero pesticide agroforestry project was initiated (Grandgirard et al., 2014) in order to test the feasibility of producing regional crops without pesticides, having recourse to integrated pests management (IPM) and soil conservation technics. Yearly, crops productivity, GHG balance and economic margins are determinated. Regarding trees, specific allometric models were elaborated; they are used to cross-validate simulated tree growth rate and CO_2 sequestration obtained from HisAFe model. Dendrometric measures (Figure) called within allometric models show that the actual trees growth follows the HisAfe simulation of a 650kg eq.CO_2/year/ha sequestration. When coupled to the 54% GHG emission reduction from the cropping system mutation, SCA0PEST actually presents an almost 100% reduction of its whole CO_2 emission meaning that C footprint and its valuation could become one of the expected evidence for farmers hesitating to adopt AFS.



Interpolated and observed (2018) DBH as a metrics of the tree growth rate across the SCA0PEST parcel

Keywords: Net CO2 balance, allometric models, Integrated pest management, Soil conservation technics, Product differentiation.

References:

1. Grandgirard et al. In Palma et al. 2nd EURAF Conference Book of Abstracts (2014) EURAF eds. 290p

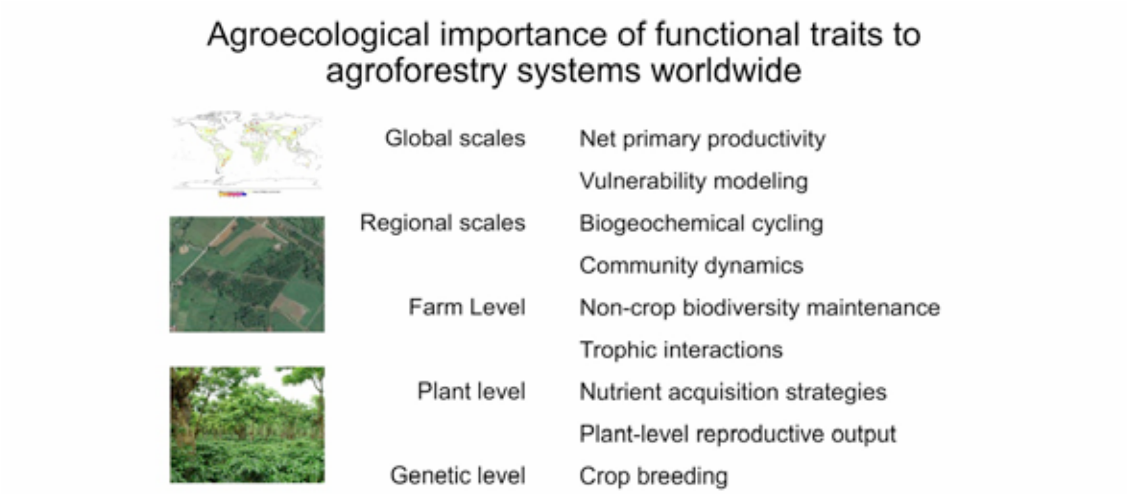
L20.P.04

Plant functional traits in agroforestry systems: advancing agroecological diagnosis

Isaac M. (marney.isaac@utoronto.ca)

University of Toronto, Toronto, Canada

Agroecological research based on plant functional traits can provide a generalizable framework to diagnose governing interactions in agroforestry systems, but principles of functional trait-based agroecology has not been widely incorporated into agroforestry research or management. The potential of trait-based research to frame and test hypotheses on agroforestry dynamics owes to the fact that functional traits provide a simultaneous understanding of how plants respond to environmental stimuli, and in turn how plants influence ecosystem function (Martin & Isaac 2018). I present the application of a functional traits approach to agroforestry systems in order to expand beyond strictly growth- and nutrient-based metrics of plant responses in agroecosystems. Empirical evidence from coffee-shade agroforestry systems shows that i) crop leaf traits follow a similar pattern of trait co-variation as hypothesized from global patterns across wild species (Martin et al 2017), ii) the expression of crop functional traits is correlated to yield (Gagliardi et al 2015) and iii) variation in root and leaf functional traits of tree crops can be explained by farm characteristics (Isaac et al 2018) and management practices (Buchanan et al 2018). This work is among the first to apply this framework to biodiversity-ecosystem function relationships in agroforestry systems. There is considerable opportunity to use a trait-based approach to answer a range of questions in agroforestry systems (Fig 1).



There is considerable opportunity to explore how functional trait-based research can be applied to questions in agroforestry management across local to global scales of integration in tropical and temperate agroforestry systems.

Keywords: Agroecology, Agroecosystem management, Biophysical interactions, Coffee, Functional traits.

References:

1. Buchanan et al., 2018, Agroforestry Systems, in press
2. Gagliardi et al., 2015, Agriculture, Ecosystems and Environment, 200:151-160
3. Isaac et al., 2018, Journal of Applied Ecology, 55:69-80
4. Martin & Isaac, 2018, Journal of Applied Ecology, 55:5-11
5. Martin et al., 2017, Functional Ecology, 31:604-612

L20.P.05

Evaluation of forest floor litter and their burning effect on Soil Quality Index in traditional and alder-based *Jhum*

Kalidas-Singh S.[1] (kalidassingh@gmail.com), P Bora I.[1], Thakuria D.[2], Changkija S.[3], Puyam A.[4]

[1] *Shifting Cultivation, Rain Forest Research Institute, Jorhat, Assam, India*; [2] *School of Natural Resource Management, College of Post Graduate Studies, CAU, Umiam, Meghalaya, India*; [3] *Genetics and Plant Breeding, SASRD, Nagaland University, Medziphema, Nagaland, India*; [4] *Plant pathology, Rani Lakshmi Bai, CAU, Jhansi, Uttar Pradesh, India*

Background
Slash-and-burn agriculture or Shifting cultivation or *Jhum* cultivation, a form of traditional agroforestry system constitutes the basic subsistence of livelihood among rural masses throughout the tropical areas. Despite its environmental impact, this practice has been continued adopting as a sole agricultural resource for the hill community residing in tough topography. Shortening of fallow length of *Jhum* cycle in one hand and supporting the inclining population in the other is challenging concern for co-existence between agriculture and hill forest ecosystem.
Aims
The present investigation aimed on comparative assessment of pre-burnt forest litter (PBFL) and their burning effect on soil quality index (SQI) at different fallow length *viz*. 2, 4 and 8-years for both traditional *Jhum* (T-JFs) and Alder-Based (*Alnus nepalensis* D. Don) *Jhum* (AB-JFs) comparing with reference to adjacent Reserved Forest (RF) at Kohima, Nagaland.
Material and Methods
Soil samples were collected from AB-JFs, T-JFs and RF. PBFL biomass and their nutrient content i.e. nitrogen (PBFL-N), phosphorus (PBFL-P) and potassium (PBFL-K), soil pH, electrical conductivity (EC), soil organic carbon (SOC), available nitrogen (Avl-N), available phosphorus (Avl-P), available potassium (Avl-K), soil microbial biomass carbon (MBC), acid-phosphomonoesterase activity (PHA), dehydrogenase activity (DHA and potential mineralizable nitrogen (PMN) of unburnt and burnt soil of T-JFs and AB-JFs were determined and compared with their SQI reference to RF soil (Mäder et al. 2002).
Major Result
All parameters were significantly increased with relative increase of *Jhum* fallow year (2 < 4 < 8-years). PBFL biomass, PBFL-N, PBFL-P, PBFL-K and all the soil parameters except soil pH showed significantly higher at $P < 0.05$ in AB-JFs over T-JFs. After burning, SOC, Avl-N, PMN, MBC, PHA and DHA were decreased at the rate of 13.79%, 8%, 40%, 23%, 5%, 21% in AB-JFs and 17.13%, 12%, 30%, 23%, 9%, 24% in T-JFs, while the other parameters like pH, EC, Avl-P and Avl-K were increased at 4.9%, 14.6%, 7%, 22% in AB-JFs and 4.6%, 18.64%, 12%, 27% in T-JFs respectively. The maximum change in percentage of each parameter in AMOEBA graph was recorded in eight-years AB-JF, followed by four-year AB-JF and minimum in two-year T-JF. Considering SQI with the reference RF as 100%, an increased SQI in AB-JF as compare to TJ-F was observed. This investigation shows the advantage of symbiotic relation of *Frankia* and *A. nepalensis* in Alder-based over traditional *Jhum* cultivation in fallow management.
Conclusion
Understanding of nutrient cycling potentials in these *Jhum* agroecosystems, will promote the co-existence of forest, sustainable food production and restoration of soil health in south-east Asian *Jhum* agroecosystems by adopting Alder-based *Jhum* as short duration fallow management in agroforestry.

Keywords: Litter biomass, Fallow phase burning effect on soil nutrient, Potential Mineralizable Nitrogen, Microbial Biomass Carbon, Soil Enzyme.

References:

1. Mäder P, Fliessbach A, Dubois D, Gunst L, Fried P, Niggli U (2002), Science 296:1694-1697

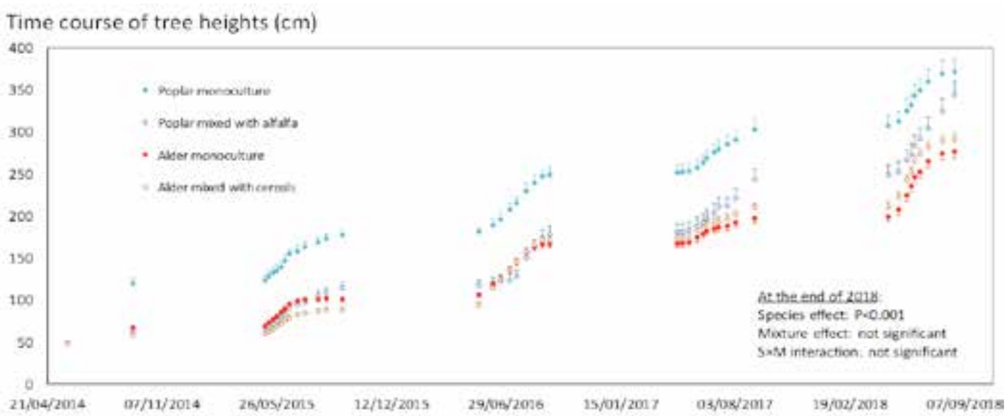
L20.P.06

Evaluation of alley cropping agroforestry potential in northeastern France

Marron N.[1] (nicolas.marron@inra.fr), Piutti S.[2], Lacroix T.[3], Cochard P.[4], Amiaud B.[5], Cuntz M.[1], Dallé E.[1], Epron D.[5], Laflotte A.[6], Petitjean C.[2], Plain C.[5], Thérond O.[7]

[1] *UMR Silva, INRA Grand-Est - Nancy, Nancy, France*; [2] *UMR LAE, Université de Lorraine, Nancy, France*; [3] *Chambre d'Agriculture des Vosges, Epinal, France*; [4] *Chambre d'Agriculture de l'Aube, Marigny-le-Chätel, France*; [5] *UMR Silva, Université de Lorraine, Nancy, France*; [6] *Ferme Expérimentale de la Bouzule, Université de Lorraine, Champenoux, France*; [7] *UMR LAE, INRA Grand-Est - Colmar, France*

Agroforestry appears as a way of diversifying farms in the European context. These practices are, however, only emerging in northeastern France. There are a multitude of reasons why farmers venture or do not venture into agroforestry practices. The general tendency is that farmers consider investing into agroforestry if have concrete production, environmental and/ or socioeconomic performance indicators for their specific regional conditions.
The overall objective of our project is to evaluate the potential of alley cropping agroforestry plantations at the scale of the French Grand-Est region, based on indicators and to simulate agroforestry deployment scenarios at the territory scale.
The impact of introducing trees into agricultural plots is assessed at 3 scales: 1) detailed analysis of biophysical processes at a well-experimented site, 2) analysis of a subset of processes at the plot scale at 6 plantations and 3) an agro-environmental and socioeconomic assessment of deployment scenarios at the scale of the territory.
Monitoring at the 6 plantations has just began, while the pilot site is monitored in terms of production and soil functioning since 5 years. The site is composed of 2 mixtures (poplar/ alfalfa and alder/cereals) and corresponding monocultures. During the first years, agroforestry plots were less productive than monoculture plots (shown for the trees on the figure below) because of an intense competition between species. However, this trend is currently changing.



Time course of poplar and alder heights in the monoculture and agroforestry plantations, and statistics (2-way ANOVA) at the end of 2018

Keywords: N2 fixation, Alley cropping, Biophysics, Socioeconomics, Agroforestry potential.

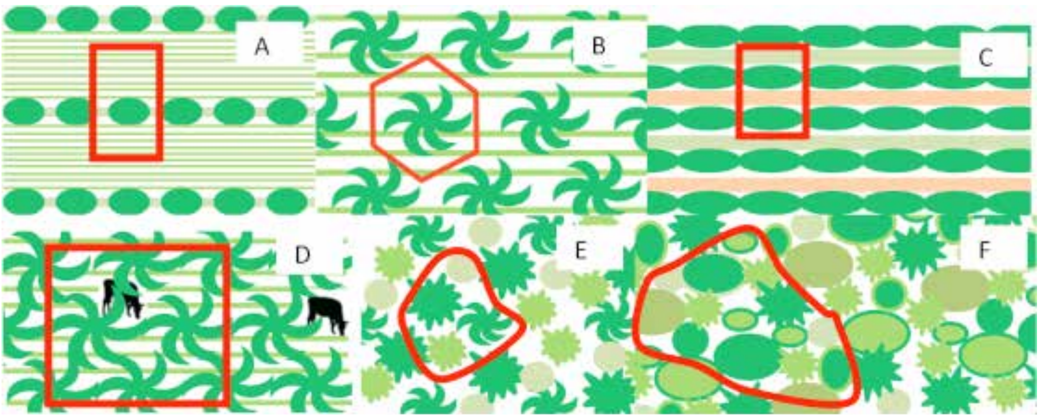
L20.P.07

Ecosystem services functional motif: a new concept to analyse and design agroforestry systems

Rafflegeau S.[1] (sylvain.rafflegeau@cirad.fr), Allinne C.[2], Barkaoui K.[3], Deheuvels O.[4], Jagoret P.[1], Garcia L.[5], Gosme M.[6], Lauri P.-E.[6], Mérot A.[6], Metay A.[7], Mézière D.[6], Saj S.[8], Smits N.[6], Justes E.[1]

[1] *Cirad - UMR System, Montpellier, France*; [2] *Cirad - UMR System, Turrialba, Costa Rica*; [3] *Cirad-UMR System, Rabat, Maroc*; [4] *Cirad - UMR System, Lima, Perou*; [5] *Cirad - Montpellier SupAgro - UMR System, Montpellier, France*; [6] *INRA - UMR System, Montpellier, France*; [7] *Montpellier SupAgro - UMR System, Montpellier, France*; [8] *Cirad - UMR System, Guyane, France*

Agroforestry systems (AFS) are multi-species systems comprising cropped and associated spontaneous species, including trees. The species in AFS provide different levels of regulating, supporting and provisioning ecosystems services (ES). We assume that the provision of ES depends on the functional characteristics of all associated species and their spatial layout in the AFS, which we call here the "functional motif". We propose the concept of Ecosystem Service Functional Motif (ESFM) defined as the smallest spatial unit that is relevant to understand the provision of all the targeted ES, at a given time. This ESFM is useful to determine the smallest scale at which data should be collected for relevant upscaling of AFS functioning. As a proof of the ESFM concept, we use it to describe existing AFS covering a wide range of species richness X spatial organisation. We show, for each AFS, the ESFM for various types of targeted (multiple) ES at various stages in the development of the system. We finally discuss the strengths and weaknesses of the ESFM concept for (i) analysing the AFS functioning, (ii) designing improved AFS according to ES targeted, and (iii) modelling such AFS.



Examples of ESFM in different types of AFS: simple AFS with tree rows and a single crop in the alleys (A, B), alternate interrows of service crops in vineyard (C), silvopastoral AFS (D), complex AFS (E) and home garden (F). Surrounding redlines delimit ESFM in each example.

Keywords: Agroforestry, agroecology, functional pattern, system design, ecosystem services.

L20.P.08

Reactive nitrogen budgeting in agroforestry systems in India

Ram A.[1] (ashusirvi84@gmail.com), Dev I.[2], A.R. U.[3], Kumar D.[4], Kumar N.[1], Handa A. K.[3], Kumar A.[1], Dotaniya M.L.[5], Meena B.P.[6]

[1] *System Research, Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India*; [2] *I/C PME, Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India*; [3] *Tree improvement, Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India*; [4] *NREM, Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India*; [5] *ICAR-DRMR Bharatpur, Bharatpur, Rajasthan, INDIA*; [6] *ICAR-IISS, Bhopal, Madhya Pradesh, INDIA*

Agroforestry systems (AFS) act as a source and sink of reactive nitrogen (N) in N-cycling in agro-ecological systems. Tree species, soil and climatic conditions, age of plantations, tree-crop combinations etc. are the major governing factors for N-cycling under AFS (Nair et al. 2009). The AFS can maintain or even restore reactive N through biological nitrogen fixation (BNF) (13-500 kg/ha/yr), deep N capture, reducing volatilization losses by leaf litter and number of other cycling mechanisms. Based on agroforestry data of eight Indian states (Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal, Gujarat, Rajasthan, and Tamil Nadu), 1.5 BNF trees/ha have been calculated (Ajit et al., 2016). On the basis of N-fixation potential of BNF trees such as *L. leucocephala, D. sissoo, A. nilotica, P. cineraria, G. sepium* etc., it has been estimated that about 7.46 kg N/ha/year/tree can be fixed and at country level trees can add N upto 0.250 Tg/yr (BNF-0.195 Tg + litter fall-0.055 Tg) in 17.45 m ha agroforestry area (Ram et al., 2014). The total reactive nitrogen addition through various sources (synthetic N fertilizers -2.07 Tg, legume crops-0.115 Tg, irrigation and rainfall-0.285 Tg, manures and crop residues-0.174 Tg and trees-0.250 Tg) has been worked out 2.894 Tg/yr in agroforestry systems of the country. Trees alone contribute 9% of total N addition in AFS in India (Fig. 1). Thus, BNF tree species can contribute a significant role in N-cycling in agro-ecological systems.

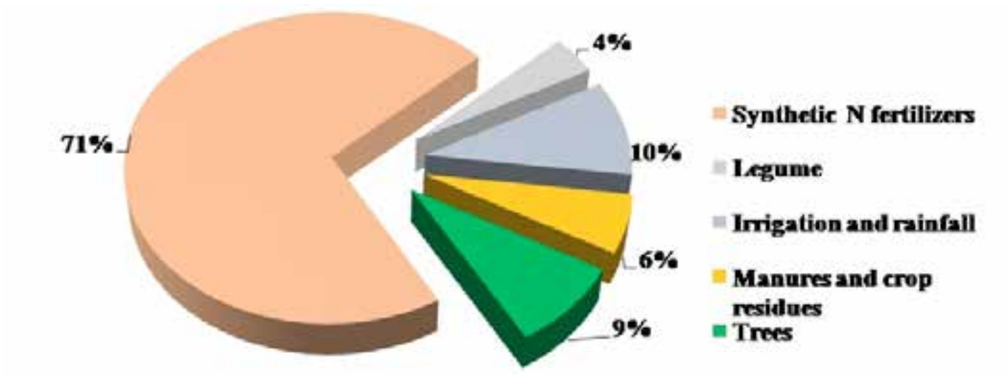


Fig.1: Reactive N contribution (%) from different sources in AFS in India

Keywords: Agroforestry area, N cycling, Nitrogen fixing trees, Chemical N Fertilizers, Tree-crop combinations.

References:

1. Nair PKR, Mohan Kumar B, Nair VD. 2009. J Plant Nutr Soil Sci, 172:10–23.
2. Ram A, Dev. I, Uthappa AR, Kumar D, Kumar N, et al. 2017.In: Abrol et al., (Eds) (pp 207-18)
3. Ajit, D.S.K.,et al., 2016. Agroforestry Systems. http://dx. doi.org/10.1007/s10457-016-9986-z.

L20.P.09

Agroforestry and Ecological farming practices to improve Landscape Restoration initiatives in the humid tropics

Ribeiro C. (Camila.Ribeiro@research.usc.edu.au), Herbohn J., Ota L., Baynes J.

Tropical Forests and People Research Ctr, University of the Sunshine Coast, Maroochydore DC, QLD, Australia

In this study, we present the main agroforestry designs and agroecological farming practices adopted by landscape scale projects aimed at restoring forests in the humid tropics. Our purpose was to understand what has been experimented in agronomy for biodiversity promotion, optimization of ecosystems services, as well as crops, trees or other plant species involved in these operations. We also sought for evidence of whether these systems are fostering social benefits to its communities. Accordingly, we carried out a database search on Web of Science and a subsequent screening methodology. More than 130 peer-reviewed papers from over 20 journals were retrieved and analysed.
Key results call for further long-term investigation on implemented systems at landscape level rather than the farm scale extent. Management type and intensity, together with low-diversity tree intercropping were the most documented topics of research. A bias for environmental sciences studies was identified, although more recent investigations have been utilizing multidisciplinary approaches, combining environmental with socioeconomic data.
This review will assist in recognizing successful applications, gaps to be addressed in future research for novel strategies, as well as humid tropical regions in the planet that require more consistent assessment.

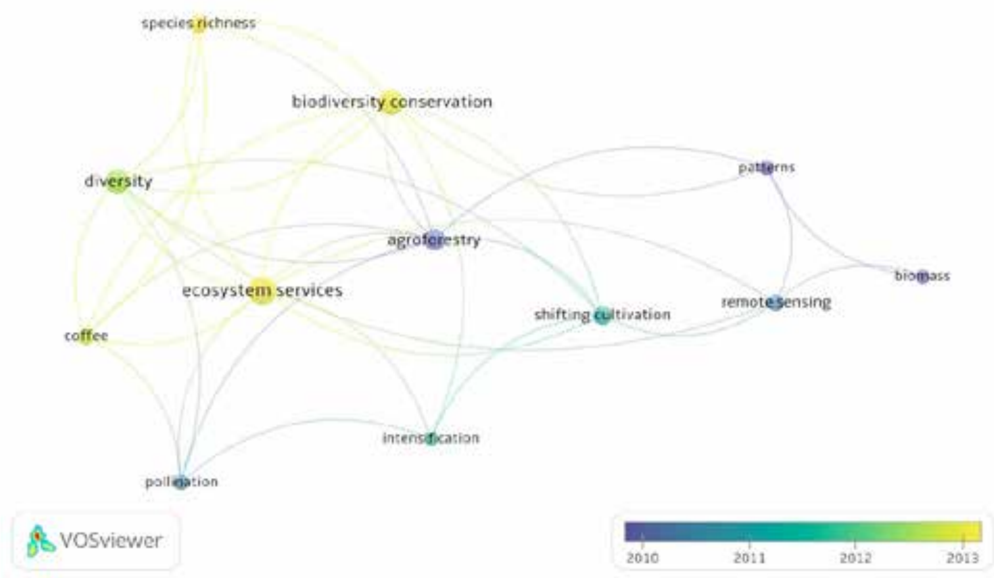


Figure 1: Keywords of high occurence in retrieved papers. Their level of relatedness is depicted by the number and lenghth of connecting lines. The gradient of temporal incidence (year) is represented by the colours' range in the bottom right legend

Keywords: agroforestry, farming practices, tropical reforestation, landscape, restoration.

L20.P.10

Multi-scale assessment of the impact of tree hedgerows on wheat root microbiota : organic vs. conventional farming

Ricono C. (claire.ricono@univ-rennes1.fr), Mony C., Vandenkoornhuyse P.

ECOBIO, Rennes, France

Agricultural intensification (i.e. landscape homogenization, intensive agriculture) induced a huge loss of biodiversity in agroecosystems, including microorganisms community. Symbiotic microorganisms are key functional group due to their action favoring plant nutrition and protection (1). Loss of biodiversity can reduce these functions and promote parasitic behavior evolution (2) leading to lower plant's performance. This work will address the impact of tree hedges in agricultural landscapes, supposing that they constitute a microorganisms biodiversity refuge, and will analyze the consequences of agricultural practices on soil and wheat roots microbial community. We hypothesized that presence of hedgerows and organic farming act as adventices plant sources and dispersal vector in crops, leading to a more diverse and efficient symbiotic microorganisms pool. The microbial community assessment will be done by mass-sequencing approaches. For each sampling time-point, we will performed soil and wheat roots sampling, floristic surveys, measures of wheat production and health. Data will be analysed under an innovative view of microbial landscape ecology. Two independent gradients of tree hedgerows density and % of organic farming will be used to study microorganisms community at landscape and parcels scale (Figure 1). This work is expected to provide a new understanding for a more sustainable agriculture by stimulating a biodiversity promoting the fertility ecological service.

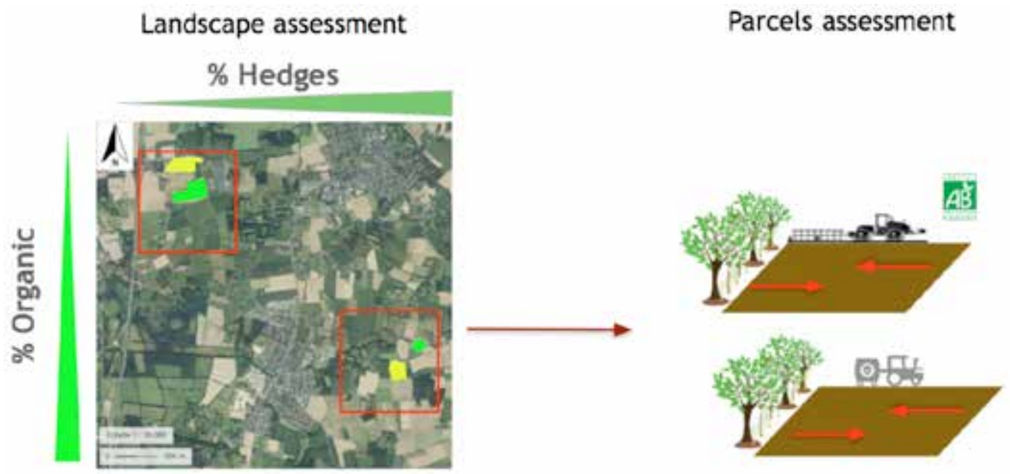


Figure 1 : Experimental plan representation : landscape scale (Left) and parcels scale (Right)

Keywords: Microorganisms, Dispersion, Hedgerows, Agricultural management, Adventices.

References:

1. Vandenkoornhuyse et al., 2015, New Phytol, 1196-1206
2. Kiers et al., 2011, Science, 880-882

L20.P.11

Shade tree species impacts on soil nutrient availability and food web in conventional and organic coffee agroforestry

Sauvadet M.[1] (marie.sauvadet@unilasalle.fr), Van den Meersche K.[2], Allinne C.[3], Gay F.[2], Virginio Filho E. D. M.[4], Chauvat M.[5], Becquer T.[1], Tixier P.[6], Harmand J.-M.[7]

[1] *UMR Eco&Sols, IRD, Univ. Montpellier, Montpellier, France*; [2] *UMR Eco&Sols, CIRAD, Univ. Montpellier, Montpellier, France*; [3] *UMR System, CIRAD, Univ. Montpellier, Montpellier, France*; [4] *CATIE, Turrialba, Costa Rica*; [5] *Ecodiv, Normandie Université, Mont Saint Aignan, France*; [6] *UPR Geco, CIRAD, Univ. Montpellier, Montpellier, France*; [7] *UMR Eco&Sols, CIRAD, ICRAF, Univ. Montpellier, Yaounde, Cameroon*

Conventional, intensively managed coffee monocultures are environmentally damaging. The use of shade trees and organic management are welcome options to reduce coffee physiological stress, reduce synthetic inputs and restore soil biological balance. However, whether the effects of shade trees on soil functioning would be similar for different coffee management practices should be investigated. Here, we measured soil total C and N, inorganic N, Olsen P, pH, biomass produced in bioassay, nematode and microarthropod communities under three shade types (unshaded coffee, shaded with *Terminalia amazonia*, and shaded with *Erythrina poepiggiana*) combined with two management practices (organic and conventional) in a 17-year old experimental coffee plantation in Turrialba (Costa Rica).

Under conventional management, soil nutrient availability and fauna densities were higher under shade, regardless of the shade tree species (Fig 1). Under organic management, only *Erythrina*, a heavily pruned, N_2-fixing species, had increased soil nutrient availability and fauna density, while *Terminalia* shade had a null or negative impact. Soil N availability was linked to bacteria-feeding nematodes while soil P availability was more linked to detritivorous microarthropods. Higher fertility was recorded in soil with balanced foodwebs. This study highlights the importance of the choice of shade tree species for soil fertility in low input systems, more so than in fertilized systems.

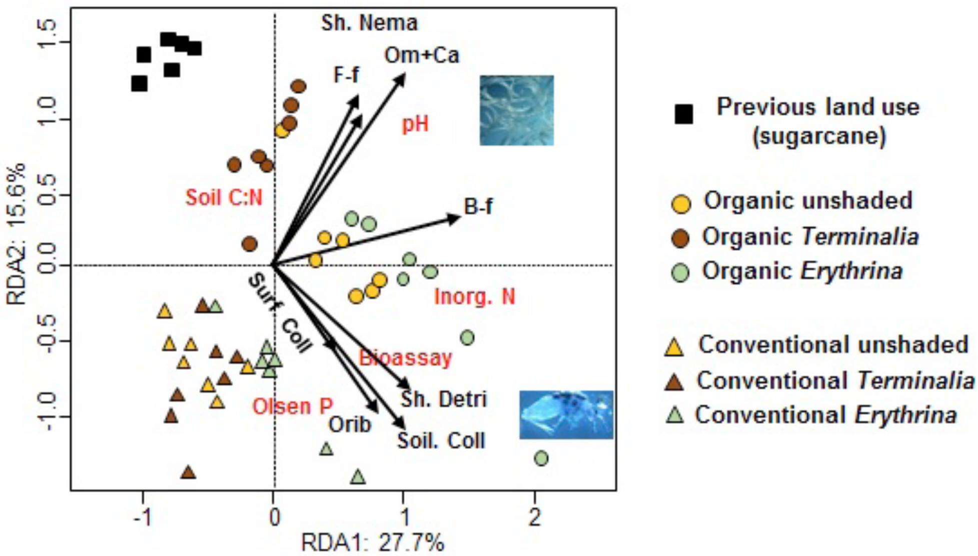


Fig 1. Redundancy analysis of soil biogeochemical parameters (in red) constrained by nematode and microarthropod communities (in black). Nema: nematodes; Detri: oribatid mites and collembola; Sh: Shannon Index; B-f: bacterial-feeding nematodes; F-f: fungal-feeding nematodes; Om + Ca: omnivorous and carnivorous nematodes; Surf. Coll: "surface-living" collembola; Soil. Coll: "soil-living" collembola; Orib: oribatid mites.

Keywords: Management practices, Shade type, Soil fertility, Soil food web, coffee.

L20.P.12

Shade tree species with Ca-enriched litter improve cocoa agroforest functions in Central Cameroon

Sauvadet M.[1] (marie.sauvadet@unilasalle.fr), Saj S.[2], Freschet G.[3], Essobo Nieboukaho J.-D.[4], Enock S.[4], Becquer T.[1], Tixier P.[5], Harmand J.-M.[1]

[1] *UMR Eco&Sols, Montpellier, France*; [2] *UMR System, Montpellier, France*; [3] *UMR 5175 CEFE, Montpellier, France*; [4] *World Agroforestry Centre (ICRAF), Yaoundé, Cameroon*; [5] *UPR Geco, Montpellier, France*

Associating shade trees to cocoa plantations supply many services to farmers, yet their contrasting impacts on soil fertility in relation to their traits remains little understood (Blaser et al., 2017). In 2017, 6 cocoa shading modalities of cocoa were studied across 8 farmers' plots (Bokito district, Cameroon): unshaded, shaded with *Canarium schweinfurthii, Dacryoides edulis, Milicia excelsa, Ceiba pentandra* and *Albizia adianthifolia*. For each shading modality, we analyzed the plant association community values of: litterfall; N and P resorption efficiency; litter C, macronutrients and tannins content; Van Soest fractions and litter pH. We measured soil C, N, NO_3^-, NH_4^+, Olsen P, pH, bioassay and cocoa yield.
Shade tree – cocoa association increased total litterfall for all the species without impacting on cocoa yield. Further, litter N was higher with *Albizia*, while litter P and Ca were higher with *Milicia* and *Ceiba* and litter pH was lower with *Canarium* and *Dacryodes*. Soil properties were not impacted by *Canarium* and *Dacryodes*, while *Albizia, Milicia* and *Ceiba* increased soil inorganic N and P content and bioassays (Fig 1). Finally, soil pH and total C and N content increased under *Milicia* and *Ceiba*, leading to the highest increase in soil fertility. Multiple regression models suggested a critical role of litter Ca to improve soil fertility in such systems. Using shade trees like *Milicia* or *Ceiba* with high Ca cycling should thus be advised to farmers to improve their system.

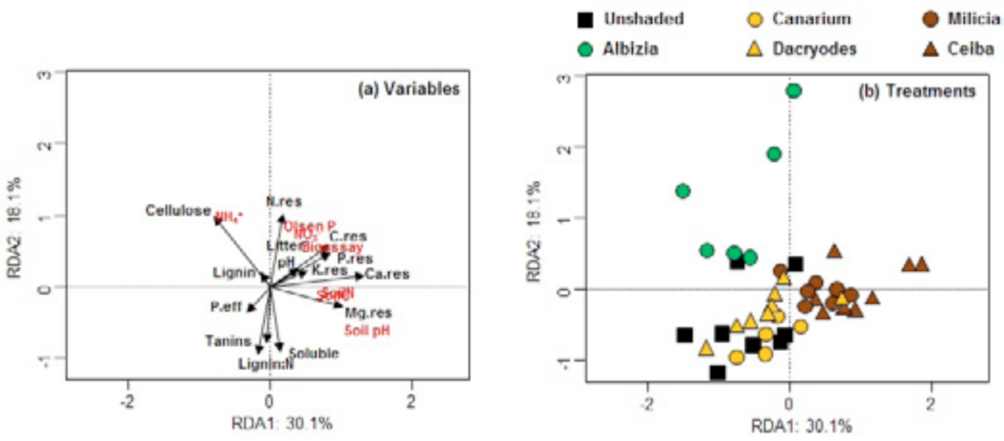


Fig. 1. Redundancy analysis correlation circle (a) and individual factor map (b) of agrosystem functions (in red) constrained by cocoa - shade tree association characteristics (in black). P res. eff: P resorption efficiency; %N, P, K, Ca, Mg: community litter N, P, K, Ca, Mg content.

Keywords: cocoa, shade type, plant traits, soil fertility, agrosystem functions.

References:

1. Blaser et al., 2017, Agric Ecosyst Environ, 83-91

L20.P.13

Water consumption of tree wind break systems in Central Asia

Thevs N. (N.Thevs@cgiar.org), Aliev K.

Central Asia Office, World Agroforestry Centre, Bishkek, Kyrgyzstan

Most of the agriculture in Central Asia depends on irrigation, e.g. agriculture in such areas like the Ferghana Valley or along other rivers in Central Asia. The major source of irrigation water are rivers. Glacier melt, snow melt, and rain fall in the mountains generate the runoff of those rivers [1]: In the course of climate change, glaciers melt down so that a decrease in runoff by 20%-50% is expected by 2050 [2].
Against this background it is of crucial importance to increase water productivity of irrigated agriculture and build resilience against water shortages. One method to achieve this goal might be introducing agroforestry, in particular tree wind breaks. Literature suggests that crop evapotranspiration is reduced and crop yields are increased inside such tree wind breaks systems compared to outside such systems [3]. Though, changes of water consumption and income are unknown when farmers change add tree wind breaks to their farm systems.
In order to understand those changes from a cropping system without tree wind breaks to an agroforestry system with tree wind breaks, water consumption of crops and trees as well as costs and benefits of crops and tree wind breaks trees were assessed during the growing seasons 2016, 2017, and 2018. The study areas were villages in the Ferghana Valley and Chui Valley, in Kyrgyzstan. Micro climate data were used in order to calculate crop water consumption. Tree water consumption was measured through sapflow measurements.
Wind speed is significantly reduced by tree wind breaks. This effect extends as far as 40 times wind breaks height. Close to tree wind breaks, single row wind breaks and multiple wind breaks with undergrowth wind breaks reduce wind speed by 30% and 60%, respectively. Reduced wind speed results in reduced crop water consumption inside a shelterbelt system. The overall water consumption of shelterbelt system was found to be lower by 5-20% compared to non-shelterbelt systems depending on tree spacing and crops [4]. In addition, accumulated income from shelterbelt trees doubles farm income compared to crops without tree wind breaks, as revealed through farm interviews.

Keywords: agroforestry, irrigated agriculture, sapflow, Poplar, evapo-transpiration.

References:

1. Rumbaur et al., 2015, Earth System Dynamics, 6: 83-107.
2. Unger-Shayesteh et al., 2013, Global Planetary Change, 110, 4–25
3. Alemu, 2016, International Journal of Ecosystem, 6, 10-13
4. Thevs et al., 2017, Water, 9(1), 842-852

L20.P.14

Behavior of mycorrhizal communities in agroforestry: Case of the walnut plantations associated with maize and faba bean

Thioye B.[1] (babacar.thioye@unilasalle.fr), Castel L.[1], Hirissou F.[2], Trinsoutrot-Gattin I.[1], Legras M.[1]

[1] *AGHYLE UP 2018.C101 - SFR NORVEGE, UniLaSalle Rouen, Mont-Saint-Aignan, France*; [2] *Chambre d'Agriculture de Dordogne, Sarlat-la-Canéda, France*

Agroforestry systems play a very important role in reducing wind speed, improving soil structure, increasing biodiversity and carbon sequestration. One of the beneficial microbiota that have a symbiotic association with most of the plants in agroforestry is arbuscular mycorrhizal fungi (AMF). The diversity of AMF can be a critical factor in enhancing both the productivity and the diversity of plants in ecosystems, and the plants in the ecosystem also strongly influence the occurrence of these fungi. However, very few studies have been carried out on the impact of mycorrhization on walnut trees with associated crops. The integration of a vegetative cover in intercrop in walnut plantations is an innovative practice, still little developed. Although cover crops are widely used in conservation agriculture or organic farming, there is little knowledge on the impact of cover crops on native mycorrhizal fungi. This mycorrhizal approach is reinforced in this study by the presence of crops in the walnut trees (maize mainly) during the first years of growth. Our study focused on the natural mycorrhization and the ecosystem services rendered two important crops in South-western France: maize and walnut. In June of 2017 and 2018, root and rhizosphere soil samples of walnut trees were collected from the agroforestry plots in Dordogne and the experimental station of Creysse (South-western France) to evaluate the relationships between different cropping systems and AMF communities. Six modalities (Walnut in Conventional farming, Walnut in Organic farming, Walnut with vegetal cover, Walnut and maize in agroforestry, Maize in direct sowing with seeds untreated and Maize in direct sowing with seeds treated) and three types of parameters (technical itineraries, biological and physicochemical indicators) are studied. Our results showed a higher mycorrhizal colonization in walnut trees in organic farming in comparison with those in conventional farming. The highest percentage of total AMF colonization was recorded for walnut trees (34%) in the presence of faba bean. These findings showed the great role played by vegetation cover in the enhancement of mycorrhizal colonization of plants. The establishment of plots of mycorrhizal communities on walnuts with intercrop maize culture would be a very beneficial model to study the transfer of arbuscular mycorrhizal fungi from walnut trees to maize.

Keywords: arbuscular mycorrhizal fungi, agroforestry, walnut, cover crops, organic farming.

L20.P.15

Evaluation of some biological properties of soil after the incorporation of seven green manures

Urbano M.[1] (mariafernandaurbanoestrada@gmail.com), Pantoja M.[1], Benavides I.[2], Cabrera P.[1], Delgado I.[1]

[1] *Universidad de Nariño, Pasto, Nariño, Colombia*; [2] *Institución universitaria CESMAG, Pasto, Nariño, Colombia*

The reduction of the biological activity in the soil accelerates the degradation, loss of fertility and the consequent loss of the capacity to provide food to the population, for which we evaluated some biological properties such as richness, diversity, abundance and biomass of the edaphic macrofauna after the incorporation of seven green manures including the aliso (*Alnus jorullensis* Humboldt, Bonpland & Kunth) as a species with agroforestry potential in Genoy soils (Pasto, Colombia). This sampling was performed using the TSBF methodology (Tropical Soil Biology and Fertility). As a general result all the green manure treatments increased the abundance, richness and diversity in comparison to the control group. The higher values in abundance, richness and diversity were found in the treatment with *Alnus jorullensis*, demonstrating that the woody perennials used in the agroforestry systems increase the biological activity of the soil, thus improving the physical properties of the soil increasing the fertility of this, reaffirming that agroforestry systems are a useful production alternative.

Keywords: green manures, richness, abundance, diversity, macrofauna.

References:

1. CABEZAS et al. (2008). U.D.C.A. p. 176.
2. MATHIEU et al. (2005). Biol. 19: 1598-1605
3. MORAN et al. (2012). Revista de ciencias agrícolas 29(2): 16 - 25.
4. CABRERA et al. (2001). Revista Cubana de Ciencia Agrícola, 35(1).

L20.P.16

Use of uncomposted woodchip as a soil improver in arable and horticultural soils

Westaway S.[1] (sally.w@organicresearchcentre.com), Smith J.[1], Rousseau A.[2]

[1] *Organic Research Centre, Newbury, United Kingdom*; [2] *Association Française d'Agroforesterie, Auch, France*

Repeated applications of composted material lead to long term improvements in soil organic matter (SOM), soil water retention and improved nutrient status. The application of uncomposted, ramial, woodchip to cultivated soils also has significant potential benefits. A long-term study in the US (Free, 1971) showed positive results in terms of soil biological activity and SOM. Research by Caron et al (1998) confirms these findings and recommends using smaller diameter material, chipped green without leaves. Few studies have followed up on these findings. This requirement for smaller material makes agroforestry systems based on short rotation coppice and boundary hedgerows ideal for ramial woodchip production.
This paper reports on the first-year results from trials comparing the addition of uncomposted and composted woodchip produced from agroforestry systems as a soil improver. The trials aim to increase the sustainability of farm systems by linking hedgerow management with soil improvement, providing an economic incentive for management of on-farm woody resources. First year results have shown no significant differences between ramial woodchip and compost in terms of soil biology, soil chemistry or crop parameters (ley biomass and spring barley yields). Where two years data were available, we saw an increase in available P, K, Mg, SOM and biological activity in both the ramial and composted woodchip. The trials will be monitored over the coming years to confirm these results.

Figure 1. Spreading ramial woodchip at Tolhurst Organics using a rear discharge muck spreader, 2018

Keywords: ramial, woodchip, hedgerow, agroforestry.

References:

1. Caron C. Lemieux G. and Lachance L. (1998) Regenerating soils with ramial chipped wood. Publication
2. Free, G.R. (1971) Soil Management for Vegetable Production on Honeoye Soil with Special Reference

L20.P.17

Towards the domestication of *Dioscorea hirtiflora subsp. pedicellata* Milne-Redh, a wild edible yam in Zambia

Zulu D.[1] (d.zulu@pgr.reading.ac.uk), Ellis R.[2], Culham A.[1]

[1] *School of Biological Sciences, University of Reading, Reading, United Kingdom*; [2] *Agriculture, Policy and Development, University of Reading, Reading, United Kingdom*

Natural and semi-natural forests in southern Africa provide examples of long-term agroforestry systems based on foraging from common lands with limited management. Lusala (*Dioscorea hirtiflora* Benth.) is a wild edible tuberous climbing plant, native to Zambia and other parts of Africa. In southern Zambia, a high proportion of rural households collect (83%), consume (96%) and sell (59%) lusala tubers, but it is threatened by overharvesting and deforestation (Zulu *et al.* 2019). The plant has limited domestication in Zambia: a few farmers establish plants from wild-harvested tubers in semi-natural forests near homesteads. There is no published information on lusala propagation to inform and improve the practices of these pioneer farmers. This study evaluated lusala's potential for domestication through propagation experiments in heated glasshouses at the University of Reading. Experiment 1 assessed the effect of planting minisetts with or without visible shoot buds from three weight classes; experiment 2 evaluated the influence of planting whole tubers or minisetts; and experiment 3 assessed the effect of planting different minisett types (proximal, middle and distal tuber parts) on sprouting and tuber yield. Sprouting in all experiments occurred between November–December with considerable dormancy. This period coincides with the onset of the rainy season in Zambia. In experiment 1, a high percentage of minisetts with visible shoot buds sprouted (96-100%), compared with only 18% in minisetts without buds. There was no interaction between minisett weight class and bud presence on yield per plant ($p>0.05$). The effect of bud presence on yield was significant ($p<0.05$) with an average of 45.0g for minisetts with buds compared with 10.4g for those without. Weight class didn't affect yield ($p>0.05$), but 1–4.9g minisetts with buds gave 73% tuberization whilst larger minisetts and all tuber sizes without buds (most did not sprout later) gave 100% tuberization. This surprising result may be a survival adaptation mechanism. In experiment 2, whole tubers had greater sprouting (96–100%) and tuber yield (71.5–92.5g) than minisetts (33% sprouting; 8.3g yield). Cultivated yam studies have shown that planting material size is correlated with yield (Ekanayake and Asiedu 2003; Morse and McNamara 2018). In experiment 3, bigger proximal (58%, 14.6g) and bigger middle minisetts (50%, 7.5g) sprouted and yielded better than smaller middle (17%, 0.6g) or smaller distal ones (29%, 2.2g). Furthermore, smaller proximal (46%, 8.7g) and bigger proximal (58%, 15.0g) minisetts gave higher sprouting and yield than smaller middle (17%, 0.6g), smaller distal (29%, 2.2g), or bigger distal (50%, 1.5g) ones. Cultivated production of lusala in agroforestry systems may be improved by planting bigger proximal minisetts prepared from tubers with visible shoot buds in November–December, but the optimum minisett size is not yet known.

Keywords: Dioscorea hirtiflora subsp. pedicellata Milne-Redh, tubers, wild edible plants, Zambia, semi-natural forests.

References:

1. Ekanayake and Asiedu 2003. J Crop Prod. 9: 1-2, 531 – 558.
2. Morse and McNamara 2018. J. Crop Improv. 22:1, 90 – 106.
3. Zulu et al. 2019. Econ Bot. https://doi.org/10.1007/s12231-018-9433-3

ABSTRACTS

Biophysics of agroforestry systems

The wonders of agroforestry's biophysics

- L21 -
Agroforestry germplasm

Sculpting the future: optimising tree genetics for agroforestry

Trees - constituting diverse species, their diverse genes, diverse populations and their land races - are the 'first resource' of agroforestry systems. Many of these trees are of key importance for improving livelihoods of millions of smallholders through the provision of important products such as fodder, food, fuel, medicine and timber, and environmental services including soil health and fertility, and carbon sequestration. Their appropriate management is fundamental to devising productive and sustainable agroforestry landscapes while also supporting their restoration. The objectives of this session are to provide the state of art knowledge on advances, key lessons learnt and the needs for future areas pertaining to:

1. Safeguarding tree genetic resources in anthropized forest and farming systems, exploring how to best preserve and promote diversity and ensure its continued availability for use;
2. Tree domestication, identifying promising wild tree species and bringing them into cultivation, as well as improving the performance of already domesticated trees;
3. Tree planting material delivery, investigating how to ensure that the right material reaches growers.

L21_O.01

Has the time come for the systematic improvement of the shea tree (*Vitellaria paradoxa*)?

Boffa J.-M.[1] (j.m.boffa@cgiar.org), Hale I.[2], Lovett P. N.[3], Padi F.[4], Dembele C.[5], Soulémane N.[6], Danquah A.[7], Hendre P.[1], Muchugi A.[1], Jamnadass R.[1]

[1] *World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [2] *Department of Biological Sciences, University of New Hampshire, Durham, NH, USA*; [3] *Savannah Nutrition, Salisbury, United Kingdom*; [4] *Cocoa Research Institute of Ghana, New Tafo, Ghana*; [5] *World Agroforestry Centre (ICRAF), Bamako, Mali*; [6] *Lab. of Genetics, Hort .and Seed Science, University of Abomey-Calavi, Cotonou, Benin*; [7] *West African Center for Crop Improvement, University of Ghana, Accra, Ghana*

The collection of sheanuts (*Vitellaria paradoxa*) provides vital livelihood and food security benefits for millions of poor rural women across 21 sub-Saharan African countries. Self-sown and rarely planted due to its extensive gestation period but systematically managed by farmers, shea displays large phenotypic variation within and between populations, offering great potential for genetic improvement. While global demand for shea products is increasing, shea parkland populations are under threat due to agricultural land use intensification, urbanization and competing resource needs. The conservation and productive utilization of shea genetic resources likely depend on the transformation of this semi-domesticated keystone species into a more actively managed and improved agroforestry crop. Research efforts on shea have been fragmented and short-lived. Germplasm available for research is limited to very few ex situ collections and a handful of permanently marked, phenotypically characterized on-farm populations. A suite of foundational genomic resources developed in the BREAD project, including an annotated reference genome and sequence variant as well as association mapping panels offer new possibilities to understand the genetics underlying important agronomic and quality traits. Realizing the promise of such resources requires coordinated investment in genetic resource development, germplasm exchange, sociocultural research and basic agronomic and horticultural studies.

Shea fruits (photo credit: Global Shea Alliance)

Keywords: Genetic resources, Germplasm, Association mapping, Crop improvement strategy.

References:

1. Allal et al. 2013. Agroforestry Systems 87(5) 1065-1082
2. Boffa 2015. World Agroforestry Centre Occasional Paper no. 24
3. Lovett and Naq 2000. Resources and Crop Evolution 47,293-304
4. Naughton et al. 2015. Applied Geography 58, 217-227
5. Rousseau et al. 2017. Journal of Agrarian Change 17(3) 497-517

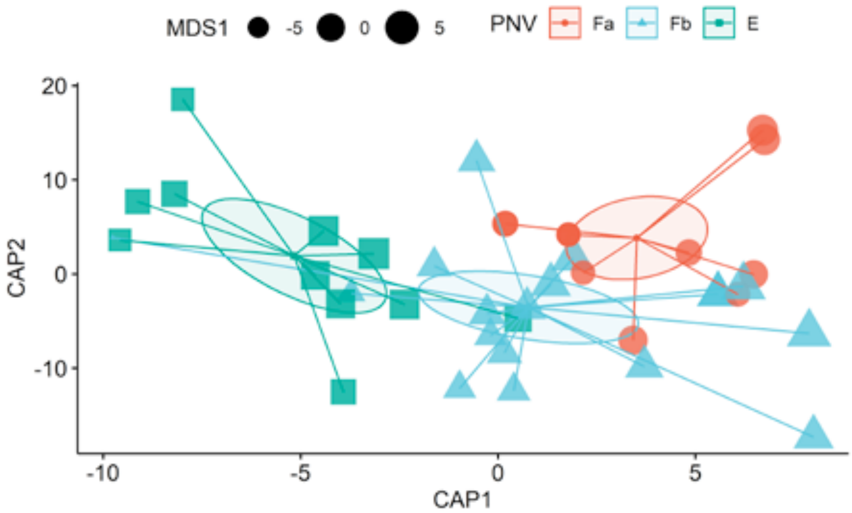
L21_O.02

Mapping tree species in geographical and environmental space: a comparison of vegetation and habitat suitability maps

Kindt R.[1] (r.kindt@CGIAR.org), Dawson I.[2], Lillesø J.-P.[3], Jamnadass R.[1], Graudal L.[3]

[1] *Tree Productivity and Diversity, World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [2] *Crop & Soil Systems Research Group, Scotland's Rural College, Edinburgh, United Kingdom*; [3] *Department of Geosciences and Natural Re, University of Copenhagen, Frederiksberg, Denmark*

Collection bias coupled with paucity of accurate point observation data complicate the calibration of species distribution models. For similar reasons, temperature and precipitation ranges published in databases may not represent the bioclimatic range of species accurately. Species distributions inferred from potential natural vegetation maps (for example, ICRAF's *Africa Tree Finder* App) or ecoregion maps (for example, WWF's *WildFinder*) may thus provide the best available approximation of suitable areas for many species. Palynology studies whereby past climates and vegetation types are reconstructed from pollen assemblages provide further support to species selection tools based on vegetation maps.
Recent initiatives such as the provision of iNaturalist.org observations via the Global Biodiversity Information Facility, or the publication of the quality-checked RAINBIO mega-database for continental tropical Africa, now allow for the calibration of better species distribution models for many species. For over 100 tree species native to Africa that were selected as priority species for a large scale restoration project in Ethiopia, distributions in geographical and environmental space were compared between the www.vegetationmap4africa.org and habitat suitability maps produced by ensemble algorithms. For species that feature in different vegetation assemblages, similar methods were used to check delineations of seed zones based on vegetation boundaries.



Constrained ordination diagram (vegan::capscale; P < 0.001) of species point observations of Hagenia abyssinica in three vegetation types. (PNV: Potential Natural Vegetation; Fa: Afromontane rain forest; Fb: Afromontane undifferentiated forest; E: montane Ericaceous belt; CAP: constrained ordination axes; MDS: unconstrained ordination axes).

Keywords: species distribution models, potential natural vegetation, seed zonation, species selection, synecological maps.

References:

1. Fithian et al. 2014. Methods Ecol Evol, 6: 424-438.https://doi.org/10.1111/2041-210X.12242
2. Prentice et al. 2001. J. Biog. 27: 507-519. https://doi.org/10.1046/j.1365-2699.2000.00425.x
3. O'Neill et al. 2017. Province of British Columbia Tech. Rep. 099. www.for.gov.bc.ca/hfd/pubs/Docs/
4. Dawson et al. 2017. Tree Genet. Genomes 13: 71. doi: 10.1007/s11295-017-1155-7
5. Ramalho et al. 2017. Front. Ecol. Evol. 5: 95 https://doi.org/10.3389/fevo.2017.00095

L21_O.03

Community based tree improvement enhance productivity of farm trees and provision of better quality tree seed

Abiyu A.[1] (a.abiyu@cgiar.org), Norgaard C.[2], Mohammed K.[1], Dimenso A. D.[3], Tadesse W.[3], Graudal L.[4], Moestrup S.[2]

[1] *ICRAF, Addis Ababa, Ethiopia*; [2] *UCPH, Copenhagen, Denmark*; [3] *EEFRI, Addis Ababa, Ethiopia*; [4] *ICRAF, Nairobi, Denmark*

In Ethiopia trees on farms have big potential as sources of germplasm and for improving livelihood through ecosystem services. However, shortage of sufficient number of plus trees and selection of ‘wrong’ plus trees may be an impediment in realizing their potential. Tree breeding and quality tree seed production are expensive ventures, in terms of capital and knowledge. Therefore, planning and implementation of tree improvement with resource poor farmers needs to be less complex and cheaper. The seed source, procurement and possibilities for improvement of two prioritized farm trees *Cordia africana* and *Faidherbia albida* were assessed in the framework of provision of adequate tree seed portfolio for forest landscape restoration in Ethiopia. Standard methodologies were followed for: seed source description, estimation of number of trees, seed crop production and possibilities for improvement. Mean tree seed production, for both species, varies between 10 – 107 kg/ha depending on number of trees per ha. Farm trees are the most common source of seed for the formal tree-seed market, and the farmers, individually or collectively, are major suppliers. There is big potential for tree improvement and quality tree seed production through the establishment of Breeding Seedling Orchards (BSO) as evidenced by *C. africana*. Similarly, there are fertile grounds to improve *F. albida* in the same pattern. BSO is a new model of tree improvement in Ethiopia. This approach can further be developed and have additional impact on the provision of quality tree seed in Ethiopia, if farm households can participate through maintaining of best quality trees on their farms.

Keywords: farm trees, tree improvement, BSO, tree seed.

L21_O.04

Characterization of native cocoa populations and their importance as quality seeds for Family Farming Systems in Peru

Pastor-Soplin S.[1] (spastor@cientifica.edu.pe), Mendoza L.[2], Perez-Cano F.[3], Castell M.[3], Best I.[4]

[1] *Agroforestry Engineering, Universidad Cientifica del Sur. Lima, Pe, Lima, Lima, Peru*; [2] *Asociación Peruana de Productores de Cac, Magdalena del Mar, Lima, Peru*; [3] *Faculty of Pharmacy and Food Science, Universidad de Barcelona, Barcelona, Catalonia, Spain*; [4] *Research Division, Universidad Cientifica del Sur. Lima, Pe, Lima, Lima, Peru*

The seed, being the most important initial input of agriculture, does not have the necessary attention in the case of Peru's cocoa. Since 2012, there is a National Register of Peruvian Cacao Cultivars (RNCCP) (1), which remains empty. In the country that is an important part of the Center of Origin of cocoa, there is not any formally registered native cultivar. In order to fill such a considerable gap, we have been working on the morpho-agronomic and biochemical characterization of four local cocoa populations known as the "Blanco de Piura", "Amazonas Perú", "Criollo de Montaña" and "Chuncho del Cusco". Local clones already selected and concentrated in seed gardens have been evaluated, established by the farmers themselves under *in situ* conditions. A selection and evaluation of fruits and seeds of a minimum of 15 trees per population have been made in the same phase of the 2018 harvest season. Fourteen morpho-agronomic descriptors have been evaluated (2), and observations regarding the health of the fruits and the plants. Then, cocoa paste has been obtained based on local protocol, and progress has been made with its biochemical evaluation, seeking to determine differences both in nutritional level and in its nutraceutical potential.
Clearly, a more advanced state of selection was observed for the "Blanco de Piura" cocoa (Coefficients of pod (IM) and seed (IS) of 17 and 680.3, respectively), the same that could already be registered as a cultivar; while the other three are more heterogeneous (IM from 16 to 27, IS from 551 to 1052). The "Amazonas Perú", cocoa with Denomination of Origin (3), ideally should move towards its registration as a single variety, while the native populations of "Criollo de Montaña" and "Chuncho del Cusco" are still very heterogeneous and could potentially lead to more than one cultivar.
The biochemical characterization of cocoa paste, obtained from the grains of each population, and especially its nutraceutical potential, adds significant value and also differentiates and specializes marketing possibilities to these four native cocoa from north central and southern Peru, where producers have been making important transformation and added value efforts.
This work is funded by the National Fund for Scientific, Technological and Technological Innovation (FONDECYT) of Peru (Contract 137-2017-FONDECYT).

Keywords: Characterization, native cocoa, genetic resources, seed, Family Farming Systems.

References:

1. Resolution No. 144/12 / AG - Creates the National Registry of Cultivars of Peruvian Cocoa (RNCCP).
2. Wilbert Phillips-Mora, Adriana Arciniegas-Leal, Allan Mata-Quirós, Juan Carlos Motamayor-Arias (201
3. INDECOPI approves the Designation of Origin CACAO AMAZONAS PERÚ. Resolution No. 014866-2016

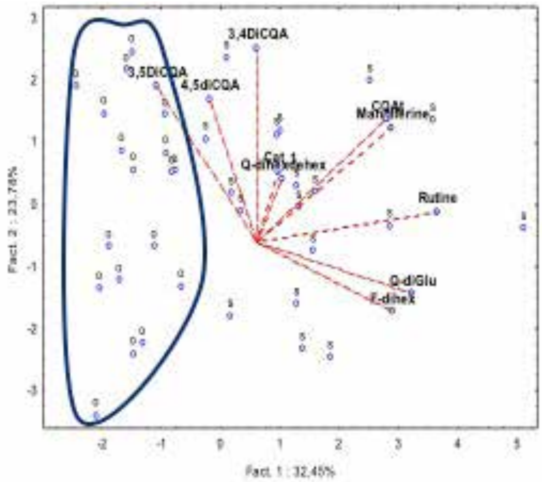
L21_O.05

A global approach to decipher molecular basis of coffee tree adaptation to shade

Duangsodsri T.[1] (teerarat.duangsodsri@gmail.com), Leran S.[2], Villegas A. M.[3], Vestalys I.[4], Artins A.[5], Etienne H.[6], Breitler J.-C.[6], Villain L.[6], Bertrand B.[6], Campa C.[5]

[1] *BIOS, IRD, Montpellier, FRANCE*; [2] *IPME, CIRAD, Montpelllier, FRANCE*; [3] *CENICAFE, Chinchina, Colombia*; [4] *Université d'Antananrivo, Antananrivo, Madagascar*; [5] *IRD, Montpellier, France*; [6] *CIRAD, Montpellier, France*

Culture under shade in AgroForestry Systems (AFS) is proposed to face the predicted negative effects of climate change on coffee plants. To decipher the molecular mechanisms involved in coffee tree adaptation to lower light, cultivars breaded for intensive full sun production systems have been grown under shade and full sun, in Mexico and Colombia. Leaves have been harvested for biochemical and transcriptomic comparative analyses. A common biochemical and transcriptomic response is observed in mature leaves of two years-old juvenile trees of *C. arabica*var. Marsellesa cultivated in Mexico at different altitudes and of six-years old producing trees of eight different Arabica genotypes cultivated in Colombia. HPLC analysis showed a significant decrease in phenolic content under shade, especially glycosylated flavonoids involved in light protection. Transcriptomic analyses showed that 70% of the under-expressed genes under shade are heat shock proteins involved in temperature but also in various abiotic stress responses. Overall, our results show that Arabica culture under shade limits the biological costs for the plant, due to stresses. This energy saving opens new question: are the resources more allocated to primary metabolism, bean production and homeostasis? We are currently testing these genes and metabolites as markers to predict the adaptation to AFS and associated abiotic stresses.



(Left) Full sun and shade culture of Arabica cultivars in Colombia (Manizales,CENICAFE) (Right) PCA ordination of full sun (s) and shaded (o) trees from the 8 genotypes cultivated in Colombia (Manizales,CENICAFE) according g to phenolic compounds. Q-diGlu, F-diHex, Rutine and Q-dihehdehex are glycosylated flavonoids.

Keywords: Shade adaptation, Coffea arabica, Biochemical, Transcriptomic, AFS markers.

References:

1. Breitler JC et al., 2016. Scientific Reports | 6:38368 | DOI: 10.1038/srep38368
2. Bunn C et al., 2015. PloS ONE 10, e0140490.
3. Camargo de MBP, 2010. Bragantia, 69 : 239-247
4. Campa C et al., 2017. Front. Plant Sci. 8:1126. doi: 10.3389/fpls.2017.01126

L21_O.06

Domestication of baobab (*Adansonia digitata* L.) in Eastern Africa: results of the Baofood project in Sudan and Kenya

Kehlenbeck K.[1] (katja.kehlenbeck@hochschule-rhein-waal.de), Wanzala F. R.[2], Omondi M. A.[2], Mubanga B.[2], Chládová A.[3], Lojka B.[3], Siddig M. E.[4], Gebauer J.[1]

[1] *Faculty Life Sciences, Rhine-Waal University of Applied Science, Kleve, Germany*; [2] *Department of Horticulture, Jomo Kenyatta Univ. of Agriculture & Tec, Juja, Kenya*; [3] *Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague, Prague, Czechia*; [4] *Inst. of Gum Arabic Research & Desertif., University of Kordofan, El Obeid, Sudan*

Baobab (*Adansonia digitata* L.) is an important wild fruit tree with multiple uses in African drylands. In Eastern Africa mainly the highly nutritious fruit pulp is used for home consumption and sale at domestic and growing export markets [1]. The increasing demand for fruit pulp may create opportunities for rural communities to use the wild baobab populations more intensively, but there are claims of decreasing abundance of baobab trees. Domestication and cultivation of baobab may result in higher quantities and better quality of baobab fruit pulp and simultaneously contribute to the conservation of wild baobab populations. Within the Baofood project, this study aimed at selecting superior baobab mother trees in Sudan and Kenya based on their morphological characteristics for future domestication of this tree species.

Two baobab populations were surveyed each in Sudan and Kenya and a total of 164 trees randomly selected for the morphological characterisation by using the 'Descriptor for Baobab' [2]. Ten fruits per tree were collected for assessing several quantitative and qualitative traits. Superior mother trees were identified by multivariate statistical methods. We combined our scientific results with outcomes regarding preferred trees from focus group discussions performed with two communities in each of the four research regions. In parallel, trials on vegetative propagation (grafting of 24 seedlings and of three mature trees, 6-times each, once in the dry and once in the rainy season) of baobab were performed in Kenya.

The studied 164 individual baobab trees were highly variable regarding both tree and fruit characteristics. Mean fruit weight per accession ranged from 46-696 g with an overall median of 155 g. Accessions from Kilifi region in Kenya had a significantly higher fruit weight than those of the other three regions ($p<0.001$), however, no accession from Kilifi had fruit pulp with very sweet taste. Pulp weight also showed a high variability (overall median 29 g, range 7-136 g) and was positively correlated with fruit weight ($r=0.935$, $p<0.001$). Mean pulp proportion from the whole fruit ranged from 12-31% with a median of 18% and only slight differences among the four research regions. Pulp proportion did not correlate with fruit weight. The cleft grafting of seedlings resulted in a success rate of 83%, while grafting of mature trees showed 17% success in the dry and 44% in the rainy season. One to two superior mother trees could be identified in each of the four research areas, focussing particularly on the quantitative traits 'fruit weight' and 'pulp proportion' and on the qualitative trait 'sweetness of pulp' for the selection. The selected trees should now be used for vegetative propagation and the grafts further evaluated on their performance.

Results of our study can contribute to better utilisation of baobab products and thus contribute to improved nutrition and livelihoods of rural communities in Sudan, Kenya and beyond.

Keywords: Characterisation, Conservation, Fruit pulp, Grafting, Nutrition.

References:

1. Gebauer et al., 2016, Genetic Resources and Crop Evolution 63, 377-399.
2. Kehlenbeck et al., 2015, Descriptors for Baobab (Adansonia digitata L.), 59 pp.

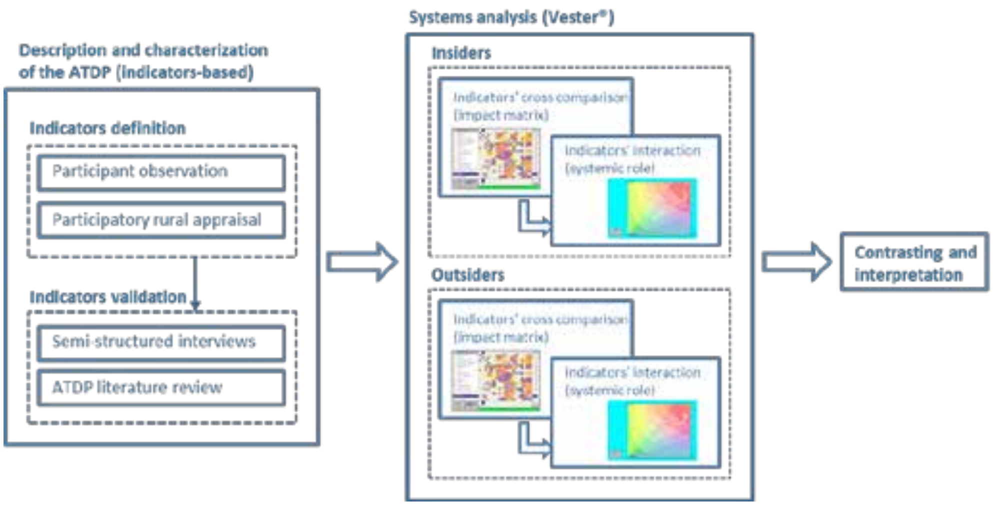
L21_O.07

Challenges of participatory tree domestication programs: lessons from the Peruvian Amazon case

Callo-Concha D.[1] (d.callo-concha@uni-bonn.de), Wiersberg T.[2]

[1] *Ecology and Natural Resources Management, Center for Dev. Research-ZEF, Uni Bonn, Bonn, NRW, Germany*; [2] *Independent, Stuttgart, Germany*

Native tree domestication programs became relevant in the 1990's as strategy to improve peoples' income possibilities while preventing ecosystems degradation. The World Agroforestry Center fostered them broadly, achieving success in West and Central Africa. However, it was to be known if that success was general. In the 2010s, a systems-based approach was applied to evaluate the impact of a participatory tree domestication program Ucayali, Peru. Coupling ethnography and systems analysis, the views of two sets of stakeholders: *outsiders*— scientists, technicians, and development workers, and *insiders*— local farmers organized and not organized, were contrasted and analyzed. Results diverged. *Outsiders* highlighted the program lastingness but relativized it to its dependence on the external counterparts, moreover, they underlined land property and marketing of products as keys to persist and succeed. Contrarily, *insiders* stressed as key features, the program lack of profitability and its dependence on external counterparts; seeking at alternatives, they started economic activities (also beyond forestry), exercising their gained technical and managerial skills. After those findings, diversifying and enlarging stakeholders and strategically define the roles and decision power before and in the implementation of similar initiatives may prevent such divergences.



Operational framework of the systemic participatory evaluation of the agroforestry tree domenstication program in Ucayali, Peru

Keywords: Tree domestication, Impact evaluation, Systems, Participation.

References:

1. Wiersberg T., Callo-Concha D., F. Ewert. 2016. Journal of Sustainable Forestry. 35(7) 486–499.
2. Callo-Concha, D. and F. Ewert. 2014. Change and Adaptation in Socio-Ecological Systems. Vol 1. pp. 1

L21_O.08

Assessing the growth performance of *Pongamia Pinnata* L. genotypes under Multilocational Trial

Divakara B. N. (bndsira@gmail.com)

Genetics and Tree Improvement, IWST - ICFRE, Bengaluru, Karnataka, India

Pongamia pinnata L. is economically important multipurpose tree species, which are grown both as domesticated species in farmlands and also occur naturally in forestlands. The tree forms the subject of recent reviews covering its chemistry and biological activity, phytochemical constituents, traditional uses and pharmacological properties and future prospects as a biodiesel yielding species. With increasing population pressure, demand for tree borne oil seeds has increased considerably. This has necessitated identifying superior elite trees for monoculture plantations, without causing genetic erosion.

Multi-location trials (MLT) in trees are usually very less because of its long gestation period, however MLT play an important role in plant breeding and agronomic research. Breeders use multi-location trials to compare different improved genotypes to identify the superior ones which are of regional specific. However, *P. pinnata* improvement for high oil and seed production is not achieved because of unsystematic way of tree improvement and until now there are no reports of multi-locational trial and possibilities of varietal release. Presently our focus is on systematic approach for genetic improvement of *P. pinnata* by assessing the performance of *Pongamia pinnata* L. genotypes under multi-locational trial.

Grafts of selected twenty-five clones out of 157 clones selected for study were raised during March, 2016 by cleft grafting method. Ramets of twenty-five clones formed the basic material for the evaluation. Samples of twelve grafts in three replications were planted in randomized completely block design (spacing of 6 m x 6 m) at three different agro-climatic conditions of Karnataka. Growth measurements viz. height, collar diameter of all the ramets planted in three locations were collected at an interval six months after planting (MAP) after collecting base/ first reading viz. 6 months after planting (MAP), 12 MAP and 18 MAP. The data recorded at 18 MAP (21 months after grafting) alone was considered for variability and Duncan Multiple Range Test (DMRT).

Variance study revealed that the morphometric traits viz height, collar diameter and volume index were highly significant indicating that, these traits are variable among the selected clones and locations. Among all the three locations of Multilocational Trial (MLT), average performance for height trait is recorded in Bathanahalli with 122.33 cm. Whereas, CS Kaval under Tumakuru research range recorded highest for trait collar diameter, number of branches and volume index with 3.11 cm, 9.10 and 1331.50 cm3 respectively. In general, the performance of clones in CS Kaval (1331.50 cm3) and Bathanahalli (1185.20 cm3) is better than Makali as indicated by scores for volume index. Accession 2 recorded highest for volume index both at CS Kaval (2329.89 cm3) and Bathanahalli (2904.84 cm3) and accession 17 recorded lowest for volume index both at Makali (189.75 cm3) and CS Kaval (613.25 cm3).

Keywords: Pongamia pinnata, Multi-location trial, Duncan Multiple Range Test.

References:

1. Chopade, VV., AN. Tanker and VV. Pande. 2008. Inter. J. Green Pharmacy, 2 (2):72–75.
2. Deswal R.P.S., N Kaushik, NS Panwar, R Laxmi, KS Bangarwa. 2015. Ind J Agrofor, 17 (1): 17-23
3. Divakara, BN and R. Das. 2011. Journal of Forestry Research, 22 (2): 193–200.
4. Divakara, BN., HD. Upadhyaya, A. Laxmi and R. Das. 2015. J. For. Res., 26 (2): 369–379
5. Gomez, AK and AA. Gomez. 1984. Statistical procedure for agricultural research. John Wiley and sons,

L21_O.09

Diverse forest genetic resources for enhanced productivity under agroforestry

Kumar A. (akcgtp@gmail.com)

Division of Genetics & Tree Improvement, Forest Research Institute, Dehradun, Uttarakhand, India

India supports world's large human and livestock population, and thus imports 5530.71 m^3 wood logs and173.10 m^3 sawn timber, which can be reduced substantially by growing genetically improved planting stocks with increased productivity under agroforestry for sustained use of forest genetic resources. Under an 'All India Coordinated Programme on Genetic Improvement of *Melia dubia'*, screening of productive and divergent genotypes was carried out from natural forests as well as manmade plantations. The candidates with index value of >75 were selected, and evaluated for various genetic relatedness. Though species had seriously been eclipsed with low germination to about 5 to 10%, consistent and pointed research efforts ensured enhancement of germination substantially, in terms of seed stones, to 300% or more. The GxE interactions under varying geographical conditions ensured screening of exceptionally productive, stable and adaptive genotypes. The variety releasing committee of Govt. of India approved release of ten most promising cultivars with an average of 34.57 $m3ha^{-1}yr^{-1}$, which varyed from 23.19 (FRI-MD-261) to 55.83 (FRI-MD-235) $m3ha^{-1}yr^{-1}$. The analysis for wood revealed less susceptiblity to drying defects with wood density ranging from 0.33 to 0.50 g per cm^3. The plywood parameters were found to be encouraging for both interior and exterior grade general purposes. The gluechear strength was recorded upto 200 kg/inch2, which was double to threshold level of 100 $kg/inch^2$.

Genetic resources of Melia dubia for agroforestry

Keywords: Melia dubia, genetic resources, productivity, varieties, G x E Interactions.

References:

1. Kumar et al., 2017, The Indian Forester 2017, 143 (11), 1203-1206
2. Terazawa S., 1965, Japan wood industry 20(5), 216-226.
3. Pandey et al., 2018, Forest Pathology, DoI 10.1111/efp.12398
4. Khali et al., 2017, Indian Academy of Wood Science, DoI 10.1007/s13196-017-0199-5.
5. Sharma et al., 2018, Indian Journal of Biotechnology, 17 (1), 185-188

L21_O.10

Multipurpose trees domestication in Uruguay: synthesis of knowledge advances

Bennadji Z.[1] (zbennadji@inia.org.uy), Alfonso M.[2], Nuñez P.[3]

[1] *Forestry Department, INIA Forestry Department, Tacuarembó, Tacuarembó, Uruguay*; [2] *Forestry Department, INIA, Tacuarembo, Uruguay*; [3] *Forestry Department, INIA Uruguay, Tacuarembo, Uruguay*

Uruguay, a traditional livestock country, experienced since the nineteens an authentic forestry boom, based on commercial plantations of fast growing exotic species. Almost two decades later, a policy for the establishment of agroforestry systems in the country was launched by the government and fairly adopted by small and medium-sized producers. As an innovation back-up for the smooth application of this process, INIA Forestry Department developed a research program on multipurpose forest trees domestication. This work presents some of its mayor developments. The first step was the identification of promising native and exotic species through wide stakeholders consultations, followed by seed sources procurement and a germplasm bank establishment. The requirements for a successful nursery planting production of the main identified species (Figure 1) and the establishment of a national provenances and progenies tests network constituted the additional knowledge accumulated for a smooth transition to the diversification of forest species and the agroforestry systems shaping in the country. These actions and results configured the first systematic effort on native multipurpose species domestication registered in the country, highlighting the importance of forest genetic resources, the impact of its adequate transfer in the country and the need for more transdisciplinary studies and interinstitutional networks.

Fig.1. Prosopis affinis nursery plants production - INIA Tacuarembó Research Station (Uruguay)

Keywords: : multipurpose trees, domestication, agroforestry systems, Uruguay.

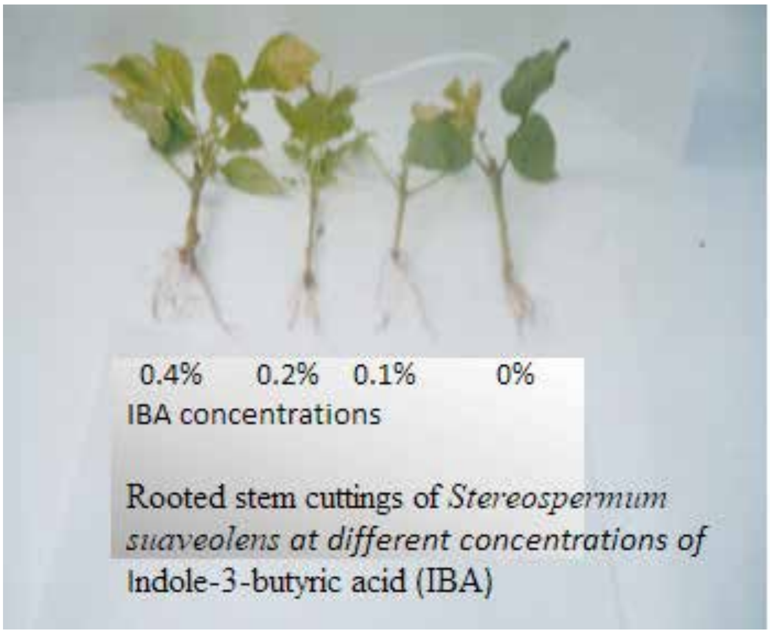
L21.P.01

Domestication potential of wild tropical promising tree species of medicinal and fruit values

Baul T. K. (tarit@ifescu.ac.bd), Alam M. J., Mohiuddin M.

Forestry and Environmental Sciences, University of Chittagong, Chittagong, Bangladesh

Stereospermum suaveolens DC, *Litsea monopetala* (Roxb) Pers. *Holarrhena pubescens* and *Mangifera sylvatica* Roxb. grown in wild in tropical forests of Bangladesh are valued for their fruit, timber and medicine. However, they are gradually eroding from forests due to deforestation, illegal harvesting, and inadequate knowledge about their uses. This study aims to assist in preserving these species and investigated their uses and domestication potentiality through seed and leafy cuttings from mother tree species with the effects of different IBA (indole-3-butyric acid, 0, 0.1, 0.2 and 0.4% IBA) concentrations, and initial growth of the rooted cuttings with the effects of different fertilizer treatment. Based on evidence from rooting percentage, survival percentage, and subsequent growth parameters (stem length, collar diameter, root biomass and leaf area of the seedlings/stecklings), first three species can be propagated by leafy-stem cutting without IBA or with low concentration of IBA and can be domesticated through homestead agroforestry, since indiscriminate harvests as fodder and fuelwood results in scarcity of seed. *M. sylvatica* is suitable to propagate by seed collected from existing stocks in forests and can be preserved in-situ and domesticated in agroforestry from a reliable and adequate supply of superior planting stock easily, locally and timely. Domestication of these species of multiple values would enable local economy while protecting them from extinction.



Rooted stem cuttings of *Stereospermum suaveolens at different concentrations of* Indole-3-butyric acid (IBA)

Keywords: cutting, domestication, growth, IBA, seed.

References:

1. Baul TK, Mezbahuddin M, Mohiuddin M. 2009. New Forests, 37: 275–283.
2. Baul T K, Hossain M M, Mezbahuddin M, Mohiuddin M. 2011. Journal of Forestry Research, 409–416
3. Baul T K, Alam MJ, Nath TK, 2016. Small-scale Forestry,15:149–158
4. Baul T K, Mezbahuddin M, Hossain M M, Mohiuddin M. 2010. Forestry Studies in China, 228–235

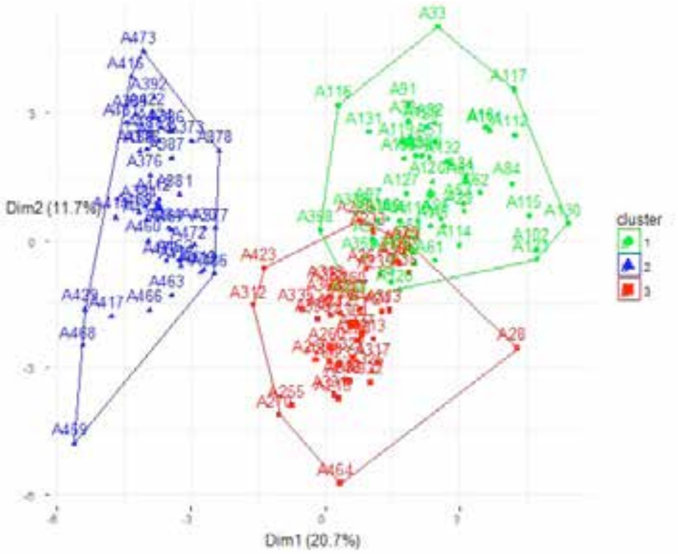
L21.P.03

Strategy for improving cashew plantations (Anacardium occidentale L.) in southern Senegal

Cheikh Oumar S.[1] (omarsamb2004@yahoo.fr), Elhadji F.[2], Diaminatou S.[1], Adja Madjiguene D.[1], Halimatou Sadyane B.[1], Souleye B.[1], Mamoudou Abdoul T.[3], Samba Arona Ndiaye S.[4]

[1] *CNRF, ISRA, Dakar, Dakar, Senegal*; [2] *ISFAR, Université Thiès, Bambey, Bambey, Senegal*; [3] *CRZ, ISRA, Dahra, Dahra, Senegal*; [4] *ENSA, Université Thiès, Thies, Thies, Senegal*

The 2415.78 km2 of cashew plantations represent an opportunity for nut production in Senegal. However, plantations are not very productive. Thus, the National Center for forest research selected 522 Potentially Candidate Trees (PCA) in a participatory manner based on the characteristics of interests (production, health, straightness, vigor) with local populations of Kolda, Sedhiou and Ziguinchor. The purpose of this selection is to provide producers with adapted and efficient plant material. To gain a better understanding of the potential of the species, the study proposes to evaluate variability of agro-morphological parameters and nuts quality.This evaluation focused on dendrometric, foliar, nut production and quality traits. Significant variability was observed according to areas and descriptors. Discriminant descriptors were crown length, tree habit, leaf size, flowering season, thickness, length and width of nuts, number of nuts kg-1, production, graining, weight nuts, almonds and KOR. Dendrogram classifies PCAs in 03 groups. Class III contains the most productive individuals. This class has 69 individuals, 15 of which are selected as Elite Trees (ET). Class II individuals have large nuts, perfect graining, excellent KOR and can be used as a breeding population for the species.



Ascending hierarchical classification of PCAs identified in three different zones of Senegal based on the study of agro-morphological and technological characteristics

Keywords: Senegal, Casamance, improvement strategy, Anacardium occidentale L, agroforestry system.

References:

1. Behrens R.1996. Cashew as an agroforestry crop: prospects and potentials. Tropical Agriculture. 9: 8
2. Camara M. Vayssie J., 1996. La filière anacardier en Guinée- Bissau. Ministère du Développement Rur
3. Chadha Y.R., 1985. The wealth of India- raw materials volume I : A ‘(revised). CSIR, New Delhi, Indi
4. Chipojola F.M. Mwase W.F. Kwapata M.B. Bokosi J.M. Njoloma J.P. & Maliro M.F. (2009année Morpholog
5. Correia A.B.R., 1963. A industrialização de castanha de caju. Ediçao da Direcção dos serviços de

L21.P.04

Conservation genetics of Bitter kola (*Garcinia Kola*): A threatened species in Agroforestry Systems of Benin

Dadjo C.[1] (dadjocolombe@gmail.com), Nyende A. B.[2], Yao K. N.[3], Assogbadjo A. E.[4]

[1] *Molecular Biology and Biotechnology, Pan African University, Nairobi, Kenya*; [2] *Institute of biotechnology research, Jkuat, Nairobi, Kenya*; [3] *Beca-ILRI, Nairobi, Kenya*; [4] *Laboratory of Applied Ecology, University of Abomey-Calavi, Cotonou, Benin*

Garcinia kola is a multipurpose tree, highly valued for its edible nuts and its different parts are used for the treatment of diverse ailments. Because of its overexploitation, natural populations of the species have drastically declined. *In Benin, G. kola* is now classified as extinct in the wild, and is only found in small populations in human-made ecosystems (farmlands, home-gardens, orchards, etc.). *Knowledge of the level of genetic diversity in G. kola is important for designing conservation strategies for their sustainable survival and to preserve their evolutionary potential. Thus, for the first time, genetic variability in G. kola population was accessed using genotyping by sequencing method.* A total of 71 individuals from 3 populations corresponding to two regions (Atlantique and Oueme) were collected. They were analysed using Diversity Array Single Nucleotide Polymorphism (DArT-SNP) markers. A total of 14,199 biallelic SNP markers were obtained and a cluster analysis revealed two main groups associated with the region of collection of the individuals. A Principal Component Analysis confirmed the grouping of the *bitter kola individuals from the cluster analysis. Analysis of population differentiation with allele-frequency based F-statistics revealed an low fixation index FST of 0.122 and a relatively high inbreeding (FIS = 0.45) coefficient, characteristics of small populations. The average observed heterozygosity was less than the expected heterozygosity for the populations from Oueme while the average observed heterozygosity was higher than the expected heterozygosity for the population of Atlantique. However, heterozygosity values were low in all populations (0.12 to 0.17). The lower heterozygosity pointed towards diminished genetic diversity in the population. In view of the declining diversity in G. kola in Benin, there is a need to manage the existing population so as to increase its size as well as its genetic diversity.*

Keywords: Heterozygosity, Genetic divesity, Single Nucleotide polymorphism, Genotyping by sequencing, Threatened species.

L21.P.06

Assessing the performance of *Pongamia pinnata* (L.) Pierre under *ex-situ* condition in Karnataka

Divakara B. N. (bndsira@gmail.com)

Genetics and Tree Improvement, Institute of Wood Science and Technology, Bengaluru, Karnataka, India

Biodiesel market is expected to produce 11.96 billion gallons of biodiesel in 2020, representing a compound annual growth rate (CAGR) of 10.1 percent during 2009 to 2020. Pongamia (*Pongamia pinnata* L.) as a source of non-edible oil, is potential tree species for biodiesel production. Shortage of edible oil for human consumption in developing countries like India does not favour its use for bio-diesel production. Tree borne oil seeds are not only potential renewable energy source to supplement the increasing energy requirement. For several reasons, both technical and economical, the potential of *P. pinnata* is far from being realized. *P. pinnata* has been documented to include variable forms with a wide range of pod as well as seed size and shape variations. Seeds contain 30 to 40 % oil. Characterization and selection of CPT's is essential for the improvement of this species in addition to experiments on controlled crossing among selected genotypes. Analysis of phenotypic diversity in germplasm collections can facilitate reliable classification of accessions and its identification with future utility for specific breeding purposes. The exploitation of genetic diversity for crop improvement has been the major driving force for the exploration and *ex situ/ in situ* conservation of plant genetic resources. However, *P. pinnata* improvement for high oil and seed production is not achieved because of unsystematic way of tree improvement.
Performance of *P. pinnata* planted by Karnataka Forest Department was assessed based on yield potential by collecting 157 clones out of 264 clones established by Karnataka Forest Department research wing under different research circles/ranges. Selection of superior germplasm based on oil and pod/seed parameters was achieved by application of Mahalanobis statistics and Tocher's technique. On the basis of D2 values for all possible 253 pairs of populations the 157 genotypes were grouped into 28 clusters. The clustering pattern showed that geographical diversity is not necessarily related to genetic diversity. Cluster means indicated a wide range of variation for all the pod and seed traits. The best cluster having total oil content of more than 34.9 % with 100 seed weight of above 125 g viz. Cluster I, II, III, IX, XV, XIX, XXI, XXIII, XXVI and XXVII were selected for clonal propagation.

Keywords: Pongamia pinnata, Mahalanobis, Genetic diversity, Ex-situ, Germplasm.

References:

1. Divakara 2014 Indian Forerster 140 (11): 1085-1091.
2. Divakara 2017 Forest Research 6:2 DOI: 10.4172/2168-9776.1000201.
3. Gohil 2008 International Journal of Plant Production 2 (4): 321-326.
4. Gomez 1984 Statistical procedure for agricultural research. John Wiley and sons, Inc.
5. Kaushik et al. 2007 Biomass and Bioenergy 31: 497–502.

L21.P.07

Fodder Trees in Agroforestry: Present Status and Challenges

Handa A.[1] (Arun.Handa@icar.gov.in), Dhyani S.[2], Bhaskar S[2], Rizvi R.[1], Kumar A.[1]

[1] *Central Agroforestry Research Institute, Jhansi, UP, India*; [2] *NRM, Indian Council of Agricultural Research, New Delhi, Delhi, India*

Agroforestry having high potential for simultaneously meeting three important objectives: protecting & stabilizing ecosystems; high economic productivity; ensuring better livelihood security. It is an option to increase tree cover in meeting the targets of SDGs and Nationally Determined Contribution for climate change action of India. India's livestock sector is one of the largest of the world with significant role in supplementing family income in rural areas. However, fodder availability is a big challenge and at the end of rainy season, animals suffer due to lack of protein rich diet. Under rainfed conditions farmers either feed their animals with the low-quality hay or travel long distances to gather fodder. In such circumstance agroforestry play an important role as fodder trees are able to withstand the drought and provide a solution. The AICRP on Agroforestry initiated research on fodder trees and identified important species in different agro-climatic regions of the country and evaluated. However, limited efforts have been made for fodder tree improvement through management and breeding. Most indigenous fodder trees not even gone through simple selection for plus trees, though, importance of quality seeds or vegetative propagation has been realized for improving the productivity. Management, agronomic features and nutritive value of these trees are being worked out so that the production and use of feed can be more efficient. The studies indicate that improvement programme for fodder trees is very tedious compared to crops. In India, so far for fodder trees, germplasm collection and breeding has been done on few species and results indicate the quality of green fodder mainly depends on the voluntary intake by the livestock and availability of protein, energy, minerals & vitamins to the animal. The low dry matter intake appears to be a limiting factor in energy supply from tree leaves and low digestibility of leaves is possibly due to high lignin and tannin content. Tannins also bind proteins and thereby lower their digestibility and also adversely affect calcium use. About 60% of fodder trees evaluated contain > 50% total digestible nutrients on a dry matter basis; 40% of trees contained < 50%. The available energy in tree leaves is low but fodder trees contain more than 55% TDN are better energy source. The season wise nutritive value of fodder trees and ranking for their nutritive value & palatability and complete value chain for tree fodder meal has been developed which is relatively cheaper compared to other feeds. The integration of fodder trees through site specific agroforestry systems have shown potential to supply nutritious fodder and conserve natural resources. Silvipasture system on an average cycle of 10 yr can generate 120 mandays/ha/yr employment with B:Cratio of 1.5 to 2.1 indicating viability of these systems. Thus fodder tree based agroforestry systems may play an important role in reducing the fodder shortage problem.

Keywords: Fodder Trees, Agroforestry, Silvipasture, Genetic improvement.

References:

1. Dhyani, S.K. and Handa, A.K., 2013. Indian Journal of Agroforestry. 15 (2) : 1 – 9.
2. Handa, A.K., Dhyani, S.K.. and Uma 2015. Agricultural Research Journal PAU 52 (3) : 1-10.

L21.P.08

Genetic Analysis of Some Baobab (*Adansonia digitata*) Populations Across Africa Using DArT-SNP Markers

Hendre P.[1] (P.Hendre@cgiar.org), Munyano P.[2], Kariba R.[2], Muthemba S.[2], Ndalo J.[2], Kinyanjui Z.[2], Kangethe S.[2], Nyoka I.[3], Dembele C.[4], Mpanda M.[5], Jamnadass R.[2], Muchugi A.[2]

[1] *Theme TREES, World Agroforestry Centre (ICRAF), Nairobi, Nairobi, Kenya*; [2] *Theme TREES, World Agroforestry Centre (ICRAF), Nairobi, Kenya*; [3] *Southern African Nodal office, World Agroforestry Centre (ICRAF), Lilongwe, Malawi*; [4] *Regional office, World Agroforestry Centre (ICRAF), Bamako, Mali*; [5] *Tanzania Country Office, World Agroforestry Centre (ICRAF), Dar es Salaam, Tanzania*

Baobab (*Adansonia digitata*) is an iconic African fruit tree of high nutritional importance due to high nutrient and anti-oxidant contents but remains neglected and undomesticated. For its domestication and improvement, ICRAF is establishing a field genebank representing Africa. The first batch of seedlings was established using seeds from ~165 individual trees from four countries (Zambia, Mali, Kenya and Tanzania) representing 17 provenances. DNA was extracted and used to generate 138 high quality DArT-SNP markers (from 4,617 SNPs) from 320 half-sib accessions. Using MicroSatelliteAnalyzer (MSA4.05), Nei's chord genetic distance was estimated and Neighbour Joining (NJ) tree was drawn using PHYLIP3.695 (Figure 1). The genetic distance data was bootstrapped for 100 times in MSA followed by drawing NJ trees and a consensus tree generated using PHYLIP. The phenetic trees were visualised and edited by FigTree v1.4.3. The data indicated very strong population structure with very good bootstrap support for three distinct genepools- Zambian (Zambia, four provenances), Malian (Mali, five provenances) and East African (Kenya- two provenances; Tanzania- six provenances). Zambian populations had the highest genetic diversity followed by Malian and the least diverse were the East African populations. This data is being used to establish core collection of 100 accessions with highest genetic diversity and 17 forced selections to ensure representation from all the populations (Figure 1).

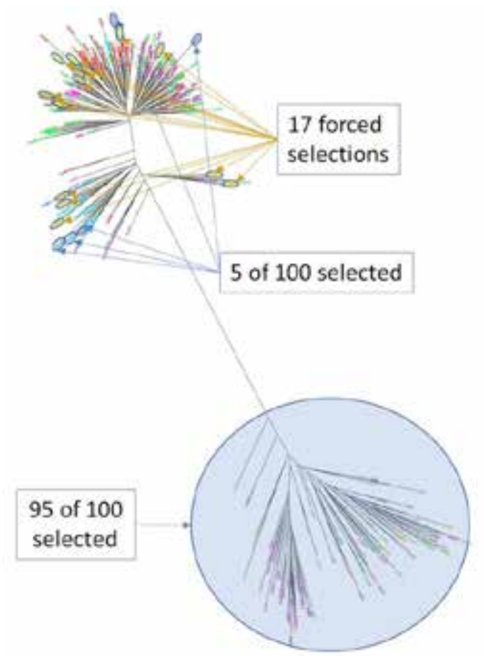


Figure 1: The Neighbour Joining (NJ) tree generated using Nei's chord genetic distance over 320 baobab genebank accessions. The 117 selections that form core genebank collection are marked and labelled.

Keywords: Baobab, Genetic diversity, DArT-seq SNP markers, Phylogeny, Prioritization.

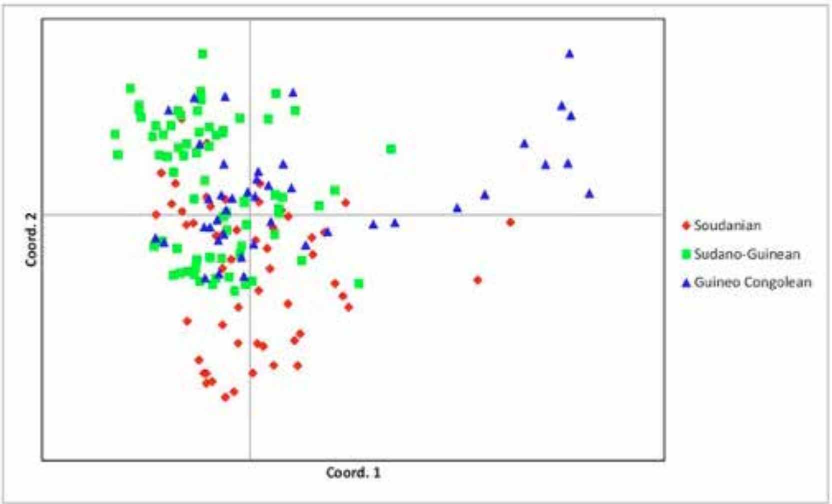
L21.P.09

Genetic diversity and population structure of the agroforestry fodder tree species *Afzelia africana* Sm. in Benin.

Houehanou T.[1] (houehanout@gmail.com), Prinz K.[2], Hellwig F.[2], Assogbadjo A.[3]

[1] *LEB, Faculty of Agronomy, Parakou, Benin*; [2] *Friedrich-Schiller-University Jena, Jena, Germany*; [3] *LEA, Faculty of Agronomic Sciences, Abomey Calavi, Benin*

Afzelia africana is a valuable fodder tree species for livestock in its occurrence range and is also preserved as agroforestry tree in Sudanian zone of Africa. Up to now, no information regarding the three genetics is available to motive the conservation of this tree species in Africa in general and particularly in Benin. This study was then carried out to assess the genetic diversity and the differentiation among populations of *Afzelia afrcana* from different zones in Benin. 170 adults' individuals from twenty-one (21) populations split into three different geographical subpopulations (Sudanian, Sudano-Guninean, and Guineo-Congolean) were analyzed at 12 microsatellite loci. All loci were polymorphic with the number of alleles per locus ranging from 4 to 20. High levels of genetic diversity were found over the three subpopulations. Mean values of observed/expected heterozygosities were 0.818/0.752, 0.877/0.753 and 0.848/0.765 respectively in Guineo-Congolean, Sudano-Guninean, and Sudanian subpopulations. We observed a weak but statistically significant genetic differentiation among geographical subpopulations regarding the values of Fst (Value = 0.028; P= 0.001) and Rst (Value = 0.055; P= 0.001). Significant isolation by distance was obtained with the Mantel test. Those findings give some useful insights to promote in situ conservation of the natural populations of *Afzelia africana* in Benin by managing its populations in protected areas and in agroforestry.



Principal coordinate analysis based on 170 individuals of A. africana sampled from the three climatic zones (Sudanian, Sudano Guinean, Guineo Congolean) in Benin and revealed by 12 SSR repeats loci

Keywords: Conservation genetics, Microsatellite, Afzelia africana, Benin.

References:

1. Mensah et al. 2016. Tropical Ecology 57(4): 717-726
2. Mensah et al. 2014. South African Journal of Botany 95: 165–173.
3. Houehanou et al. 2013. Ecological Complexity, 13: 60-68.
4. Houehanou et al. 2011. Forest Policy and Economics 13: 554-562.

L21.P.10

Genetic diversity of *Cedrela odorata* in the Nicaragua-Honduras Sentinel Landscape and its implications for conservation

Kalousová M.[1] (kalousovam@ftz.czu.cz), Palacios C.[2], van Zonneveld M.[3], Finegan B.[2], Lojka B.[1]

[1] *Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague, Prague, Czech Republic*; [2] *CATIE, Turrialba, Costa Rica*; [3] *Genetic Resources and Seed Unit, World Vegetable Center, Shanhua, Taiwan*

Cedrela odorata is a tree species with a high commercial value that has been negatively affected by overexploiting to such an extent, that it is now rarely present in natural forests and is mainly associated with agroforestry and other agricultural systems. The populations of *C. odorata* are becoming increasingly isolated in a matrix of different land use systems which impedes their connectivity and influences their genetic variability. In the present investigation, the genetic diversity of populations of *C. odorata* in the Nicaragua-Honduras Sentinel Landscape was studied with the objective to identify potential resources of germplasm for forest restoration and conservation *circa situm*. Samples of 164 individuals were fingerprinted with 10 SSR loci. The results showed significant differences in population structure among three genetic clusters (Fig. 1a), where clusters A and B showed high diversity and allelic richness, whereas cluster C presented low genetic diversity. Furthermore, the patterns of genetic diversity showed close relations to the phenological status and altitude a.s.l. of the sampled trees. From the conservation point of view, cluster A (high in genetic diversity and clearly geographically defined, Fig. 1b) can be considered an important source of germplasm. However, there is still a lack of deeper understanding of the cause of genetic differences among subpopulations from a small area with relatively homogeneous environmental and topographic characteristics.

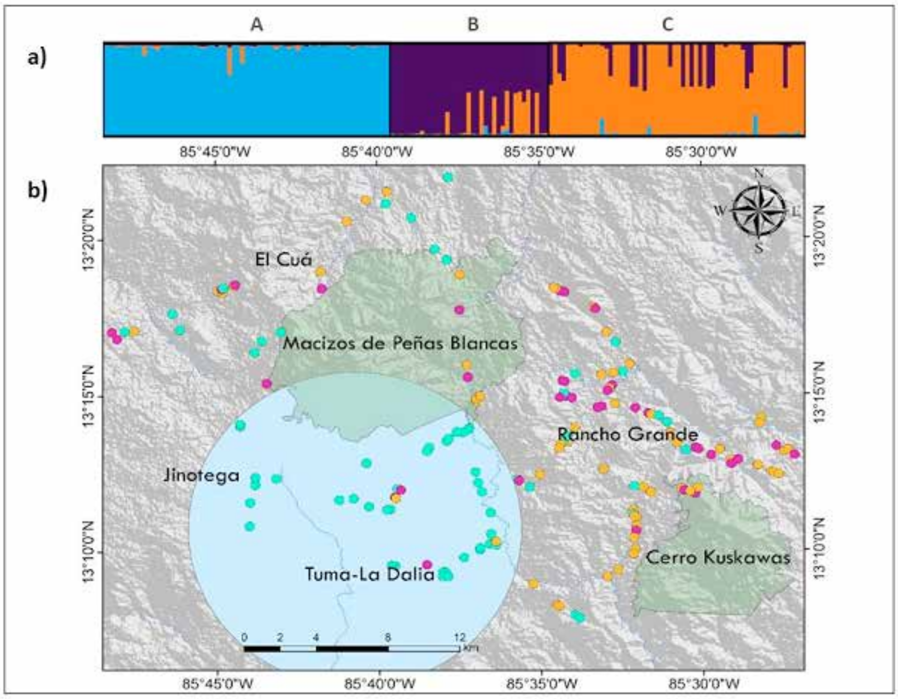


Figure 1. Division of sampled individuals of C. odorata into three genetic clusters. a) Clusters inferred by STRUCTURE software. Different colours represent different clusters, each column represents an individual. b) Geographic distribution of individuals belonging to inferred clusters. Blue: cluster A, purple: cluster B, orange: cluster C.

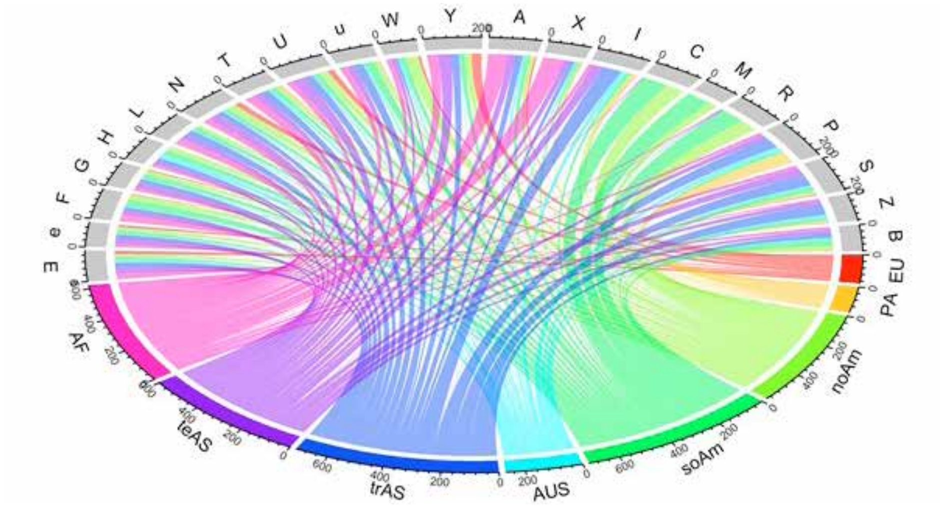
L21.P.11

A top 100 trees for planting in tropical countries: representational and invasiveness challenges

Kindt R. (R.Kindt@CGIAR.org)

Tree Productivity and Diversity, World Agroforestry Centre, Nairobi, Kenya

The total number of tree species globally is high at >60,000. Priority setting is therefore required when planning species-based research (*e.g.,* breeding) and practical upscaling (*e.g.,* planting), especially in tropical countries where most species are located and research resources are limited.
To create a current 'top 100' list of tree species planted in tropical nations primarily for agroforestry and mosaic forest landscape restoration, we interpreted the number of entries of woody perennial species across a range of databases as an indicator of species' usefulness. Examples of databases included in the study are The Tropical Forestry Handbook with the 215 most frequently used tree species for tropical forestry plantations, and the 86 country reports compiled for the 2014 State of the World's Forest Genetic Resources report.
To our knowledge, there has been no broad international prioritization of currently-considered useful tree species based on an ensemble of the global and regional databases that have recently become available online. We therefore collated species lists from a geographically and functionally diverse range of these databases, with a focus on tropical nations, and explored properties of the commonly revealed species. Our analysis indicated species that may be priorities for research, as well as geographic imbalances in representativeness in listed species origins and locations of importance, along with biosecurity concerns.



Circular diagram showing the percentage of species native to specific continents (AF: Africa, teAS: temperate Asia, trAS: tropical Asia, AUS: Australasia, soAM: southern America, noAM: northern America, PA: Pacific, EU: Europe) in the top-100 (B), global (E [Ecocrop], e [World Economic Plants in the Germplasm Resources Information Network], F [Selection of Forages for the Tropics], G [Global Species Matrix], H [Tropical Forestry Handbook], L [Seed Leaflets], N [NewCROP], T [AgroforesTree Database], U [Food Composition Databases], u [Useful
Tropical Plants Database], W [The Wood Database], Y [FAO Crop statistics]) and regional databases.

Keywords: top 100, forest landscape restoration, useful tree species, databases, invasiveness.

References:

1. Kindt et al. 2017. URL http://www.worldagroforestry.org/products/switchboard/
2. Beech et al. 2017. J. Sustain. For. 36: 454-489. http://dx.doi.org/10.1080/10549811.2017.1310049
3. Laestadius, L. et al. 2011. Unasylva 62: 47–48.
4. Pancel in: Tropical Forestry Handbook. 2015. Köhl & Pancel. 1221–1440. https://link.springer.com/ref
5. Commission on Genetic Resources for Food and Agriculture. 2014. http://www.fao.org/forestry/fgr/6458

L21.P.12

Save *Dodonea viscosa*, an initiative for preservation/conservation of a threated medicinal plant for comminatory usage

Koudouvo K.[1] (kkoudouvo@gmail.com), Tozo K. S.[2], Aguiyi J. C.[3], Gbeassor M.[4]

[1] *University of Lome, Lome, Togo*; [2] *Botany and Plant Ecology, University of Lome, Lomé, Togo*; [3] *ACEPRD, University of Jos, Jos, Nigeria*; [4] *CERFOPLAM, University of Lome, Lomé, Togo*

Background: Dodonea viscosa (DV) used to treat malaria, in Togo (West Africa) is threatened (Koudouvo *et al.*, 2011, 2017). Germination's biotechnical method for its cultivation was established (Tozo *et al.*, 2004)
Aims: The aim of this study is to produce seeds of DV for wide scale cultivation for preservation/conservation and availability of this plant for comminatory usage in the treatment of malaria in Togo and in West Africa.
Materials: Young plants of DV identified by Akoegninou *et al.* (2006) were obtained from the traditional garden of the Togolese NGO "Sauve Flore". Floristic garden of Faculty of Sciences/ University of Lomé/Togo (FG/FDS/UL/T) and the Royal Court of Ewe People of Bè/Lomé/Togo (RC/EP/BL/T) were sites of plantation of DV.
Methods: Eight young plants obtained, were cultivated 4 in each site in July and August 2017. During the period of fruits production (Fig. 1 and 2), seeds were harvested every week.
Results: From the eight plants, three have survived in each site of cultivation. Fruits obtained from the plants (Fig 3) have produced till to September 2018, 1325 and 3849 seeds respectively at RC/EP/BL/T and FG/FDS/UL/T (Fig 4). The 6 plants are still producing fruits and seeds
Conclusion: The cultivation of DV in home court and in garden could contributed to the availability of this threatened plant. The production of seeds of DV in garden is better than in court. ProSADOVIS is planning to cultivate DV in 2000 home courts of Lome and on 2 ha in the farm of UL.

Fig 1: The plant of DV in FG/FDS/UL/T

Fig 2: The plant of DV in RC/EP/BL/T

Fig 3: Fruits of DV produced by the plants

Fig 4: Seeds produced by DV in the two areas

Plant Fruit and Seeds of Dodonea viscosa

Keywords: Dodonea viscosa, Threatment, Save biodiversity, Togo.

References:

1. Koudouvo et al., 2011; J. of Ethnopharm., 183–190; doi:10.1016/j.jep.2010.12.011
2. Koudouvo et al., 2017; J. of Agri. and Eco. Res. Int., 1-9; doi : 10.9734/JAERI/2017/29303
3. Tozo et al., 2004; Acta Botanica Gallica, 197-204; doi: 10.1080/12538078.2004.10516034
4. Akoègninou et al., 2006. Cotonou & Wageningen, Backhuys Publishers, 1034 p

L21.P.13

Indonesian nutmeg (*Myristica fragrans*) genetic diversity: conservation and sustainable management applications

Kusuma J.[1] (kusuma@polinela.ac.id), Scarcelli N.[2], Duminil J.[2]

[1] *Plant Production Science, Politeknik Negeri Lampung, Bandar Lampung, Lampung, Indonesia*;
[2] *UMR-DIADE, Institut de Recherche pour le Développem, Montpellier, Montpellier, France*

In the Tropics, forest trees contribute to food security and cash incomes for rural people. Despite their importance, these food tree species (FTS) are barely known. In particular, their genetic diversity is often poorly documented, which impedes the development of efficient conservation and sustainable management strategies.
Nutmeg trees (*Myristica fragrans*, *M. fatua* and *M. argentea;* Myristicaceae) are native from Indonesia, where their seeds and maces are exploited as spices. The main purpose of this research is to characterize the distribution, genetic diversity and structure of nutmeg species in Indonesia.
To this aim, we have conducted filed trips in the Banda island, where nutmeg is supposed to have originated, as well as in other Indonesian populations, where the species have been introduced. During these field trips we have sampled a maximum of wild and cultivated populations and engaged discussions with local farmers on the recognition of wild and cultivated populations. This poster presents our first data on the distribution of the nutmeg genetic diversity, using newly developed genomic resources. This work is expected to contribute to the conservation and the sustainable management and use of nutmeg species.

Keywords: nutmeg, genetic diversity, population structure, conservation management.

L21.P.14

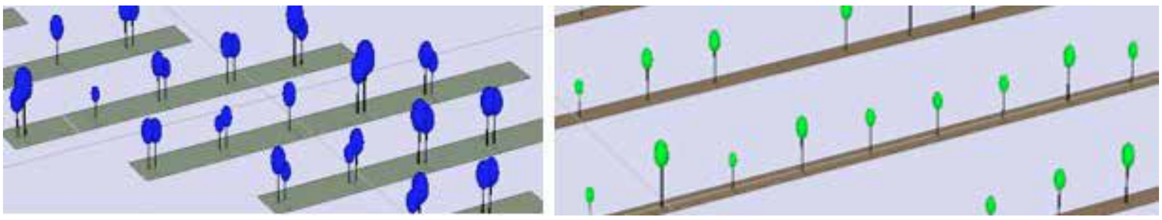
EcoAF on CAPSIS, simulates the economic effects of your choices when building and managing an agroforestry field !

Liagre F.[1] (liagre@agroof.net), Santi F.[2], Sotteau C.[3], de Coligny F.[4]

[1] *AGROOF SCOP, Anduze, France*; [2] *UMR BioForA, INRA, Ardon, France*; [3] *A2RC, Orléans, France*; [4] *UMR AMAP, IINRA CIRAD CNRS IRD Univ Montpellier, Montpellier, France*

With EcoAF, download a group of concrete farm parcels, place if needed the polygons of main soil types, then play with possible futures! You can choose whatever combinations of lines, straight or broken or in spots, around or inside the field, decide where to plant trees, shrubs and grasses, in hedges or placed points, the species/varieties and the quality of the bundles of plants. The growth will depend on further choices on how you intend to manage the bundle of plants, the plantation, then all the components during their life. A further development will include simplified crop/animal productions, and the possible impact of the growth of trees and shrubs on them. Each simulation will include variability and aleas. 2D and 3D graphic interfaces and visualizations, at once and delayed datasheets let compare the consequences of different choices.

The EcoAF module is developed in French and English on CAPSIS (Computer-Aided Projection of Strategies In Silviculture ; http://www.inra.fr/capsis), with the aims to be user-friendly and transparent about the degree of reliability of parameters. Its conception and evolution take into account the need of advisors in agroforestry. We illustrate some consequences of genetic and silvicultural choices: plant an ordinary or improved variety, densify or not the plantation, take great care or not of the young plants while planting etc.



3D visualizations

Keywords: simulation, genetic, agroforestry, farm, economy.

L21.P.15

Diversity towards domestication: example of bitter kola (*Garcinia kola*) from Cameroon

Maňourová A.[1] (manourova@ftz.czu.cz), Leuner O.[1], Van Damme P.[2], Tchoundjeu Z.[3], Lojka B.[1]

[1] *Crop Sciences and Agroforestry, Czech University of Life Sciences, Prague, Czech Republic*; [2] *Ghent University, Ghent, Belgium*; [3] *HIES, Yaoundé, Cameroon*

Garcinia kola Heckel (Clusiaceae), bitter kola, is a key fruit tree species in West/Central Africa. As a consequence, it was selected by ICRAF as a priority species for domestication. Seeds, the most valued product, are consumed raw to prevent/cure gastric problems and for their stimulating effect. Secondary metabolites present in the seeds have potential to treat cancer, malaria and hepatitis. Apart from studies on biological activities of the kernels, the species remains scientifically neglected. Information is missing on seed nutritional content, tree silvicultural management and genetic structure. Our research focuses on morphological, chemical and genetic diversity of *G. kola*. We sampled 160 trees and interviewed 80 farmers in Southwest, Central and South regions of Cameroon. Each tree was measured, while 10 fruits + 5 leaves were taken for morphological evaluation. Seeds were morphologically and chemically characterized, whereas leaves served for genetic analysis. Simple morphological descriptor was developed for the species. Seed nutritional content [%] was determined as follows: ash 0.33, moisture: 42.3, crude fat: 1.5, crude fibre: 2.3, crude protein: 6.5 and NFE: 47.2. Preliminary results show that morphological and genetic diversity is high especially within populations. We believe that our research can lead to superior trees selection, hence accelerating the domestication process.

Morphological features of Garcinia kola, known as bitter kola tree.

Keywords: agroforestry, tree domestication, indigenous fruit tree species, diversity, West Africa.

L21.P.16

Domestication syndrome in *Dacryodes edulis* (G.Don) H.J.Lam, an emblematic fruit tree species from tropical Africa

Mboujda F.[1] (francameguem@yahoo.fr), Avana M. L.[1], Onana J. M.[2], Rimlinger A.[3], Couderc M.[4], Leila Z.[4], Duminil J.[4]

[1] *FORESTRY, University of Dschang, Dschang, Cameroon*; [2] *Plant Biology, University of Yaounde I, Yaounde, Cameroon*; [3] *UMR DIADE/DYNADIV, University of Montpellier, Montpellier, France*; [4] *UMR DIADE/DYNADIV, IRD, Montpellier, France*

Since millennia, people have harvested fruits from the wild for their alimentation. Gradually, they have selected individuals presenting traits of interest from wild populations, as the starting point toward their domestication process, leading to the cultivation of improved varieties on farm. The passage from a wild to a cultivated status is generally accompanied by a modification of a number of morphological (eg increase of fruit size for fruit tree species) and genetic traits (genetic bottleneck), commonly known as the domestication syndrome. In this study, we assessed these domestication-related traits modifications in an emblematic fruit tree species from the lower Guinea and Congo Basin: *Dacryodes edulis* (G.Don) H.J.Lam (Burseraceae) known as 'African plum'. Thought the species is widespread in various natural and cultivated systems in Central Africa, its domestication history is still unknown. DNA samples were collected from 124 and 76 wild and cultivated *D. edulis* individuals in South and East Cameroon, and genotyped using 14 microsatellite markers. These data allow (i) comparing the level of genetic diversity between wild and cultivated populations; (ii) examining the level of gene flow between populations. Such knowledge are important to ensure the conservation of wild genetic resources of the species and its future adaptation to global change. The domestication syndrome is discussed based on further ecological and morphological data along a cultivation gradient.

Phenotypic variation of cultivated (left side of the figure) and wild (right side) fruits of Dacryodes edulis in south Cameroon

Keywords: domestication syndrome, Dacryodes edulis, wild populations, cultivated populations, Tropical Africa.

References:

1. Benoit L., Born C., Vignes H., Chevallier M.H., Todou G., Debain C., Joly H.I. (2011). Polymorphic m
2. Bitocchi E., Rau D., Benazzo A., Bellucci E., Goretti D., Biagetti E., Papa R. (2016). High level of
3. Leakey R.B.R., Tchoundjeu Z., Smith I.R., Munro C.R., Fondoun J.M., Kengue J., Anegbeh P.O., Atangan
4. Todou G. (2015). Distribution, adaptation environnementale et diversité génétique de Dacryodes eduli
5. Onana J. M. (2008). A synoptic revision of Dacryodes (Burseraceae) in Africa, with a new species fro

L21.P.17

Morpho-physiological characterization of jackfruit accessions in Bangladesh

Miah M. G.[1] (giash1960@gmail.com), Rahman M.. M.[1], Saha S. R.[1], Rizvi J.[2], Muchugi A.[3]

[1] *Agroforestry and Environment, Bangabandhu S.M.R. Agril. University, Gazipur, Bangladesh*; [2] *South Asia Office, World Agroforestry Centre, New Delhi, India*; [3] *Tree Genetic Resources, World Agroforestry Centre, Nairobi, Kenya*

Bangladesh is often recognized as potential hotspots for the diversity of jackfruit (*Artocarpus heterophyllus* Lam.), which, profusely grown in almost every homesteads and orchards. The fruit of this plant is an important source of nutrients, provide fairly good timber, possess pharmacological properties, and widely used in folk medicine to treat a range of ailments. Despite this enormous importance, this rich recourse has been degrading due to genetic erosion before being fully documented and utilized for potential crop improvement. The present study was aimed to collect superior accessions from the major jackfruit growing areas of Bangladesh through in-situ evaluation and then documented based on morphological (qualitative and quantitative) data in order to conserve the superior local races. With these aims, twenty-eight jackfruit accessions were collected across the country during 2016-2017. The data on 26 important quantitative and 36 qualitative characters were analyzed following the procedure of IPGR, 2000. Results of the correlation coefficient of quantitative features demonstrated that out of 325 coefficients; 136 and 53 were significant at p0.05 and 0.01 levels, respectively, and the rest (136) were found insignificant. Hierarchal cluster analysis grouped both accessions and variables into four clusters and heat-map analysis indicated that wide range of variations exists among the accessions levels as well as variables levels. Although all of the qualitative characters have potential roles in characterization of Jackfruit, while some of them have very high potential because of wide range of genetic variations. These were fruiting season, fruit-bearing, shape, rind color, flake-shape and texture, pulp-taste, flavor, juiciness, vivipary, seed coat adherence to the kernel. These information will be useful for tree breeding programs, as part of our effort to popularize jackfruit as a commercial crop.

Keywords: Jackfruit, Accessions, Characterization.

L21.P.19

High value tree genetic resources diversity conservation and use paradox

Muchugi A.[1] (a.muchugi@cgiar.org), Bramwel P.[2], Jamnadass R.[1], Dawson I.[1]

[1] *Tree Productivity and Diversity Theme, World Agroforestry Centre (ICRAF), Nairobi, Nairobi, Kenya*;
[2] *Global Crop Diversity Trust, Bonn, Germany*

Imagine waking up one day and cannot get a cup of your preferred coffee, tea or chocolate bar. It may not be easy to relate this issue to agroforestry but think of the tree crops in the farmers' fields being destroyed and cannot be replaced! Almost 90% of the of economically important tropical tree crops such as cocoa, tea, coffee, palm oil, mangoes etc. are produced by small holder farmers who own an average of less than two hectares of land. Breeding is important to maintain the quality and production of these tree crops and relies heavily on the maintenance of the species diversity. However, in most countries breeding and improvement of these species, rely on the diversity collected and selected over years. Most of these species' diversity has been lost due to deforestation, degradation and destruction of natural habitats, including clearing for urban centres, settlement and farming, logging, forest fires, overexploitation and unsustainable harvest, natural disasters and climate change. It is therefore important to safeguard these national collections. However, maintaining these collections has several challenges such as limited funding and intermediate/recalcitrant seed (can only be maintained as field, suspension cultures or cryopreservation). It is therefore important to address how these national collections can be secured. Continued breeding will require promoting diversity exchange across the countries. However, germplasm exchange for commercially important species is limited due to national rivalry. Where they exist, international collections (such as cocoa and coffee collection in CATIE) are easily accessible to breeders. This paper explores the challenges relating to conservation of high value tree genetic resources and proposes options to facilitate their conservation and use

Keywords: Tree genetic resources, Conservation, Tree improvement, Tree breeding.

References:

1. FAO, 2014. The State of the World's Forest Genetic Resources. Commission on Genetic Resources for Fo
2. Ian K. Dawson, Roger Leakey, Charles R. Clement, John C. Weber, Jonathan P. Cornelius, James M. Rosh

L21.P.20

High value tree genetic resources diversity conservation and use paradox

Muchugi A.[1] (a.muchugi@cgiar.org), Bramwel P.[2], Jamnadass R.[3], Dawson I.[3]

[1] *Genetic Resources Unit, World Agroforestry Centre, Nairobi, Nairobi, Kenya*; [2] *Global Crop Diversity Trust, Bonn, Germany*; [3] *Tree Theme, World Agroforestry Centre, Nairobi, Kenya*

Imagine waking up one day and not getting a cup of your preferred coffee, tea or cocoa because the tree crops in the farmers'fields and in the forest are vulnerable and cannot be replaced! Almost 90% of the of economically important tropical tree crops such as cocoa, tea, coffee, palm oil, mangoes etc. are produced by small holder farmers who own an average less than two hectares of land. Breeding is important to maintain the quality and production of these tree crops and relies heavily on the long-term maintenance of the species diversity. In many countries, the breeding and improvement of these species rely on the diversity currently conserved ex situ that has been selected over years. Much of these species' diversity is being lost due to deforestation, degradation and destruction of natural habitats, including clearing for urban settlement or farming, forest fires, unsustainable harvest, natural disasters and climate change. It is therefore important to safeguard and expand these nationally based ex situ collections. However, maintaining these collections has many operational and technical challenges, such as limited funding and intermediate/recalcitrant seed, that require actions to secure their long-term conservation and use. Continued breeding will depend upon greater diversity exchange across the countries. However, international germplasm exchange for commercially important species has been limited due to unclear national access and benefit sharing policy. Where they exist, international collections (such as cocoa and coffee collection in CATIE) can be more easily accessible to users. This paper explores the challenges of conservation of high value tree genetic resources and proposes options to facilitate their global conservation and use

Keywords: breeding, commercially important, conservation, germplasm sharing, tree genetic resources.

L21.P.21

Caracteristique de germination des semences *P. curatellifolia, V.doniana et Z.zanthoxyloides*

Neya T.[1] (neyatiga@gmail.com), Daboue E.[1], Neya O.[2]

[1] *National Tree Seeds Center, Ouagadougou, Burkina Faso*; [2] *WASCAL, Ouagadougou, Burkina Faso*

Au Burkina Faso les produits forestiers occupent de plus en plus une part importante dans la lutte contre la pauvreté et l'insécurité alimentaire. En effet *P. curatellifolia*, *V. doniana et Z. zanthoxyloides* ont des intérêts ethnobotaniques avérés notamment en matière de produits forestiers non ligneux. Cependant peu d'information existe sur la conservation et la germination de leurs semences.Pour chaque espèce trois lots de fruit correspondant à trois stades de maturité des fruits ont été récoltés.Pour les caractéristiques de germination les essais comparatifs de prétraitement ont été réalisés (l'acide, trempage à l'eau et scarification) et des tests de germination à 15°C, 20°C, 25°C, 30°C et 35°C pour apprécier l'effet de la température sur la germination des ces semences.Effets du séchage - *P.curatelifolia*: la Te est passé de 25% à 8% en 18j de séchage avec un taux de germination nul - *V.doniana*: la Te est passé de 27,5 % à 7% en 12j de séchage avec un taux moyen de germination de 4%. -Z. zanthoxyloides: la Te est passé de 12% à 5% en 18j de séchage avec un taux de germination de 3%. les températures testées et pour les espèces étudiées seules les semences de *P. curatellifolia* ont germé à 35°a 13,33%.. les faibles taux de germination enregistrés pour la quasi-totalité montrent des problèmes de germination mais pas une intolérance à la dessiccation. *V.doniana et Z. zanthoxyloides* ont une dormance tégumentaire et *P.curatellifolia* à a une dormance combinée .

Fruit de Zanthoxylum zanthoxyloides collecte pour le besoin de l'étude

Keywords: Germination, Domestication, semences, sechage, conservation.

L21.P.22

Griffonia simplicifolia seed and leaves valorization against poverty in rural area of Togo

Novidzro K. M. (donnenovi@yahoo.fr), Koudouvo K., Melila M., Dossou B. R., Mondedji A. E.

Chimie, Université de Lomé, Lomé, Golfe, Togo

Griffonia simplicifolia is a legume native to the west coast of sub-Saharan Africa with a seed rich in fatty acid and also known to be the most abundant natural source of 5-hydroxytryptophan (5-HTP). 5-HTP is a natural precursor of serotonin, a neurotransmitter secreted by the brain and involved, among other things, in the regulation of mood. In Togo, this plant is used as a medicine. Indeed, the leaves of the plant are eaten like vegetables; while the various organs of the plant are exploited by traditional healers for the manufacture of traditional medicines involved in the treatment of a variety of ailments. The seed of *Griffonia simplicifolia*, which is very rich in fatty acids, is a potential source for the production of lipids which can be used in nutrition.
The overall objective of this study is to promote the agroforestry culture of the *Griffonia simplicifolia* plant with a view to food security and the fight against poverty in rural area of Togo. More specifically, it involves: to make the phytochemical screening of the leaves and the seed of *Griffonia simplicifolia*; to isolate some molecules with interesting bioactivities from these organs; to perform a physico-chemical characterization and to determine the nutritional factors of the mentioned organs and the oil extracted from the *Griffonia simplicifolia* seed.
5-HTP was quantified by High Performance Liquid Chromatography (HPLC) analysis. After hexanic extraction with Sohxlet, the extraction yield and physicochemical characteristics of the oil were determined. The results show that *Griffonia Simplicifolia* seed of Togo contains a 5-HTP with content of 90.24 ± 4.00 mg/g of powder and an oil yield of 25.25 ± 0.30%. The phytochemical test revealed the presence of alkaloids, tannins and flavonoids. Biochemical analyzes show that *Griffonia Simplicifolia* seed is rich in rare amino acids, necessary for the proper functioning of the human body. The physico-chemical characteristics obtained show that *Griffonia simplicifolia* oil from Togo is rich in micronutrients. The obtained results then justify the use of the plant as a medical food in Togo. However, for a better conservation of the biodiversity of this plant species, it is important to promote the cultivation of this plant with many advantages, but which is consumed until now by the picking.

Keywords: Griffonia simplicifolia, phytochemical composition, nutritional values, agroforestry culture, biodiversity conservation.

References:

1. Garrett, R. H.; Grisham, C. M.; 2006. Thompson Corporation: Mason, OH.
2. Aiyegoro O A and Okoh AI; 2010. Complement Altern Med, 10:21-28.
3. Chlopickaa et al., 2012. Food Sci Technol, 46: 548-555.
4. Lemaire and Adosraku, R. K.; 2002. Phytochemical Analysis 13, 333-337.
5. Zeng et al., 2010. Molecules, 15, 7775-7791.

L21.P.23

Docynia indica superior genotypes selection and their evaluation in clone trials in Northwest Vietnam

Pham H T.[1] (P.Thuong@cgiar.org), La N.[1], Ha V T.[2], Harwood C.[3]

[1] *World Agroforestry Center (ICRAF), Hanoi, Vietnam*; [2] *Forestry Science Center in Northwest VN, Son La, Vietnam*; [3] *CSIRO Land and Water, Hobart, Australia*

Son tra (*Docynia indica* (Wal.) Decne) is found in the high-elevation mountainous areas, above 1000 masl, in China, Bhutan, India, Myanmar, Nepal, Pakistan, Thailand and Northern Vietnam. Analysis of Son tra fruit showed that it contains polyphenol is with antioxidant properties that benefit human health. Son tra has been used prominently in the reforestation program of Vietnam. The area of plantation has expanded rapidly, using unimproved local seed sources. Breeding to improve fruit value could therefore contribute to the livelihoods of farmers and fruit processers in the mountainous area in Vietnam. The potential to convert existing unimproved plantations by top-working with scion material from selected clones was confirmed in field trials.

Dominant trees were selected based on their fruit yield and fruit morphology. Scion material from 11 selected trees was grafted onto seedling rootstocks and the growth and fruit yield in trials was monitored. Fruit quality of 11 selected clones and eight unselected control trees was evaluated by a panel of 19 experienced farmers and fruit traders. The farmers and buyers' assessment indicated that there was clear significant difference between genotypes in their sale price, fruit size, fruit attractive, sweetness, sourness but not acerbity. There was a strong correlation between estimated price and fresh fruit attractiveness.11 clonal seedlings from Tuan Giao population planted in the trials in Tuan Giao district, Dien Bien province had shown the quick growth and early bearing fruit at 3rd year. The average fruit yield at year 5 was 21.9 kg per tree twice that of seedling trees which typically yield 11 kg per tree at year 7.

36 plus trees were selected based on fruit's yield and quality. From selected trees, the grafted seedlings were produced and on-going tested in three provinces, Dien Bien, Son La and Yen Bai.

Further selection of Son tra plus trees should be led by farmers based on market demands in order to reach the highest value. Research to rank and select the best clones on their market value nutritional value, pest and disease resistance, is recommended for profitable expansion of Son tra growing.

L21.P.24

Propagation techniques for agroforestry: the case of the rare native medicinal plant, *Lunasia amara* Blanco

Pilapil J. D. (jppilapil@up.edu.ph), Disonglo A., Quimado M., Fernando E.

Department of Forest Biological Sciences, University of the Philippines Los Baños, Los Baños, Laguna, Philippines

Lunasia amara Blanco is a small evergreen tree under the family Rutaceae with great ecological and medicinal value. The plant is indigenous to the Philippines and is regarded as rare. While various production methods can be generally implemented to forest trees, determination of the most suitable technique for propagating rare native species remains to be limited. In this study, three production methods, namely through seed technology, clonal propagation by stem cuttings, and tissue culture *via* direct organogenesis of *L. amara* were evaluated. Seeds were surface sterilized then sown on soil and in *vitro,* resulting to 17.25% and 74.75% germination within 30-60 days, respectively. Stem cuttings were treated with 200 mg l-1 IBA (Indole-3-butyric acid), producing 100.00% multiple shoot formation wherein 87.70% rooted. Embryos were also inoculated onto hormone-free Murashige and Skoog (1962) medium, resulting to 85.00% germination within 30 days. Cotyledonary nodes from in *vitro* grown plant materials were transferred onto MS medium with 5.0 mg l-1 BAP (6-Benzylaminopurine), producing 2.50 ± 0.50 shoots per nodal segment after 30 days. The results of this preliminary investigation have shown the promising potential of macro- and micropropagation onto production, commercialization, and conservation of *L. amara.*

Lunasia amara Blanco inoculated onto Murashige and Skoog (1962) medium

Keywords: macropropagation, micropropagation, rare tree, 6-benzylaminopurine, indole-3-butryric acid.

References:

1. Murashige T. and Skoog F., 1962, Physiologia Plantarum, 473-497

L21.P.25

Resilient Trees: the role of genetic diversity for adapting landscapes to climate change

Soolanayakanahally R. (raju.soolanayakanahally@canada.ca)

Agriculture and Agri-Food Canada, Indian Head, Saskatchewan, Canada

In Canada, since the commencement of the Prairie Shelterbelt Program in 1901, significant advances have been made in the selection and improvement of genetically superior tree and shrub species provided through the Program at Indian Head, Saskatchewan. The tree breeding and evaluation has been led by Angus McKay (1888-1903), Norman Ross (1904-1941), John Walker (1942-1946), Bill Cram (1947-1974), Gordon Howe (1975-1980), William Schroeder (1981-2010) and Raju Soolanayakanahally (2011-present). Improvement efforts touched many genera and species but focused primarily on the genera of trees (*Populus*, *Salix*, *Fraxinus*, *Quercus*, *Larix*, *Pinus*, *Picea*) and shrubs (*Hippophae*, *Shepherdia*, *Prunus*, *Caragana*). During the 100+ years the Program encompassed species introductions and testing, plant exploration, classical breeding and selection, *ex situ* conservation and genomics. To date, the breeding efforts have changed the landscape and quality of life for thousands of prairie people by protecting 50,000 farmyards and one million hectares of farmland by distribution of >700 million trees and shrubs. Selected examples of the tree breeding program outcomes, and their potential applications for shelterbelts, biomass and bioenergy, limiting nutrient enrichment of riparian ecosystems, value added biochar and bio-products prospects, and tree species resilience to climate change will be discussed.

Staff and students working on agroforestry research, development and tree distribution at Indian Head, Saskatchewan, Canada (photo 2011).

Keywords: tree improvement, ex situ conservation, genetic diversity, progeny test, bioproducts.

L21.P.26

Allanblackia floribunda Oliver: ethnobotanical potential and prospects for conservation and sustainable use in Cameroon

Tsobeng A.[1] (a.tsobeng@cgiar.org), Avana M. L.[2], Van Damme P.[1], Muchugi A.[3], Degrande A.[4], Ofori D.[5], Fongnzossie E.[6], Tchoundjeu Z.[7]

[1] *Department Plants & Crops, Ghent University, Ghent, Belgium*; [2] *FASA, University of Dschang, Dschang, Cameroon*; [3] *Genebank, World Agroforestry Centre, Nairobi, Kenya*; [4] *TGR, World Agroforestry Centre, Yaounde, Cameroon*; [5] *FORIG, Kumasi, Ghana*; [6] *ENSET, Douala University, Douala, Cameroon*; [7] *TGR, World Agroofrestry Centre, Yaounde, Cameroon*

The participatory domestication of a tree species usually begins with an ethnobotanical assessment and studies of its population structure and vulnerability in natural stands. This work is essential to understand the species' importance to people and the threats it faces, in view of boosting its cultivation. The present study assesses the ethnobotanical potential and the population structure and vulnerability of *Allanblackia floribunda* in the Center, Littoral and South regions of Cameroon. The ethnobotanical assessment was conducted using semi-structured questionnaires with farmers from four different ethnic groups (i.e. Ewondo, Bassaa, Bakoko and Batanga). A total of 69 farmers were interviewed. The species' population structure (including natural regeneration and diameter classes) was determined by observing, counting and measuring trees in different land-use systems (i.e. forest, fallow, cocoa, oil palm, annual food crop, home garden and swamp); while the species' vulnerability was evaluated by calculating a vulnerability index (VI). Results show that *A. floribunda* plants are used for firewood, medicine, food, cosmetic and hunting purposes. Sexual weakness, malaria, fevers, headaches, gastric ulcers, furuncle, high blood pressure and wounds were mentioned by different ethnic groups as diseases and symptoms cured by *A. floribunda.* Bark is a highly exploited material and its collection is typically detrimental to the species' conservation. Many trees are still dying as a result of ring debarking. Trade of *A. floribunda's* products provides benefits that can amount to USD 500 per household, as recorded for farmers from the Batanga ethnic group. In terms of natural regeneration, analysis of variance of seedling density in the different land-use systems showed some significant differences ($p = 0.03$), with the highest frequency observed in forest areas where more than 50% of the total counted trees were observed. Diameter class distributions generally formed a reversed J curve, implying there is a decrease in tree density with age. The VI of *A. floribunda* was 2.21, indicating the species is vulnerable at the sites studied. From this study, it can be concluded that *A. floribunda* is a highly useful species at study sites. Revenue generated per household is considerable. To ensure the long-term availability of resources from *A. floribunda*, appropriate management strategies such as participatory tree domestication and the establishment of appropriate debarking methods must be put in place.

Keywords: Ethnic group, medicine, natural regeneration, sex ratio, uses.

References:

1. Aleza et al, 2015, Agrofrestry Systems, DOI 10.10007/s10457-015-9787-9.
2. Assogbadjo et al., 2015, Journal of Medicinal Plants Research 5(9), 1549-1557
3. Franzel et al, 2008, CAB International 2008, pp 1 – 27
4. Vandebroek et al., 2004, Social Science and Medicine 59, 837-849
5. Betti, 2002, Systematic and geography of plants 71, 661-678

L21.P.27

Domestication of *Balanites aegyptiaca*: Phenotypic variation in fruit traits and tree selection in Eastern Chad

Tsobeng A.[1] (a.tsobeng@cgiar.org), Degrande A.[1], Uwishaka C.[2], Muchugi A.[3], Atangana A.[4], Souleymanou A.[5], Tchoundjeu Z.[1], Kouame C.[6], Jamnadass R.[3], Hassab A.[2]

[1] *TGR/Genebank, World Agroforestry Centre, Yaounde, Cameroon*; [2] *Concern Worldwide, N'djamena, Chad*; [3] *TGR/Genebank, World Agroforestry Centre, Nairobi, Kenya*; [4] *Centre for Forest Research (CEF), Quebec, Canada*; [5] *Laboratory of cell biotechnology, University of Yaounde 1, Yaounde, Cameroon*; [6] *World Agroforestry Centre, Abidjan, Côte d'Ivoire*

Malnutrition is key issue for people living in Eastern of Chad. Indeed, nutrition of people from this zone is poor in iodine, vitamin A, protein and iron, which are key nutrients. In the framework of the building-resilience-and-adaptation-climate-extremes-and-disasters (BRACED) programme, high-value indigenous tree species of tropical Africa including *Balanites aegyptiaca* were enrolled in a domestication programme aiming at increasing and securing fruit and seed production while conserving genetic resources. This domestication matched intraspecific variability in required nutrients for human nutrition to the needs of subsistence farmers. We sampled 24 fruits in each of the surveyed 51 trees occurring in wild stands in Goz-Beida (Eastern Chad) and determined whether the species could be genetically improved for fruit/seed production. Highly ($P < 0.0001$) and continuous tree-to-tree variation were observed in fruit mass, seed crude protein and iron. Iodine was found in the seeds of one surveyed tree, and traces of vitamin A were observed in the seeds of all surveyed trees. Moderate and positive relationships ($r2 = 0.496$) were found between fruit mass and seed mass, and very weak relationships were observed between other fruit traits ($r2 = 0.009 – 0.069$), between seed traits and between fruit size traits and seed traits. Application of independent culling method to the set of traits retained for selection allowed the sampling of 6 'plus trees' for breeding in the study site, with expected responses to selection amounting to 1.42 g, 2.41% and 0.084 mg/100 g for fruit mass, seed crude protein content seed iron content, respectively, representing a potential increase of 22.33%, 89.26% and 1.45% in the selected traits in the first-generation breeding population. Adoption of tree planting being a key option to alleviate nutritional in a context of climate change, our results highlight among-trees variation in desired characteristics for subsistence farmers, principal actors and beneficiaries of tree domestication. Genetic resources conservation may capitalize on these findings.

Keywords: Breeding, Crude protein, Desert date, Iodine, Tree selection.

References:

1. Ashaah et al. (2010). Ethnopharmacol. 127, 495-501
2. Leakey et al. (2000). Agroforestry Systems 50, 47-58
3. Leakey et al. (2005). Agroforestry Systems 64, 25–35
4. Simons et al. (2004). Agroforestry Systems 61, 167-181

L21.P.28

How diverse is tree planting by farmers in the Central Plateau of Burkina Faso?

Valette M.[1] (michel.valette88@gmail.com), Vinceti B.[2], Traoré D.[3]

[1] *Bioversity international, Kuala Lumpur, Selangor, Malaysia*; [2] *Bioversity international, Rome, Italy*, [3] *Association tiipaalga, Ouagadougou, Burkina Faso*

Burkina Faso is actively engaged in implementing actions aimed at containing environmental degradation and strengthening sustainable use of natural resources. Restoring forest landscapes not only tackles desertification but also some major environmental problems, notably climate change and loss of biodiversity. With strategic planting of trees that are useful to local people, restoration can also bring benefits such as increased food security and income generation. An adequate supply of high-quality forest reproductive material is critical in assisting this effort.

Between 2017 and 2018, we carried out a survey to assess tree planting practices adopted by farmers in the Central Region, comparing three groups of farmers: group 1 = farmers partnering with a local association tiipaalga, supported by this in the establishment of small fenced plots (fencing excludes grazing and encroaching and foster natural regeneration of indigenous plants; group 2 = farmers in the same villages as those above, not setting up fences but exposed to the sustainable tree management practices promoted by the association); group 3 = farmers in villages other than those above, not reached by externally driven interventions. For each farmer, we recorded the diversity of tree species planted, the proportion of exotics, planting densities and seed sources used.

Significant differences in the types of species planted were found between farmers of group 1 and other groups. Within fenced plots, a greater diversity of tree species and a larger representation of indigenous trees (including important food tree species) was found. Overall a diverse set of tree species was planted, but only a handful of were planted in large numbers. Better access to diverse seed sources and farmers greater technical knowledge of seed propagation resulted to be positively correlated with a greater diversity of tree species planted and a larger representation of indigenous tree species. Overall, 47% of the seed used was obtained through autonomous collection by farmers in surroundings. When harvesting their own seeds, farmers seemed to privilege as seed sources those individual mother trees with an interesting phenotype but tended to disregard collection criteria that ensured appropriate diversity in the seed lot. Access to formal sources of seed was constrained by a high seed price and limited diversity in tree species available.

This study highlights the importance of promoting a combination of approaches to tree planting in order to ensure the conservation of a greater tree diversity in the landscape. Capacity building initiatives promoting adequate seed collection practices among farmers would also play a crucial role in supporting forest restoration. Finally, the study indicates that the formal tree seed sector needs to take steps to accommodate farmers needs and demands to enable a scaling up of tree planting efforts across the country.

Keywords: germplasm, seed supply, fences, tree planting, Burkina Faso.

L21.P.29

The genetic improvement of promising Amazonian tree species is at the same time very much needed and very problematic

van Leeuwen J. (johannes.leeuwen@gmail.com), Chaves W., Matos S., Gomes J. B., Alfaia S. S.

COTEI - Núcleo Agroflorestal, INPA - Nat. Research Inst. of the Amazon, Manaus, AMAZONAS, Brazil

The high variability of economic traits makes genetic improvement of Amazonian trees a need. This won't be easy: several fruit only after ten years; a market for improved material will take many years to develop, government support is unreliable. Fruits, differing in taste, size and pulp percentage, scare consumers and can turn industrial use inviable. Breeding programs need to be cheap, while improved material must be available as soon as possible. This is possible with comparative trials of (seedling or clonal) progenies of outstanding trees, using single-tree plots (van Leeuwen, 2009). Such trials use only few land to compare a high number of progenies, while culling can transform them into seed orchards of genetically improved material. Early 2010, such a trial was installed, comparing 28 peach palm (*Bactris gasipaes*) progenies at 10 locations, mostly smallholders. This was done in the municipality of Coari, AM, Brazil, where peach palm is an important cash crop. Soon after this, the project ended, leaving the trials without supervision. A 2014-visit to nine trials considered six "very good" or "good". Where trials bordered forest land, a strong border effect occurred. In future trials, a border row of the same planting material can avoid this. Following peasant logic, spontaneous trees of useful species were maintained in the trials. Annual visits can remedy this, as farmers will only accept to eliminate such trees, when they are still very small.

Variability of peach palm (Bactris gasipaes) fruit in the municipality of Benjamim Constant, AM, Brazil (photo: Clement, INPA).

Keywords: Agroforestry, progeny trial, border effect, peasants, tree elimination.

References:

1. van Leeuwen, in: Alternativa agroflorestal na Amazônia em transformação,2009, Embrapa, 805-825.

L21.P.30

Genetic diversity distribution in the multi-purpose tree species *Garcinia kola* in Central Africa

Yogom B.[1] (yogomboni@yahoo.com), Duminil J.[2], Avana M. L.[3], Zakraoui L.[2], Couderc M.[2]

[1] *Plant Biology, University of Dschang, Dschang, Cameroon, Cameroon*; [2] *DIADE, Research institute for development, Montpellier, France, France*; [3] *Forestry, University of Dschang, Dschang, Cameroon*

In sub-Saharan Africa, forest and trees play a crucial role in the livelihood of local populations. However, a number of tree species are threatened by use, and conservation strategies need to be established. This requires in particular a good characterization of species genetic diversity distribution (Duminil et al., 2013) and of the influence of local management practices on genetic diversity (Vinceti et al., 2013). *Garcinia kola* (Clusiaceae), commonly known as bitter kola, is an economically-important African tropical tree species (Guedje and Fankap, 2001). This multi-purpose species is heavily overexploited in its natural habitat for its bark, which implies high mortality rate. Accordingly, it has been classified vulnerable by IUCN. It is thus urgent implement conservation and sustainable management strategies relying on scientific criteria. In this context, we have characterized its genetic diversity in Central Africa. 1020 individuals have been collected from different populations from Cameroon, Gabon and the Republic of Congo and 13 nuclear microsatellite markers have been used to characterize species genetic diversity. We here present a map of the genetic diversity distribution of the species and interpret the results in relation to species evolutionary history and local management practices. Such a map is particularly useful to define priority populations for conservation.

A: The tree of G. kola in the agroforestry system, B: Fruits of G. kola,
C: Seeds of G. kola in the Manjo market-Cameroon

Keywords: Garcinia kola, conservation, microsatellite markers, Central Africa, NTFP.

References:

1. Guedje, 2001, National Botanic Garden of Belgium, 11
2. Duminil et al., 2013, BMC Evolutionary Biology, 13.
3. Mariac et al., 2014, Molecular Ecology Resources, 14.
4. Vinceti et al., 2013, PLoS ONE, 8.

ABSTRACTS

Biophysics of agroforestry systems

The wonders of agroforestry's biophysics

- L22 -

Agroforestry: pests, diseases and weeds

Hidden gifts: why agroforestry makes life hard for pests, diseases and weeds

Agroforestry systems (AFS) are biodiverse, with several vegetational strata, where complex interactions occur. AFS can impact the development of pests, diseases and weeds, through multiple interacting mechanisms, i.e. microclimate modifications, soil quality improvement, host plant physiology changes, permanent shelter for invertebrates (beneficials, pests, others), alternate sources of disease inocula, and others, taking place at different scales (plot, farm, landscape). These mechanisms can lead to the regulation of pests, pathogens and weeds, or conversely increase their populations, depending on their specific requirements. Structure and management of AFS are thus essential for optimizing the functioning of the system, by promoting desirable mechanisms while weakening undesirable ones. One option to assess the performance of AFS in terms of pest, disease and weed regulation is to quantify yield losses and quality losses of products in the system. In this session, authors will present the diversity of AFS effects on pests, diseases, and weeds, and the main mechanisms involved at different scales, and how management can help regulate noxious populations and reduce losses.

L22_O.01

Vertebrates contribute to natural control of the millet head miner in tree-crop agroforestry systems

Sow A.[1] (s_ahmadou@yahoo.fr), Seye D.[1], Faye E.[2], Benoit L.[3], Galan M.[4], Haran J.[3], Brévault T.[5]

[1] *UCAD-FST, Dakar, Senegal*; [2] *UPR HortSys, CIRAD, Dakar, Senegal*; [3] *UMR CBGP, CIRAD, Montpellier, France*; [4] *UMR CBGP, INRA, Montpellier, France*; [5] *UPR AIDA, CIRAD, Dakar, Senegal*

The millet head miner, *Heliocheilus albipunctella* (Lepidoptera, Noctuidae), is a major constraint to millet production in sub-Saharan Africa. In the absence of any insecticide application by farmers, millet production relies on pest regulation by natural enemies [1]. However, the continued delivery of such ecosystem service is threatened by biodiversity loss due to simplification of land uses in agricultural landscapes. A better understanding of factors driving natural pest control is a major challenge for designing sustainable cropping systems [2]. The objective of the present study was to assess the association between canopy openness in traditional tree-crop agroforestry systems, richness and abundance of birds and bats, and their role in the natural regulation of the millet head miner.
Ten study sites were selected in a 50 km² area in the Peanut basin in Senegal. In each site, a couple of millet fields were selected according to canopy openness and tree species richness. Monitoring of birds and bats, pest regulation and crop damage was carried out. Nine insectivorous bird and bat species were observed and their predator status confirmed by direct observation or DNA analysis on feces. Egg infestation of panicles was greater in open fields (+25%) and negatively correlated with bird abundance (P = 0,034). Grain losses were reduced when birds had access to panicles. Further research is needed to better understand relationships between trees, food webs and biological control.

Grey-headed sparrow (Passer griseus) eating a larva of the millet head miner

Keywords: biological control, biodiversity, birds, bats, Africa.

References:

1. Soti et al., 2019, Biol Control, doi.org/10.1016/j.biocontrol.2018.10.006
2. Brévault & Clouvel, 2019, Crop Prot, doi.org/10.1016/j.cropro.2018.09.003

L22_O.02

Analysis of the interactions of shade trees on coffee leaf diseases and coffee yield in complex agroforestry systems

Durand-Bessart C.[1] (clementine.durand.bessart@gmail.com), Tixier P.[2], Quinteros A.[3], Andreotti F.[4], Rapidel B.[1], Tauvel C.[1], Allinne C.[1]

[1] *CIRAD, UMR System, Montpellier, France*; [2] *CIRAD, UPR GECO, Montpellier, France*; [3] *CIRAD, UMR System, Turrialba, Costa Rica*; [4] *CATIE, Programa de Agricultura y Agroforesteria, Turrialba, Costa Rica*

In complex coffee-based agroforestry, quantifying interactions within the agrosystem that impact on coffee disease regulation and on coffee yield is a major stake to design sustainable cropping systems. To this end, we analyzed the interaction network between shade trees, coffee trees (Catimor variety), coffee foliar diseases complex (CFDC; majority of *Mycena citricolor*) and soil characteristics. The system is characterized by 40 variables measured in 60 plots spread on three farms (monitored for 2 years) in Nicaragua. We used Partial Least Square Path Modeling (PLSPM) to study the network interaction. We built 6 blocks with the more significant variables of each component: shade trees (shade percentage, species), soil (Cation Exchange Capacity, P), CFDC (incidence, severity), coffee trees age and size, coffee growth and coffee yield. The second part of the PLSPM was performed between blocks. Shade trees, mostly the shade percentage, had direct positive effects on CFDC and soil quality, and negative effects on coffee growth and yield. Shade had also an indirect negative effect on coffee trees by increasing CFDC, which impedes coffee growth and yield. Soil variables being negatively related to CFDC, shade had an indirect effect on coffee trees. Reducing excessive shade cover seems to be a solution to enhance positive impacts of shade trees on coffee yield. Overall, shade management requires an analysis of trade-offs between soil quality, diseases regulation and yield gains.

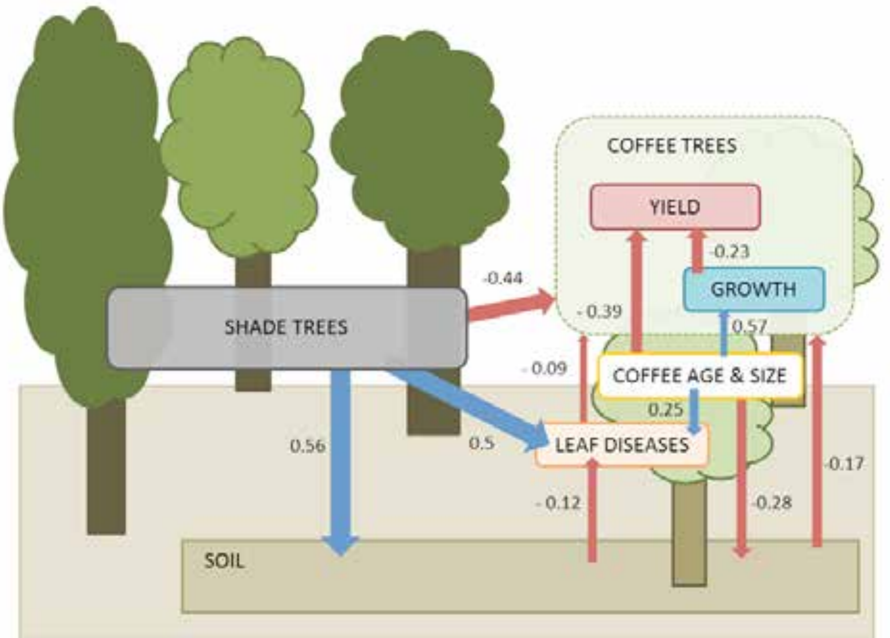


Figure 1. Results of PLSPM model showing direction and quantifying all interactions inside this coffee-based agroforestry network. Blue arrow represents positive effect, red arrow negative effect, associated with their own regression coefficient.

Keywords: disease regulation, ecological process, trade-off, structural equation modeling.

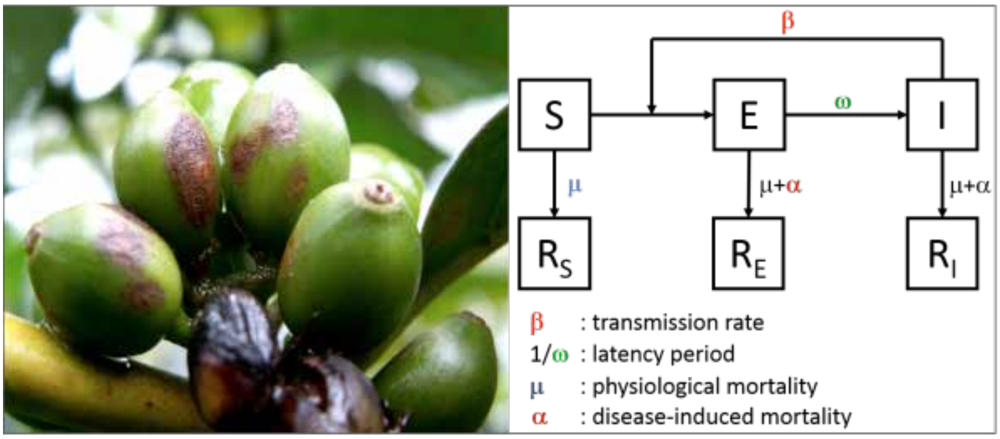
L22_O.03

Antagonistic effects of shade on the epidemiological mechanisms driving coffee berry disease

Motisi N.[1] (natacha.motisi@cirad.fr), Papaïx J.[2], Poggi S.[3]

[1] *BIOS/Bioagresseurs, Cirad, Montpellier, France*; [2] *Biostatistics and Spatial Processes, Inra, Avignon, France*; [3] *IGEPP, Inra, Le Rheu, France*

Coffee berry disease (CBD) is widespread in Africa and has been responsible for massive yield losses of *Coffea arabica*. Shade trees are one of the promoted strategies to control CBD because they are supposed to reduce disease dispersal through rainsplash[1]. Nevertheless, data collected over two consecutive years in West Cameroon showed that shade did not necessarily reduce the disease incidence and could even increase it. The objective of our study was to determine the epidemiological mechanisms and environmental covariates involved in the differences between epidemics observed under shade and full sun cropping systems. For this purpose, we developed a Susceptible - Exposed - Infectious - Removed (SEIR) model, some of the parameters being function of environmental covariates. This model was combined with a probabilistic model of observation via a mechanistic-statistical approach and parameters were estimated in a Bayesian framework. According to our model, temperature and relative humidity were the main environmental variables explaining differences in disease transmission between shade and full sun. Our results show that shade treatment exhibits antagonistic effects on epidemiological mechanisms, notably it reduces disease transmission but also the latency period. This suggests that depending on the local climatic conditions, one specific mechanism may be fostered, thereby explaining the variability in shade efficacy described in the literature.



Left: symptoms of coffee berry disease caused by Colletotrichum kahawae; right: Susceptible - Exposed - Infectious - Removed model (SEIR) where the disease transmission rate and the latency period are function of environmental covariates.

Keywords: SIR model, Colletotrichum kahawae, Bayesian inference, Mechanistic-statistical approach, Agroecological crop protection.

References:

1. Mouen Bedimo et al., 2010, Plant Pathology, 59, 324–329

L22_O.04

Pests, but not predators, increase in mixed apple tree - cabbage plots as compared to control cabbage plots

Imbert C.[1] (camille.imbert@inra.fr), Papaïx J.[2], Husson L.[1], Warlop F.[3], Lavigne C.[1]

[1] *PSH, INRA, Avignon, France*; [2] *BioSP, INRA, Avignon, France*; [3] *GRAB, Avignon, France*

Mixed fruit tree - vegetable systems combine the production of vegetables at the ground level with that of fruits in tree canopies. They are expected to be ecologically intensive by making the best use of the 3D space in fields (Warlop et al., 2017; Wolz and DeLucia, 2018) and to decrease pest abundance even if results about pest control in agroforestry are variable (Letourneau et al., 2011, Pumariño et al., 2015).
We tested if mixed apple tree - cabbage systems may reduce herbivores on the cabbages. We monitored arthropod pests and predators at six sampling sessions over one growing season (2016),in two mixed apple tree-cabbage plots and two cabbage control plots located in Avignon, South of France. We analyzed the results using autoregressive models to account for the time dependence in the data.
Unexpectedly, we found that four out of seven pest stages (the aphid *Myzus persicae*, caterpillars and two stages of whiteflies) were more abundant or more frequent in mixed fruit tree - vegetable plots than in control plots. Only the aphid *Brevicoryne brassicae* was more abundant in control plots. In contrast, we observed more of four out of the six main predator taxa in the control plots. These were Coleoptera, chilopods, earwigs and ants (Figure 1).
The mechanisms underlying our results include better microclimatic conditions and dilution of predators in mixed plots, as well as the longer generation time of predators versus pests.
The study was funded by Fondation de France.

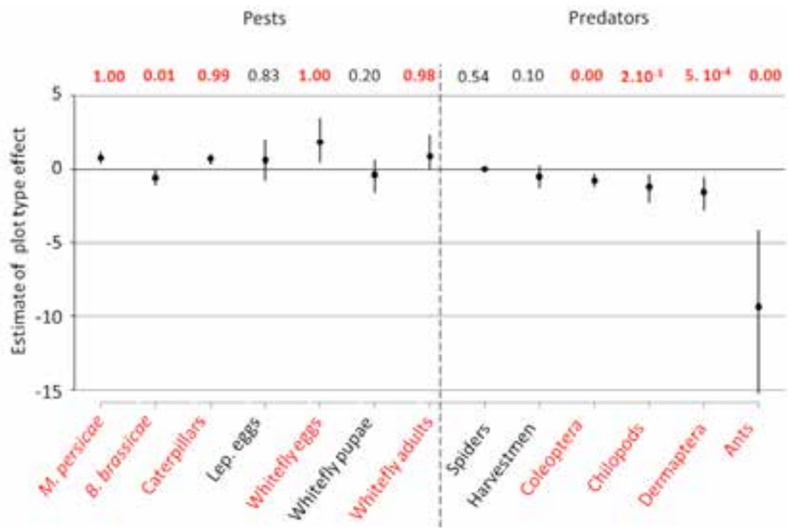


Figure 1. Posterior density of the plot type effect (control=0). Positive values indicate higher abundance or probability of occurrence in mixed apple tree-cabbage plots, while negative values indicate higher abundance or probability of occurrence in control plots. Dots represent the posterior median and vertical bars represent the [0.025, 0.975] credibility intervals. The probability that the plot type effect for mixed apple tree-cabbage plots is positive is provided above each individual graph. Values below 0.025 and above 0.975 in red.

Keywords: Mixed fruit tree-vegetable plots, Alley cropping, Brassica, Conservation biological control, Malus.

References:

1. Letourneau, D.K. et al., Ecological Applications 21, 9–21.
2. Pumariño, L. et al., Basic and Applied Ecology 16, 573–582.
3. Warlop, F. et al. Report from the SMART project 40p.
4. Wolz, K.J. & DeLucia, E.H., Agriculture, Ecosystems & Environment 252, 61–68.

L22_O.05

Estimating microclimate in agroforestry systems based on nearby full sun measures to forecast coffee rust development

Merle I.[1] (isabelle.merle@cirad.fr), Villarreyna Acuna R.[2], Tixier P.[3], Ribeyre F.[4], Cilas C.[4], Avelino J.[1]

[1] *UPR Bioagresseurs, CIRAD, Turrialba, Costa Rica*; [2] *Sistemas agroforestales, CATIE, Turrialba, Costa Rica*; [3] *UPR GECO, CIRAD, Montpellier, France*; [4] *UPR Bioagresseurs, CIRAD, Montpellier, France*

In Central America, coffee is grown in agroforestry systems. Since 2012, coffee leaf rust, caused by the fungus *Hemileia vastatrix*, has produced major epidemics in this region. To prevent future epidemics, the European Union through its PROCAGICA program (Programa Centroamericano de Gestión Integral de la Roya del Café) promotes the creation of an early warning system based on weather monitoring.
To build models to forecast the disease we must first identify which microclimatic variables are responsible for rust development and then be able to estimate these variables under different agroforestry systems as a function of the data provided by weather stations, established at full sun. From a trial set up in Costa Rica where disease and weather data were monitored, we deduced, without a priori [1], that the different disease development stages (see figure) were the result of complex combinations of microclimatic variables acting at different periods (times and durations). Then, to estimate the effect of agroforestry systems on these microclimatic variables, a second trial was conducted in Costa Rica within an altitudinal gradient. In each site, meteorological stations were set up in a full sun reference plot and coffee plots with different shade trees. Using boosted regression tree method, we found that microclimate under shading depends mainly on full sun weather with nonlinear relationship, hour, shade tree species, orientation, canopy openness and plot slope in this order.

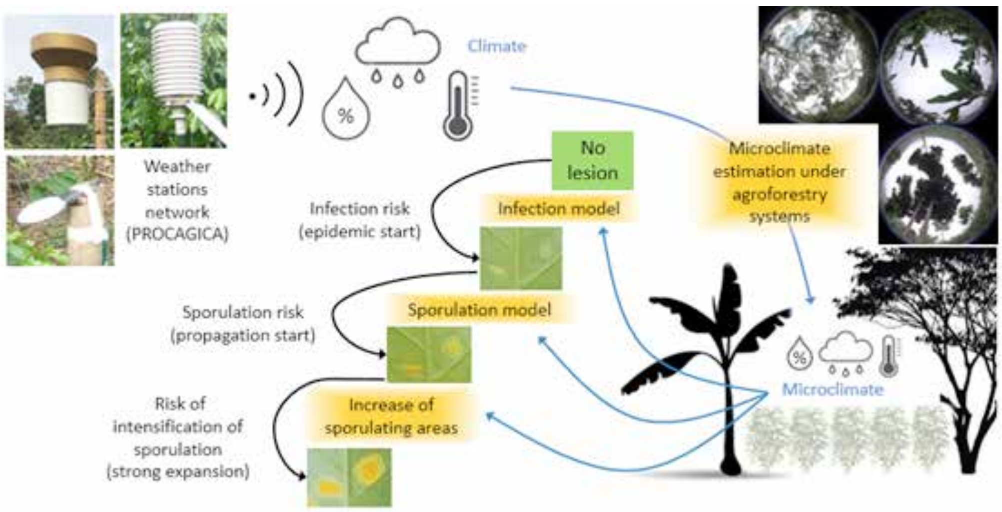


Illustration of modeling needs (orange) for weather based coffee leaf rust forecasting in Central America

Keywords: Hemileia vastatrix, Shade.

References:

1. Bugaud et al., 2015, J Sci Food Agric, 96(7): 2384-2390

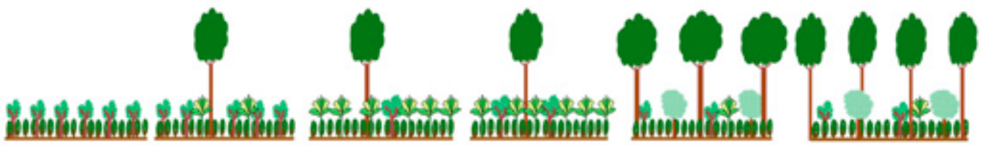
L22_O.06

Coffee agroforestry systems that reduce crop losses due to pests and diseases, while providing ecosystem services

Cerda R.[1] (rcerda@catie.ac.cr), Allinne C.[2], Gary C.[3], Tixier P.[4], Harvey C.[5], Avelino J.[6]

[1] *Agriculture, Agroforestry and Livestock, CATIE, TURRIALBA, CARTAGO, Costa Rica*; [2] *UMR System, CIRAD, Montpellier, France*; [3] *UMR System, INRA, Montpellier, France*; [4] *UPR GECO, CIRAD, Montpellier, France*; [5] *Conservation International, Arlington, United States*; [6] *UR Bioagresseurs, CIRAD-CATIE-IICA, Montpellier, France*

Crop losses caused by pests and diseases threaten the food security and income of thousands of families worldwide. In Latin America and the Caribbean, coffee losses have caused severe crises since 2012. Most of coffee farmers manage diverse types of coffee agroforestry systems (CAF); therefore, it is important to know: what shade canopy and management characteristics are able to reduce coffee losses due to pests and diseases, but also provide other ecosystem services such as provisioning, maintenance of soil fertility and carbon sequestration? We worked with two-year data of 61 coffee plots in Costa Rica: firstly, we estimated primary yield losses and secondary yield losses; secondly, we assessed the relationships (trade-offs) between yield losses and indicators of the other ecosystem services; finally, we identified the CAF which had the lowest losses and provided high levels of agroforestry products, soil fertility and carbon sequestration. We identified six CAF as the most promising ones for reducing losses while providing other ecosystem services. One of these systems was a simple CAF; three were medium diversified CAF; and two were highly diversified and dense CAF. For each of these CAF, we described the structure and composition of their shade canopies, management and costs, and the levels of ecosystem services they provide (see Figure). The six CAF represent different options to offer for the design of new CAF or re-design of old and/or unproductive CAF.



	CAF1	CAF2	CAF3	CAF4	CAF5	CAF6
PYL (%)	2	6	4	5	2	3
SYL (%)	11	18	4	17	18	0
Fertilizers	+++	++	++	+++	+	+
Fungicides	+++	++	+	+	+++	+
Weedings	+++	+	++	++	++	++
Costs	++	++	++	+++	++	+

CAF: coffee agroforestry system; CAF1: a simple CAF (coffee grown only under-service trees); CAF2, CAF3 and CAF4: medium diversified CAF (coffee, musaceaes, service trees, fruit trees, and timber trees); CAF5 and CAF6: highly diversified and dense CAF
PYL: primary yield losses of coffee; SYL: secondary yield losses of coffee
The signs (+) indicate which CAF have more (or less) activities or costs in comparison with the others

Figure. Characteristics of the most promising coffee agroforestry systems that reduce coffee yield losses, while providing other ecosystem services (agroforestry products, soil fertility and carbon sequestration).

Keywords: Design, Yield, Shade, Soil, Carbon.

L22_O.07

Shade effects on coffee rust (*Hemileia vastatrix*)

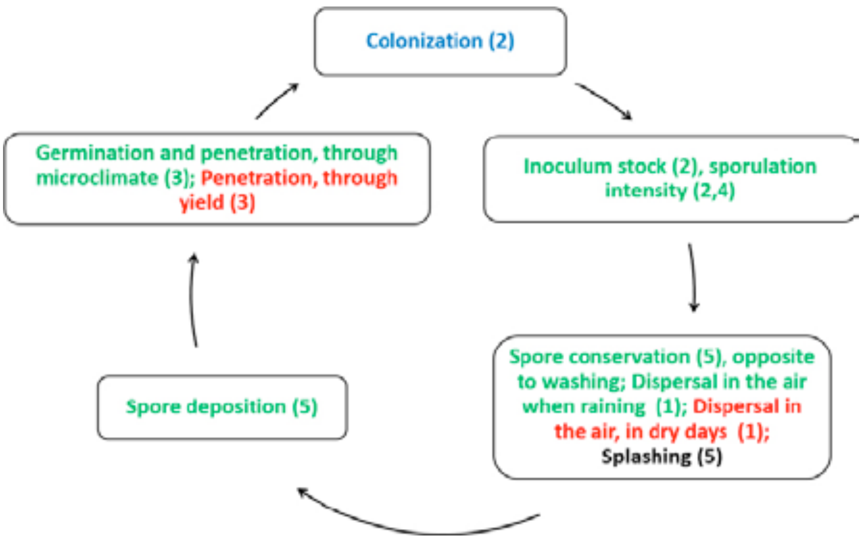
Avelino J.[1] (jacques.avelino@cirad.fr), Badaroux J.[2], Boudrot A.[1], Brenes A.[2], Granados E.[3], Henrion M.[2], López D.[2], Merle I.[1], Pico J.[2], Segura B.[2], Vílchez S.[2], Smith M.[4], de Melo E.[2]

[1] *UPR 106, CIRAD, Turrialba, Costa Rica*; [2] *CATIE, Turrialba, Costa Rica*; [3] *Sede del Atlántico, UCR, Turrialba, Costa Rica*; [4] *WCR, Portland, Oregon, USA*

To better understand shade effects on coffee rust (*Hemileia vastatrix*), we studied pathogen dispersal, deposition, germination, penetration, colonization and sporulation under shade and full sun conditions (Figure). Studies were conducted from 2008 in the CATIE agroforestry system long term trial, at Turrialba, Costa Rica, at 600 m of altitude.

Shade had a preponderant and unwished effect on spore conservation during rains. At full sun, spores were washed from the leaves to the ground more easily. An average loss of 69 spores cm^{-2} of ground, at full sun, was estimated after a rainy day, under coffee trees, while under shade, only 52 spores cm^{-2} were lost, despite inoculum stock being on average about 25 638 spores per coffee tree branch at full sun and 63 579 spores under shade. The reduction of the inoculum stock by rains was therefore 3.3 times higher at full sun as compared to shade. This can be explained by the interception of rainwater by shade trees. As lost spores cannot contribute to the growth of the epidemic, this effect seems to be one of the most relevant effects favoring rust under shade.

Shade is necessary to cope with climate change in coffee systems. Many of the negative effects of shade have to do with the interception of rainwater (reduced throughfall water and also higher raindrop kinetic energy). Shade tree functional traits or management systems that allow to increase throughfall water in coffee plots would be of great interest to manage rust.



Shade effects on coffee rust; green: shade improves; red: sun improves; blue: no difference between shade and sun; black: the mechanism seems secondary; numbers are for references

Keywords: Dispersal, Inoculum stock, Througfall kinetic energy, Raindrop interception, Spore washoff.

References:

1. Boudrot et al. 2016. Phytopathology 106: 572-80. 10.1094/PHYTO-02-15-0058-R
2. Brenes Loaiza 2017. Master Thesis. CATIE, Turrialba, Costa Rica. 51 pp.
3. Lopez-Bravo et al. 2012. Crop Protection 38: 21-29. 10.1016/j.cropro.2012.03.011
4. Pico Rosado 2014. Master Thesis. CATIE, Turrialba, Costa Rica. 79 pp.
5. Segura Escobar 2017. Master Thesis. CATIE, Turrialba, Costa Rica. 51 pp.

L22_O.08

Do cacao agroforestry systems increase pest and disease incidence? Evidences from a long-term system comparison trial

Armengot Martinez L.[1] (laura.armengot@fibl.org), Ferrari L.[1], Milz J.[2], Velasquez F.[2], Schneider M.[1]

[1] *FiBL, Frick, Switzerland*; [2] *Ecotop Consult, La Paz, Bolivia*

Pests and diseases affect considerably cacao production. Agroforestry systems, in comparison with monocultures, can provide some pest and disease regulating services, i.e., complex systems can encourage natural enemies and prevent outbreaks. However, some pests and diseases might be favoured by higher air humidity, and less aeration and light. The capacity of agroforestry systems to regulate pests and diseases might highly depend on their management. Without good management practices, differences between systems are often observed. Management of agroforestry systems can be quite poor due to lack of resources of the farmers, economic profitability or knowledge.
Here we compare the incidence of pests and diseases in different cacao production systems. Data were collected between 2015 and 2017 in a long-term trial established in Bolivia in 2009. Five different production systems are compared: monoculture and agroforestry systems both under organic and conventional farming and one successional agroforestry system without external inputs. Four replications were established in a randomised block design. Each plot measued 48×48 m, with a net plot of 24×32 m. Pest and disease control do not differ between systems, and it relies on preventive measures, i.e., regular tree pruning and fortnight removal of infested pods, but no external inputs are used. Frosty pod rot (*Moniliophthora roreri*) was monitored all-year round every two weeks. Infected pods were registered and cut to avoid the spread of the spores. At harvest (every two weeks), the incidence of other pests and diseases was registered. Incidence of pests and diseases at tree level was also monitored, i.e., witches broom (*M. perniciosa*) on vegetative tissue, stem borers and cacao mirids.
Across systems, only about 14% of the pods were affected. About 70% of the infested pods were affected by frosty pod rot, followed by witches' broom, black pod rot (*Phytophthora* spp) and pods eaten by birds or mammals. At tree level, very few trees were registered with any pest or disease.
The percentage of pods affected by pests and diseases did not differ between production systems, with the exception of a slightly significant higher incidence (3% above) in the successional agroforestry system. In this system there were also more pods eaten by birds or small mammals, indicating that this system supports their presence but, at the same time, it can cause more yield losses (trade-off between biodiversity and production). However, the pod losses caused by these animals were still low. At tree level, significantly higher incidence of witches' broom was registered in the monocultures, while no differences were detected for the stem borers and cacao mirids.
In conclusion, our results show that under no external inputs for controlling pests and diseases, low and no significant differences of pest and disease incidence were observed between monocultures and agroforestry systems when good management practices were applied.

Keywords: management practices, organic farming, Bolivia, monocultures.

L22_O.09

Shade and leaf retention: an aspect of effective Coffee Leaf Rust management

Alwora G.[1] (gedohal@yahoo.com), Miano D.[2], Mutitu E.[2], Gichuru E.[1], Pinard F.[3]

[1] *Plant Pathology, KALRO- Coffee Research Institute, Ruiru, Kenya*; [2] *Plant Science and Crop Protection, University of Nairobi, Nairobi, Kenya*; [3] *UR 106 Bioagresseurs/Plant Health, Cirad /ICIPE, Nairobi, Kenya*

Coffee Leaf Rust (CLR) has been reported in over 50 coffee growing countries causing significant economic losses in Arabica coffee. The aim of this study was to determine the effect of shade on leaf life span in relation to severity of coffee leaf rust. To achieve this objective, three shade levels (shaded, partial shade, unshaded) were applied in three agro-ecological zones (AEZ) i.e. Upper-Midland (UM) I, II and III. Each treatment was replicated 4 times in 7 farms in each AEZ. All the farms had similar agronomic management levels. Infected leaves were counted per tree and disease severity was scored every month, between January and September, 2014 which is the peak period for CLR. Yields per plot were estimated using the method of Cilas and Descroix, 2004.
The results showed that shaded trees retained the infected leaves 8 weeks longer than the unshaded in all the agro-ecological zones. Similarly, yield estimate from the shaded coffee (1521kg/ha clean coffee) was significantly higher than the unshaded (1050kg/ha clean coffee). Although leaves remain longer on shaded trees, allowing more time for the disease to develop and progress, severity level of shaded trees remains lower (12.8%) than unshaded (19.0%), suggesting the expression of regulation mechanism under the control of shade. Moreover, full shade generated by dense canopy, such as the one from mango or avocado tree best manages CLR across all the tested three agro-ecological zones.

Left: High leaf retention under CLR infected shaded coffee Right: High leaf senescence under CLR infected unshaded coffee

Keywords: agroecological zones, Diseases, Leaf span, Severity.

L22_O.10

Effects of complex cocoa-based agroforests on Citrus trees dieback

Akoutou Mvondo E.[1] (akoutoumvondoetienne@yahoo.fr), Ndo E. G. D.[1], Bidzanga Nnomo L.[2], Abondo Bitoumou J.[3]

[1] *Programme Fruits, IRAD, Yaoundé, Cameroon*; [2] *IRAD, Yaoundé, Cameroon*; [3] *Université de Dschang, Dschang, Cameroon*

In southern Cameroon, citrus trees are usually planted in complex cocoa-based agroforests by smallholder producers. The health and the productivity of trees are generally jeopardized by a host of pests and diseases, for which the environmental conditions of the system are critical drivers. An evaluation of the intensity of citrus dieback diseases in three shading conditions and various spatial organization of citrus trees was carried out in 26 cocoa fields in four sites. A net plot of 2500 m^2 comprising a minimum of 12 citrus trees was mapped, associated vegetation was characterized, and spatial structure of citrus trees described using the Ripley's method. Disease intensity on the organs attacked was evaluated using a scale varying from 1 to 4. ANOVA and a comparison of means was performed. Results showed that 98.1 % of citrus trees were infested with pests, mostly mealybugs and mites on leaves. High rates of dieback on citrus trees (76.36 % to 100 %) were recorded. The intensity of citrus trees dieback under shade was significantly low (2.22±1.02^a), as compared to those under moderate shade (2.52±1.12^b) and cocoa/citrus (2.55±1.13^b). Citrus trees in aggregate and random spatial structure showed a high intensity of dieback (2.88±0.88^b; and 2.63±1.17^b respectively), as compared to those with a regular spatial structure (1.72±0.84^a). The involvement of structural features of agroforestry system to reduce significantly dieback on citrus trees was demonstrated.

		Citrus dieback	Phytophthora foot rot disease of citrus	Pseudocercospora leaf and fruit spot disease	Mites
Shade trees effect	moderate shade	2.52±1.12b	2.16±0.99b	0.61±0.66b	3.02±0.93a
	cocoa/citrus	2.55±1.13b	2.05±0.88ab	0.65±0.76b	2.95±0.84a
	Citrus trees under shade	2.22±1.02a	1.81±0.93a	0.39±0.57a	2.79±0.95a
	Anova/Tukey test				
	Df	2	2	2	2
	F value	4.966	6.679	8.276	2.946
	Pr (>F)	0.00734 **	0.00138***	0.000293***	0.0535
Spatial structure effect	Aggragate spatiale structure	2.88±0.88b	2.13±0.98b	0.54±0.65a	3.08±0.89b
	Random spatial structure	2.63±1.17b	1.97±0.93ab	0.56±0.62a	2.90±0.99ab
	Regular spatial structure	1.72±0.84a	1.82±0.92a	0.45±0.67a	2.72±0.88a
	Anova/Tukey test				
	Df	2	2	2	2
	F value	66.51	4.605	1.204	6.651
	Pr (>F)	<2e-16 ***	0.0104 *	0.301	0.00142 **

The values of the intensity of the diseases and pests are presented on a scale ranging from 1 to 4, where 1 represents the state of a tree presenting no symptoms and 4 a tree with an intensity of more than 50%.

Effect of shading and spatial structure on major citrus diseases in cocoa-based agroforestry systems in Cameroon

Keywords: Integrated pest management, Shade trees, Spatial structure, Cameroon.

References:

1. Akoutou Mvondo et al., 2017., Agroforest Syst, DOI 10.1007/s10457-017-0140-3
2. Calonnec et al., 2013. Eur J Plant Pathol 135:479–497
3. Kuate et al., 2006. Fruits 61(6):373–387
4. Ndo et al., 2010. Eur J Plant Pathol 128:385–397
5. Ngo Bieng et al., 2013. Appl Ecol 14:329–336

L22.P.01

Importance of *Faidherbia albida* (Delile) "Gao tree" dieback in agroecosystems of south western Sahelian Niger.

Amadou Tougiani A.[1] (abasse.tougiani@gmail.com), Massaoudou M.[2], Haougui A.[3], Laouali A.[4]

[1] *Natural Resources Management, Institut National de Recherche Agronomiq, Niamey, Niamey, Niger*; [2] *Natural Resources Management, Institut National de Recherche Agronomiq, Maradi, Maradi, Niger*; [3] *Crop Protection, nstitut National de Recherche Agronomiq, Niamey, Niamey, Niger*; [4] *Rainfed crop, Institut National de Recherche Agronomiq, Maradi, Maradi, Niger*

Faidherbia albida is an agroforestry species whose agro ecological and socioeconomic roles have been proven in several studies in arid and semi-arid areas. For a long time, anthropogenic pressures and droughts were considered the main threats to *Faidherbia albida*, which is associated with annual crop in Parkland resources in Niger. Diseases with considerable mortalities and whose identification of causal agents is in progress are studied in the context of agro sylvo pastoral system. The disease damage would not allow leaves formation nor the fruiting on tree, and thereafter would reduce the litter fall and soil fertility, which is of great concern for rural communities. The objective of this study is to evaluate the level of disease attack on *F. albida* trees in the southern Sahelian western part of Niger. A radial sampling with a distance of 1.2 km, leaving from the center of the large villages towards the bush following the four geographical directions was carried out. On each of the four (4) transects per village, square plots of 50 m x 50 m with 300 m equidistance were installed. The measurements concerned dendrometric parameters, new natural regeneration, observations on the incidence and the severity of the disease. The results revealed a list of 12 adult woody species with an alpha diversity of 1.33 bits. The stand is almost mono-specific with a beta diversity of 0.37, dominated by *F. albida*, the specific contribution was 77.65%, while the density value was of 26.5 individuals / ha and the structure was bell-shaped. Observations revealed an incidence of the disease of 18.87% and a mortality of 5.66%. The most affected parts of the tree were 53.77% branches and 38.68% trunks. The main component analysis showed that large diameter trees were the most heavily attacked. This decline of *F. albida*, observed only in this south western Niger, is a serious threat to the survival of rural communities. These results can be applied to guide Parkland management strategies to better define and control disease in the area. Resistant phenotypes selected could be also used to rehabilitate the infested parkland in Niger.

Keywords: Faidherbia albida, disease attack, phenotypes, Sahel, Niger.

References:

1. Ousmane Laminou Manzo, Massaoudou Moussa,Hassane Bil-Assanou Issoufou, Diouf Abdoulaye, Boubé Morou,
2. Massaoudou Moussa , Larwanou Mahamane et Mahamane Saadou 2015 ; Caractérisation des peuplements

L22.P.02

Shade trees improve coffee health without reducing (too much) coffee potential yield

Barkaoui K.[1] (karim.barkaoui@cirad.fr), Nyaga J.[2], Pinard F.[3], Vaast P.[4], Lamanda N.[1]

[1] *UMR SYSTEM, CIRAD, Montpellier, France*; [2] *World Agroforestry Centre, Nairobi, Kenya*; [3] *UPR Bioagresseurs, CIRAD, Montpellier, France*; [4] *UMR Eco&Sols, CIRAD, Montpellier, France*

Shade trees are increasingly recognized to benefit to biological regulation in tropical agroforestry systems (AFS). However, studies have revealed contradictory results for cryptogrammic diseases, suggesting strong interactions with local abiotic conditions and management. In AFS, the development of diseases depend on microclimate modifications caused by shade trees. Here, we aimed at evaluating the impacts of shade trees on disease infestation within coffee AFS in Central Kenya (Murang'a). We mapped and assessed the horizontal and vertical structure of 15 AFS plots with contrasting shade tree cover and spatial organization. We monitored the incidence and severity of Coffee Berry Disease (CBD) and Coffee Leaf Rust (CLR) on 50 coffee plants with contrasting shading conditions within each plot during the harvest in 2010. Our results showed that coffee under trees, especially under dense-canopy trees (e.g. Macadamia, Mango), have similar yield potential (around 2.35 kg of cherries/coffee plant, estimated over 5 fruiting branches) but significantly lower CBD (– 53 %) and CLR (– 13 %) symptoms. At the plot level, intermediate and homogeneous canopy tree cover enabled lower disease infestation. In addition, we showed that architectural traits of trees (e.g. growth habit, total height, crown size, foliar density) can modulate the impact of shade trees on disease regulation. Our results open perspectives for designing complex canopy structure towards healthier tropical AFS.

A coffee AFS in Central Kenya (Murang'a region). Species, location and size of each shade tree have been recorded. Coffee yield, CBD and CLR have been monitored in spring 2010.

Keywords: Coffee agroforestry, Coffe Berry Disease, Coffee Leaf Rust, Spatial structure, Kenya.

L22.P.03

Botryosphaeriaceae disease complex: a threat to baobab and marula in agroforestry systems in Kenya.

Cherotich S.[1] (cherotich.sheillah@yahoo.com), Njuguna J.[2], Graziosi I.[3], Muchugi A.[3], Muthamia J.[1]

[1] *Egerton University, Nakuru, Kenya*; [2] *Kenya Forestry Research Institute, Nairobi, Kenya*; [3] *World Agroforestry Centre, Nairobi, Kenya*

Cultivation of indigenous fruit trees baobab (*Adansonia digitata*) and marula (*Sclerocarya birrea*) plays a pivotal role in providing key nutrients and income for smallholders and enhancing diversification of agroforestry systems in the drylands of South Saharan Africa. Tree decline associated with stem cankers and canopy dieback is increasingly observed impacting baobab and marula in domestication trials and farms in Kenya, but little is known about the disease occurrence and associated pathogens. We evaluated incidence and severity in the field, isolated and characterized fungi in family Botryosphaeriaceae through comparisons of DNA sequences (ITS and Tef 1-α gene), and tested the pathogenicity of selected isolates to baobab, marula and additional agroforestry trees *Vachellia xanthophloea* and *Calodendrum capense* .We identified nine taxa belonging to genera *Lasiodiplodia*, *Neofusicoccum* and *Dothiorella,* co-occurring in both symptomatic and asymptomatic plant material. Seedlings inoculated with isolates of *L. pseudotheobromae*, *L. theobromae* and *N. parvum* showed similar symptoms but with various degree of pathogenicity. These findings suggest that Botryosphaeriaceae spp. may occur as endophytes and act as a disease complex, with the potential of infecting a wide range of trees in Eastern Kenya. We plan to further investigate ecology and impact of this potential threat to agroforestry systems in the African drylands, and lay ground for developing mitigation strategies.

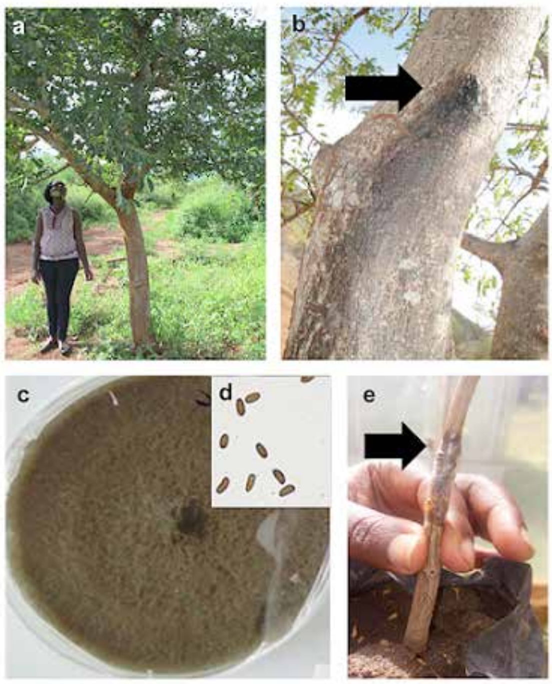


Fig. 1. Sclerocarya birrea in domestication trial in Kitui County, Kenya (a), canker on Sclerocarya birrea stem with exudate produced from the necrotic lesion (b), laboratory culture (c) and conidiospores (d) of Botryosphaeria spp., gum exudates and canker on S. birrea seedling inoculated with Lasiodiplodia theobromae (e).

Keywords: Adansonia digitata, Sclerocarya birrea, tree decline, Botryosphaeriaceae, African drylands.

L22.P.04

Effective management and control of the mahogany shoot borer

Espinoza H.[1] (hernan_espinoza@fhia-hn.org), Coto J.[1], Martinez R.[2], Martinez A.[2], Diaz J.[2]

[1] *Plant protection, FHIA, La Lima, Cortes, Honduras*; [2] *Cocoa and Agroforestry, FHIA, La Lima, Cortes, Honduras*

Mahogany, *Swietenia macrophyla* King, the Neotropical forests' most important commercial wood is threatened and often proposed as a species in extinction. Due to its value, mahogany is the first choice as permanent shade in cacao agroforestry systems in Honduras. However, mahogany plants are affected by early attack of the mahogany shoot borer, *Hypsipyla grandella* (Zeller) (Lepidoptera: Pyralidae). The insect does not kill the plant but induces branching that results in short, non-commercial boles. A team in the Honduran Agricultural Research Foundation (FHIA) conducted a series of trials to develop a strategy to prevent borer damage until 4 m bole length was reached. **Experiment 1 (2010 – 11).** A physical barrier (tangled fiber), chemical odor masking (creolin and naphthalene vapor delivering systems) and chemical control (weekly and fortnightly spot deltamethrin application) were compared against an untreated control. Pest attack among chemical control treatments (8% weekly and 15% fortnight application) was not statistically different, but were significantly lower than the remaining treatments. Physical barrier and chemical masking were statistically similar to non-treated control. **Experiment 2 (2011 – 12).** Deltamethrin was compared to methoxyfenozide and imidacloprid in weekly and fortnightly spray applications. Deltamethrin applications (12% and 21% damaged plants for weekly and fortnightly applications, respectively) were statistically similar to both methoxyfenozide applications (12 to 24% borer damaged plants, respectively), whereas, plants treated with imidacloprid had significantly more borer damage (34 and 78%, respectively) than deltamethrin and methoxyfenozide applications. **Experiment 3 (2013 – 2014).** Weekly spot spray applications of *Bacillus thuringiensis* and *Metarhizium anisopliae* were compared against weekly spot applications of deltamethrin. Borer damage was recorded in 49 and 58% of plants treated with *B. thuringiensis* and *M. anisopliae*, respectively, whereas the insecticide control had 7% damaged plants. Each trial lasted 18 months, time required for plants to reach 3.5 to 4 m height under local conditions. No borer damage was observed before 6 months after planting, therefore, plants were treated for about one year. However, borer feeding on buds continues, but it does not appear to have a significant effect on the plant. Based on these results, we recommend insecticide applications directed to the bud, alternating deltamethrin (Decis®) and methoxyfenozide (Intrepid®) every two weeks until the plant reaches the desired height. Plants attacked during the trial were pruned, selecting the best of new shoots, thus restoring the trunk linear growth. Cost is estimated at $US 20.00 per hectare per month.

L22.P.05

The role of functional leaf traits in pathogenic transmission in agroforestry systems

Gagliardi S.[1] (stephanie.gagliardi@mail.utoronto.ca), Isaac M. E.[1], Avelino J.[2]

[1] *Physical and Environmental Sciences, University of Toronto Scarborough, Scarborough, Ontario, Canada*; [2] *CIRAD, Turrialba, Cartago, Costa Rica*

Variation of plant functional traits may predict ecosystem function[1], yet there is little work linking functional traits of crops and service trees, their interactions, and processes in agroforestry systems[2], specifically the transmission of pathogens. Focusing on coffee as a model, we explore how multi-species functional traits adjust abiotic processes that affect the dispersal and persistence of coffee leaf rust (CLR)[3]. We hypothesize that shade tree canopy and leaf traits will mediate CLR transmission via abiotic modifications and that key coffee functional leaf traits will suppress CLR under different agroforestry systems. This study was conducted in CATIE's coffee agroforestry research trial in Costa Rica. Throughfall kinetic energy under diverse shade tree canopies was modified by shade tree composition, canopy characteristics (e.g. crown base height; CBH) and functional leaf traits (e.g. specific leaf area; SLA). Certain shade tree traits such as canopy depth, CBH and SLA also related to trends in plant-level CLR incidence (Figure 1). CLR tended to favour certain coffee leaf functional traits, where coffee plants with low mean leaf nitrogen concentration and high mean SLA had higher plant-level CLR incidence. These results suggest that managing the functional leaf trait variation of shade trees and targeting key coffee functional leaf traits can change the persistence of CLR, thus improving our understanding of alternative resistance measures available in agroforestry.

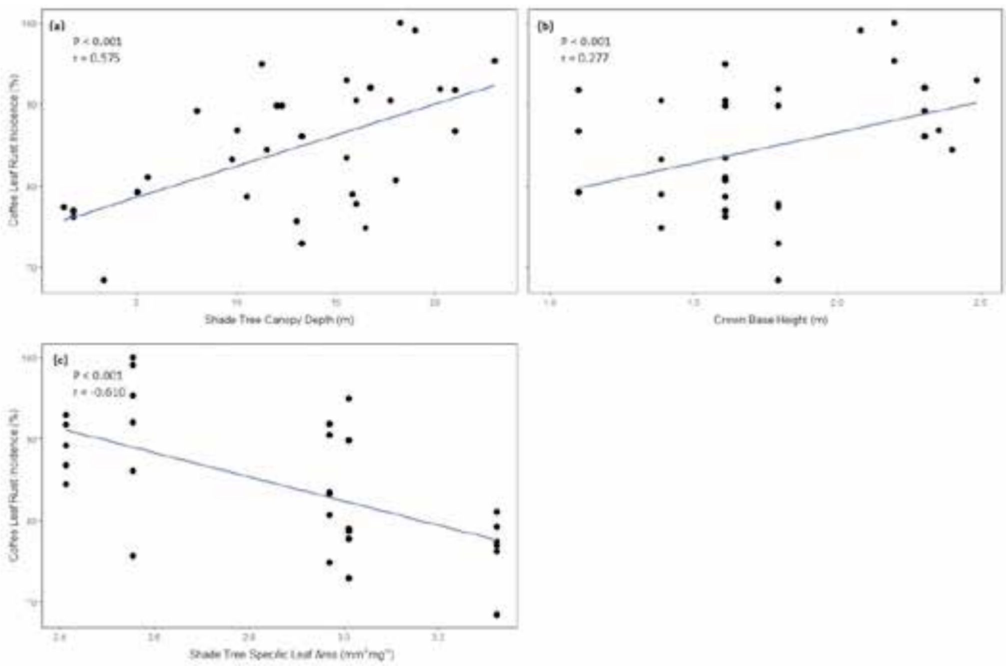


Figure 1. Bivariate relationships between mean plant-level CLR incidence and (a) shade tree canopy depth, (b) log-transformed crown base height, and (c) log-transformed mean shade tree specific leaf area in coffee agroforestry systems.

Keywords: Coffea arabica, coffee leaf rust, Hemileia vastatrix, throughfall kinetic energy, fungal plant disease.

References:

1. Díaz et al., 2016, Nature, 167–171, doi.org/10.1038/nature16489
2. Garnier et al., 2012, Agron. Sustain. Dev., 365–399, doi.org/10.1007/s13593-011-0036-y
3. Boudrot et al., 2016, Phytopathology, 572–580, doi.org/10.1094/PHYTO-02-15-0058-R

L22.P.06

Pest-regulation service of the coffee berry borer (*Hypothenemus hampei*) in agroforestry systems

Roudine S.[1] (sacha.roudine@gmail.com), Carval D.[2], Quintero Perez J. A.[1], Bagny Beilhe L.[1]

[1] *UPR Bioagresseurs, CIRAD/CATIE, Turrialba, Cartago, Costa Rica*; [2] *UPR GECO, CIRAD, Montpellier, France*

The coffee berry borer (CBB) is one of the main pests affecting coffee production leading to significant yield losses. Pest control service within agroforestry systems (AF) results from complex biotic and abiotic interacting components. Factors explaining regulation of the CBB can interact with each other and have potential antagonistic effects. This explains many contradictory results for studies focusing on the impact of few factors on a single response variable. This is particularly true with the effect of shade on the CBB (*Morris et al, 2018*). This factor can directly affect CBB development but also indirectly by affecting the community of natural enemies. Studying this pest-regulation service requires therefore a systemic approach. Here we developed structural equation models describing the interactions within these systems. Using data from three complex AF in Nicaragua and from an experimental farm in Costa Rica, we assessed the effects of environmental conditions and agricultural practices on the CBB, and on the diversity and abundance of predaceous ants (***Fig 1***). The area occupied by coffee-associated trees, the thermal amplitude and the shade were negatively related to CBB. Ant diversity and abundance were negatively related to coffee density, and positively related to CBB. While our results on a systemic scale confirm the potential of AF to provide a pest control and interesting management alternatives, it also reveals the difficulty of studying this service.

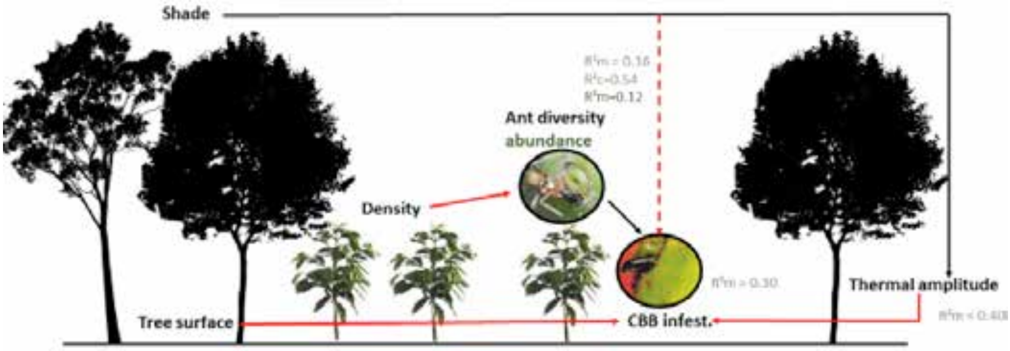


Fig 1. Representative summary of results from global pathway models showing the effects of biodiversity on the coffee berry borer regulation with predaceous ant diversity and abundance, CBB infestation and thermal amplitude as response variables. Black and red arrows represent significant ($p<0.05$) positive and negative relationships respectively. The red dotted arrow represents the negative effect of shade cover on CBB infestation when abundance is considered as a response variable. Marginal (m) and conditional (c) R^2 values for each response variable are indicated. "CBB infest. " is the CBB infestation in September 2017.

Keywords: Hypothenemus hampei, shade, natural control, structural equation modeling.

References:

1. Morris, J. R., Jimenez-Soto, E., Philpott, S. M., & Perfecto, I. ,2018, Myrmecological News, 26,1-17

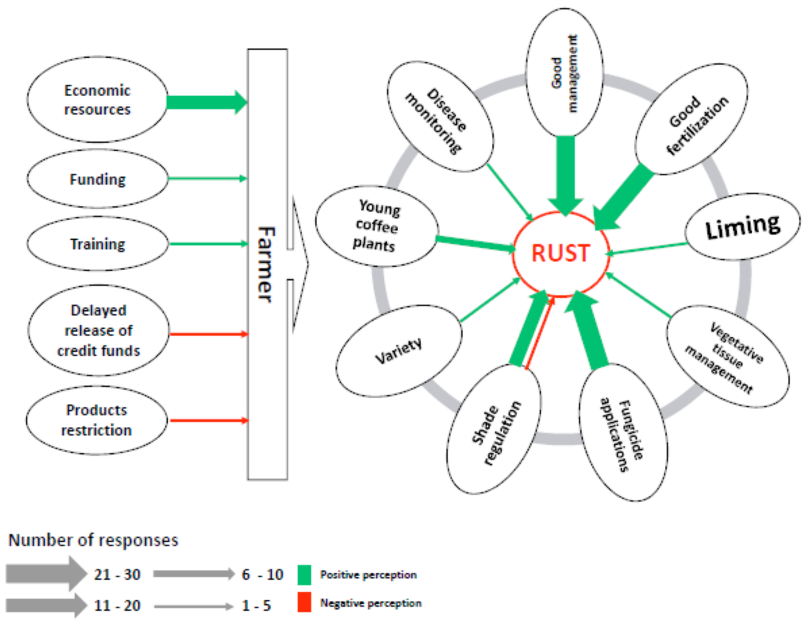
L22.P.07

Not shade, but economic pressures as important drivers of coffee rust epidemics in Nicaragua

Villarreyna R.[1] (rvillareyna@catie.ac.cr), Barrios M.[2], Vílchez S.[1], Cerda R.[1], Vignola R.[3], Avelino J.[4]

[1] *CATIE, Turrialba, Costa Rica*; [2] *CATIE, Managua, Nicaragua*; [3] *Environmental Policy Group, Wageningen University and Research, Wageningen, The Netherlands*; [4] *UPR 106, CIRAD, Turrialba, Costa Rica*

Very severe coffee rust (*Hemileia vastatrix*) epidemics of an intensity never seen before have hit Central America from 2012.
This study aimed at identifying management factors that hampered coffee rust development in Nicaragua and at learning about how producers understood these epidemics. Twenty nine pairs of coffee-based agroforestry plots (a pair was one plot severely hit and another one slightly hit in the same location) from the municipalities of Jinotega, Tuma-La Dalia and San Ramón were characterized for their management, including shade, and coffee rust impact, and their owners interviewed for studying their perception (2).
The main drivers of these coffee rust epidemics were meteorological (1). In these propitious weather conditions for rust, some producers avoided intense epidemics and losses. According to field measurements, shade did not make the difference, contrary to timely applications of fungicides and fertilizers. However, interviewed producers mentioned that shade affected rust (Figure); but this was the only controversial effect mentioned. Interestingly, this controverse also exists in scientific literature. Producers were well aware and agreed, in general, about practices to control rust. Although producers knew how to fight rust, they did not implement the required management to control this disease, mainly due to economic difficulties. To our knowledge, this is the first time that the development of severe outbreaks is related to economic drivers.



Conditions that favored or hampered coffee rust in 2012 according to producers

Keywords: Hemileia vastatrix, Outbreak, Chemical control, Fertilizer.

References:

1. Avelino et al. 2015. Food Security 7: 303-21. 10.1007/s12571-015-0446-9
2. Villarreyna Acuña 2014. Master Thesis. CATIE, Turrialba, Costa Rica. 80 pp.

ABSTRACTS

Biophysics of agroforestry systems

The wonders of agroforestry's biophysics

- L23 -
Root issues in agroforestry

Tree and crop roots: exploring the hidden half of an agroforest

Interactions between tree and crop root systems are poorly understood in agroforestry systems, yet are crucial for the success of co-existing crops.
Although access to resources of water and nutrients can be enhanced by a greater extension of fine roots in space and through time, major competition can occur between tree and crop roots for the same resources. Appropriate management can help to reduce this competition and even stimulate facilitative and complementary interactions. Management tools include suitable species selection, spacing, timing of sowing, mulch applications, shoot pruning, and ploughing or root pruning. Patterns of root activity around individual plants also differ between species; understanding these patterns may help to avoid excessive competition and unproductive nutrient losses in agroforestry systems through suitable spacing and fertiliser placement.
In this session, we will discuss: what are the specific interactions between root systems of different tree and crop species and how can these interactions be managed? How does the biological and physical soil environment influence root system interactions? Can belowground interactions between species be included in growth and production models?

L23_O.01

Effect of coppice management of shrubs associated with cereals on their root dynamics features in dry Western Africa

Jourdan C.[1] (jourdan@cirad.fr), Sambou D.[2], Ouedraogo A.[3], Dione M.[4], Tounou N.[3], Pouya M.[3], Arnal D.[5], Bayala R.[6], Lahmar R.[7], Douzet J.-M.[8], Cournac L.[9]

[1] *UMR Eco&Sols, CIRAD, Dakar, Senegal*; [2] *UCAD, Dakar, Senegal*; [3] *2IE, Ouagadougou, Burkina Faso*; [4] *University of Thiès, Thiès, Senegal*; [5] *UMR Eco&Sols, INRA, Montpellier, France*; [6] *CERAAS, ISRA, Thiès, Senegal*; [7] *UPR AIDA, CIRAD, Tunis, Tunisia*; [8] *UPR AIDA, CIRAD, Ouagadougou, Burkina Faso*; [9] *UMR Eco&Sols, IRD, Dakar, Senegal*

To cope with nutrient depletion in poor soils, agronomic strategies have been set up in West Africa by combining traditional annual crops with local shrubs, such as *Guiera senegalensis* or *Piliostigma reticulatum*, which contribute significantly to improve soil fertility. These shrubs are traditionally cut to provide fodder to livestock and let the aerial parts of associated crops, such as millet or sorghum, growing freely. The objective of this study was to evaluate the effect of the management mode of *Guiera* and *Piliostigma* in association with millet and sorghum, respectively, on the dynamics and phenology of shrub roots and the agronomic performances of cereals. An experiment was conducted under natural conditions in Senegal where 6 shrubs of *Guiera*, already well established for several decades, were chosen. Nine young *Guiera* plants were transplanted to characterize juvenile stage. A millet crop has been established per pouch in and near each shrubbery. A similar experiment was installed in Burkina Faso at the same time where 12 shrubs of *Piliostigma*, 6 aged of several decades and 6 transplanted juveniles, were associated or not with sorghum. In both situations, half of the shrubs were coppiced, the other left intact as a control object. Rhizotrons of 1x1m were placed 20cm from each shrub in a vertical position, allowing observation of the roots of the shrubs and cereals between 0 and 1m deep.

The results showed the positive impacts of the shrubs on the aerial phenology of millet and sorghum (earlier heading, flowering and maturation), their growth (millet four times larger, 1.5 times more leaves, 1.8 times more tillers) and their yield (3.8 times more spikes, 3 times more spike biomass and straw). The root dynamics of shrubs are stalled over the rainy season with a very pronounced seasonal variation in all root categories: higher elongation rates in the wet season compared to the dry one. This seasonal variation was observed in both young 1 to 3 year-old plants (0.62 cm/day in the rainy season and 0.36 cm/d in the dry season) and old (0.15 cm/d and 0.13 cm/d respectively the same year). On the other hand, shrub coppicing did not show any significant depressive effect on the average rate of elongation of their roots. However, a 1-month root-growth stop was observed for *Guiera* 1.5 months after cutting, a condition that did not exist in uncut shrubs. In addition, these growth stops correspond exactly to the peak of cereal root growth, a phenomenon observed for the 3 consecutive years.

The coppice management of the shrubs has a positive influence on the phenology, the agro-morphological parameters and yield of millet and sorghum through a better conservation of the physicochemical and biological properties of the soil as well as a good complementarity of root growth providing benefits and sustainability to cereal shrub intercropping in the context of climate change with strong drought constraints.

Keywords: Guiera senegalensis, Piliostigma reticulatum, Pennisetum glaucum, Sorghum bicolor.

L23_O.02

Do perennial alleys help to maintain arbuscular mycorrhizal communities in temperate agroforestry systems ?

Battie-Laclau P.[1] (patricia.laclau@mycea.fr), Taschen E.[2], Dezette D.[2], Plassard C.[2], Abadie J.[3], Arnal D.[2], Benezech P.[2], Duthoit M.[4], Pablo A.-L.[5], Jourdan C.[4], Laclau J.-P.[4], Bertrand I.[2], Hinsinger P.[2]

[1] *Mycea, Montpellier, France*; [2] *Eco&Sols, INRA, Montpellier, France*; [3] *INRA, Montpellier, France*; [4] *Eco&Sols, Cirad, Montpellier, France*; [5] *Eco&Sols, IRD, Montpellier, France*

Arbuscular mycorrhizal (AM) fungi are crucial for plant nutrition and the sustainability of agro-forestery systems. However, the contribution of each agroforestry component (i.e. trees, under-tree herbaceous vegetation -UtHV- and crops) in the establishment and maintenance of AM communities is poorly documented particularly in temperate areas. This study investigates the spatio-temporal dynamics of AM fungi colonizing roots of the three agroforestry components in southwest France. Standing fine root length density and production, AM activity (colonization and extraradical hyphal growth) and diversity of walnut trees, UtHV and soft wheat were assessed over one year in two agroforestry systems at different distances from the perennial tree-UtHV alley. Compared to UtHV, trees showed a higher ability to colonize superficial layers far into the cultivated alleys due to their wider root system in summer. However, due to higher root densities and well established AM fungi observed throughout all the year, UtHV appeared to be more ecologically relevant to maintain an active source of AM inoculum for newly developing crop roots in winter. High degree of root proximity and similarity of AM fungal communities among the three agroforestry components provide new perspectives in deciphering the significance of common mycorrhizal networks in plant to plant interactions.

Keywords: metabarcoding, phenology, root length density, root distribution, under-tree herbaceous vegetation.

L23_O.03

Competition and complementarity of agroforestry components by carbon sequestration in soil: 13C labeling and tracing

Shi L.[1] (slingli@gwdg.de), Pausch J.[2], Kuzyakov Y.[3]

[1] *Agricultural Soil Science, Georg August University of Göttingen, Göttingen, Germany*; [2] *Department of Agroecology, University of Bayreuth, Bayreuth, Germany*; [3] *Kazan Federal University, Kazan, Russia*

The most carbon (C) budget studies in agroforestry (AF) focus on aboveground plant biomass accumulation. However, the plant C input belowground, rhizosphere processes and their functions are disregarded despite they are crucial for short- and long-term C budget, SOM formation and C sequestration, microbial activities and nutrient mobilization as well as formation and stability of soil aggregates , and so, for soil fertility and ecosystem stability. The objective of our study was to trace the photosynthetically fixed C distribution patterns of plant components of AF system, to calculate their rhizosphere C inputs and to evaluate the contribution of each AF component to the whole C budget of AF system. The experimental AF system located in the central part of Germany included three components: willow (tree), rape (crop) and *Lolium* (grass).13C pulse labeling experiment was conducted under field conditions to investigate pools and fluxes of photosynthetically fixed C in willow, rape and grasses. Grasses have larger 13C losses by soil respiration right after the labeling: larger and faster than the rape and the willow. After 2 months, rape incorporated the highest recovered 13C in shoot biomass (40%), followed by *Lolium (20%)* and lowest in tree (10%). *Lolium* have higher recovered 13C in root biomass than rape (4%) and willow (1%). Recovered 13C in total soil organic C were higher in *Lolium* than in rape or willow. 13C leaching as DOC was maximal under willow. 13C incorporation into soil microbial biomass was maximal under grassland. Recovered 13C in soil C pools under rape and *Lolium* were higher in surface soil (0-15 cm) than in deeper soil (15-30 cm). In contrast, willow show similar 13C incorporation in both soil layers. We conclude that tree in AF system incorporated C slowly into the stem biomass and a part will be leached as DOC into deeper soil . This can be beneficial for C stabilization on clay minerals and sesquioxides, which further benefit for long term C sequestration. In contrast, grassland have the highest and fastest rhizosphere C input to microbial community. Microorganisms use this C, recycle it and mobilize nutrients. Concluding, the combination of tree with grassland or cropland within the AF system decreases C losses and accelerate nutrient transformation necessary for crop growth.

Keywords: 13C labeling, agroforestry, carbon sequestration, C budget, willow.

L23_O.04

Tree roots anchor soil and reduce landslide risk: case studies in Indonesia

Hairiah K.[1] (kurniatun_h@ub.ac.id), Widianto W.[1], Suprayogo D.[1], van Noordwijk M.[2]

[1] *Soil Science, Brawijaya University, Malang, East Java, Indonesia*; [2] *-, World Agroforestry Centre, ICRAF, Bogor, West Java, Indonesia*

Landslides can be destructive for any vegetation or people in its path. In the context of a broad evaluation of agroforestry role in maintaining/restoring watershed functions in the humid tropics, we tested two hypotheses: (1) Differences in the distribution of tree roots between species in coffee agroforestry systems can be used to reduce landslide risks, (2) Shear strength of soil increases with root length density in the topsoil, regardless of plant species.
Root systems of about 570 5-year old trees belonging to 114 species commonly found in agroforestry systems were observed across 5 landscapes (Figure 1). The *Index of Root Anchoring* (IRA) and the *Index of Root Binding* (IRB) were calculated as S Dv2 /dbh2 and as S Dh2 /dbh2, respectively, where dbh is tree diameter at breast height, Dv and Dh are the diameters of vertical (angle >45o) and horizontal (angle <45o) roots.
High IRA values (>1.0) were observed in non-pruned coffee, *Artocarpus elasticus, Parkia speciosa* and *Durio zibethinus.* The common shade trees in coffee agroforestry system incl. *Gliricidia sepium* and *Calliandra calothyrsus,* have low IRA values, indicating little 'soil anchoring'. Where root length density (Lrv) in the topsoil is less than 1 cm cm-3 shear strength largely depends on texture; for Lrv > 1 we can expect shear strength to be > 1.5 kg m-2 regardless of texture. In conclusion, a mix of tree species with deep roots and grasses with intense fine roots will provide the highest river bank stability.

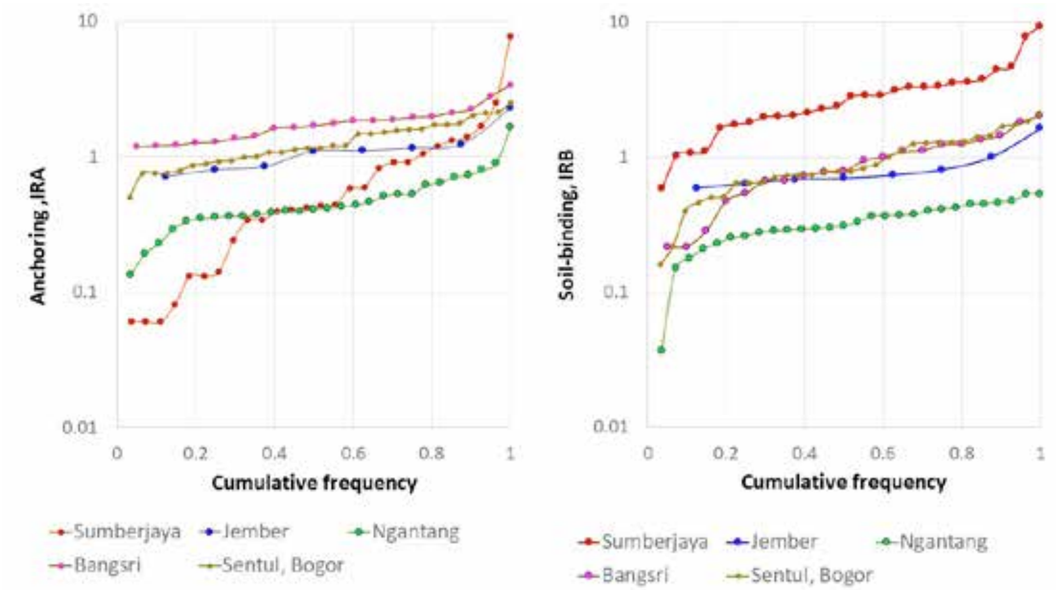


Figure 1. Cumulative frequency of average Index Root Anchoring (IRA) and Index of Roots Binding (IRB) of 570 plants sample of 114 trees species across five study sites

Keywords: Index of Root Anchoring, slope stability, soil shear strength, root length density, root strength.

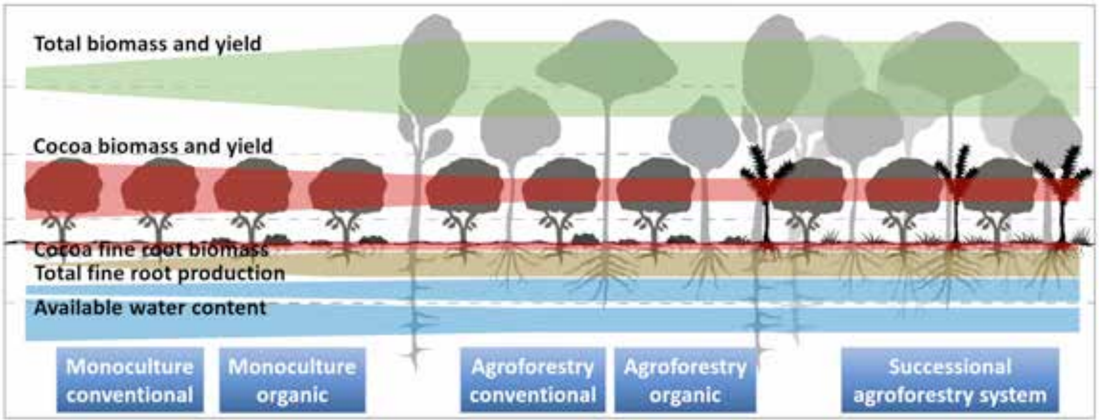
L23_O.05

Belowground competition and aboveground production in cocoa (*Theobroma cacao* L.) monocultures and agroforestry systems

Niether W.[1] (wiebke.niether@geo.uni-goettingen.de), Schneidewind U.[1], Fuchs M.[2], Schneider M.[3], Gerold G.[1], Armengot L.[3]

[1] *Institute of Geography, University of Göttingen, Göttingen, Germany*; [2] *University of Kassel, Kassel, Germany*; [3] *Department of international cooperation, FiBL, Frick, Switzerland*

The cocoa tree has a shallow rooting system, but rooting characteristics of associated trees are rarely known, making belowground competition for water and nutrients likely. To show the use of resources of cocoa and associated species, we compared five cocoa production systems comprising a conventional monoculture, an organic monoculture with a leguminous cover crop, both conventional and organic agroforestry systems with associated trees and bananas, and a successional agroforestry system that included additional trees and herbaceous crops. We measured cocoa above- and belowground biomass and horizontal distribution of cocoa fine roots in the topsoil and analyzed the total fine root production in one year. We referred this to the aboveground production of the systems. Soil moisture was measured to account for water competition. The cocoa root growth was homogenously distributed over the area in all production systems with no differences between systems, but the increase of the root:shoot ratio from monocultures to agroforestry systems imply a nutrient competition with the associated trees and crops. Total fine root production increased strongly by the leguminous cover crop and further by trees and bananas in the agroforestry systems. In agroforestry systems, the high aboveground biomass and total system yield compensated for the lower cocoa yield compared with monocultures and the lower water content below the cocoa rooting zone implied high total soil resource exploitation.



Cocoa and total system roots and aboveground production and the available water content over a gradiant of cocoa production systems

Keywords: root competition, cover crop, organic, water, yield.

L23_O.06

Root studies in agroforestry systems – a case study of coffee and cocoa trees

Hosseini Bai S.[1] (shossein@usc.edu.au), Trueman S. J.[2], Wilson R.[2], Keller A.[3], Shapcott A.[2], Hannet G.[4], Wallace H. M[2]

[1] *Central Queensland University, Bundaberg, QLD, Australia*; [2] *University of the Sunshine Coast, Maroochydore, Australia*; [3] *University of Würzburg, Würzburg, Germany*; [4] *NARI, Keravat, Papua New Guinea*

Root interactions between cash crops and neighbouring trees remain a major gap of knowledge. Both cacao and coffee are important cash crops and are usually planted under shade trees to optimise their yield. Ideal shade trees would develop their root systems below the cacao and coffee root zones, minimizing plant competition for nutrient uptake in the soil layers. However, assessment of root development in soil remains highly challenging. Destructive excavation provides root biomass and root morphology data. However, the abundance of fine roots of an individual plant species in a mixed-species plantation remains unknown because it is difficult to identify the species of fine roots that are present. We used DNA meta-barcoding to determine the presence and abundance of fine roots of each species in the soil profile to a depth of 80 cm. We assessed two plantations at 9 years after the establishment of cacao and coffee with an overstorey of canarium trees. We also examined soil and foliar nutrient concentrations including total nitrogen (TN), phosphorus (P) and potassium (K), and N isotope composition (δ15N). Cacao and coffee had higher fine-root abundance at 0-30 cm depth, whereas canarium had higher fine-root abundance at 30-80 cm depth. Stepwise regression indicated that soil nitrate at a depth of 10-30 cm explained 92% of foliar δ15N variation in cacao and coffee. Foliar TN was higher in cacao and coffee than in canarium and foliar K did not differ significantly between cacao, coffee and canarium. Our study indicated that canarium could be a suitable shade tree for cacao and coffee. DNA metabarcoding allowed us to develop a deeper understanding of root development through the tropical soil profile.

Keywords: nitrogen isotope composition, soil fertility, agroforestry, canarium, rbcL gene.

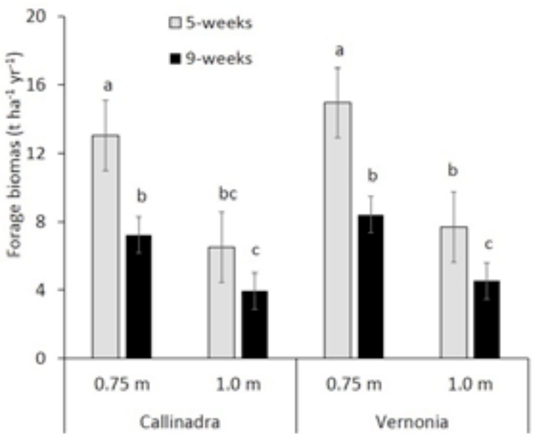
L23_O.07

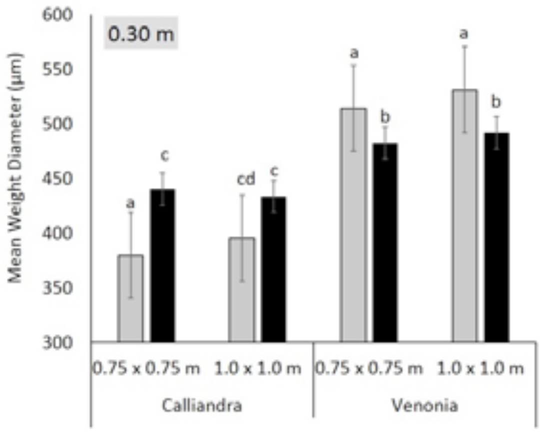
Forage biomass yield and soil aggregate carbon under fodder banks with contrasting management regimes

Fungo B. (bfungo1@yahoo.com), Buyinza J., Sekatuba J., Nansereko S., Ongodia G., Kwaga P., Mudondo S., Eryau K., Akellem R.

Agroforestry Research Program, NARO, Kampala, Uganda

Fodder banks agroforestry can improve animal feed for smallholder farmers but depletion of soil nutrients and organic carbon (OC) in biomass transfer downplays sustainability. We determined effect of management (spacing & pruning frequency) on fodder yield and soil aggregate C distribution of two contrasting fodder shrubs (leguminous *Calliandra calothyrsus and* non-leguminous *Vernonia amygdalina*). A field trial was established with the two shrubs separately planted at different spacing (75 x 75 m and 100 x 100 m) & pruning frequency (1.5 & 3 months interval) in a three-replicate randomized complete block design. Harvesting of biomass was done for two consecutive years from the start of cutting-back. Soil aggregate C (0-15 and 15-30 cm) was assessed in four particle-size fractions (<0.53-S+C, 53-250-SM, 250-1000-M and > 1000 µm-LM). Forage biomass was 1.2 times higher for *Calliandra sp* than *Vernonia sp*. Wider spacing reduced forage biomass by 20%. Cutting-back at nine weeks produced more forage biomass for *C. calothyrsus*, but not for *V. amygdalina*. Mean Weight Diameter of soil aggregates increased by 8% in the nine-week compared to five-week cutting frequency. Total organic carbon (TOC) in subsoil under *C. calothyrsus* was 7% higher than under *V. amygdalina*. Wider spacing and lower cutting frequency increased OC in subsoil by 4% and 9%, respectively. Thus, soil improvement and sustainability of fodder banks can be achieved by optimizing cutting frequency and plant spacing.





Keywords: Forage biomass, Harvesting frequency, Plant spacing, Soil carbon, Aggregate distribution.

L23_O.08

Stand density influences on fine root dynamics in *Acacia mangium* Willd stands at Kerala, India

Kunhamu T.K.[1] (kunhamutk@gmail.com), Rocha D.[2], Santhoshkumar A.V.[2], Jamaludheen V.[1]

[1] *Silviculture and Agroforestry, College of Forestry, Kau, Thrissur, Kerala, India*; [2] *Forest Biology and Tree Improvement, College of Forestry, Kau, Thrissur, Kerala, India*

The functional role of fine roots in carbon and nutrient dynamics in woody systems is imperative despite the limitation in quantitative information for most tropical tree species (Gill and Jackson, 2000). Stand density regulation is a proven strategy for optimizing productivity and product quality in forest plantations and agroforestry which may also influence fine root production. In this pursuit a field study was conducted to assess the fine root production and turnover, decomposition, carbon and nutrient flux and their response to variable stand density in a 12-year-old *Acacia mangium* stand located at Thiruvazhamkunnu, Kerala, India during 2013-14. The *A. mangium* stand was established during September 2001 at four planting densities viz 5000, 2500, 1250 and 625 trees ha^{-1}. Annual fine root production was estimated following soil ingrowth method (Neill, 1992). Sequential coring method was employed for the assessment of standing root biomass (Jordan et al., 2008). Fine root decomposition rate, carbon and nutrient (N, P, K) content and release was assessed for a period of one-year using conventional litter bag technique and standard nutreint analysis procedures.
Stand density clearly influenced the fine root production with higher production attached with high density stands. The annual fine root production estimates were 5.78, 5.38, 3.74, and 3.38 Mg ha^{-1} for 5000, 2500, 1250 and 625 tree ha^{-1} stand densities, respectively. Mean tree fine root production followed inverse trend with highest production from low density stand (5.42 kg yr^{-1}; 625 trees ha^{-1}). *Acacia mangium* showed fairly high fine root turnover that ranged from 2.81 to 3.16 yr^{-1} which however had less effect on stand density. Allometric models based on tree diameter or basal area as predictor variables showed good predictions of fine root production. Simple and quadratic models were better in fine root predictions. Carbon content in the annual fine root production ranged from 1.36 to 2.39 Mg ha^{-1} across the stand densities of which >90% released to the soil in one year. Nitrogen, phosphorus and potassium in the decomposing fine roots had undergone substantial release to the soil. The corresponding percentage release to the soil through fine root decomposition was 75.78, 76.50 and 75.89 respectively for N, P and K respectively.
The prominent role of fine roots as the major player in soil nourishment in *A. mangium* and their regulation through density management has been clearly demonstrated in the study. This self-nourishment may be advantageous for integrating suitable intercrops especially in widely spaced stands. Higher C return through fine roots suggest fast growing tree species like *A. mangium* may be a suitable candidate tree in the carbon inventory sector. Furthermore, development of allometric models for fine root estimation has been a prudent strategy to quantify fine root production through nondestructive means.

Keywords: fine root production, turnover, allometric model, decomposition, nutrient release.

References:

1. Gill, et al, 2000, New Phytol, 13–31
2. Jourdan, et al, 2008, For. Ecol. Manage, 396–404
3. Neill, 1992, Ecology, 1918–1921

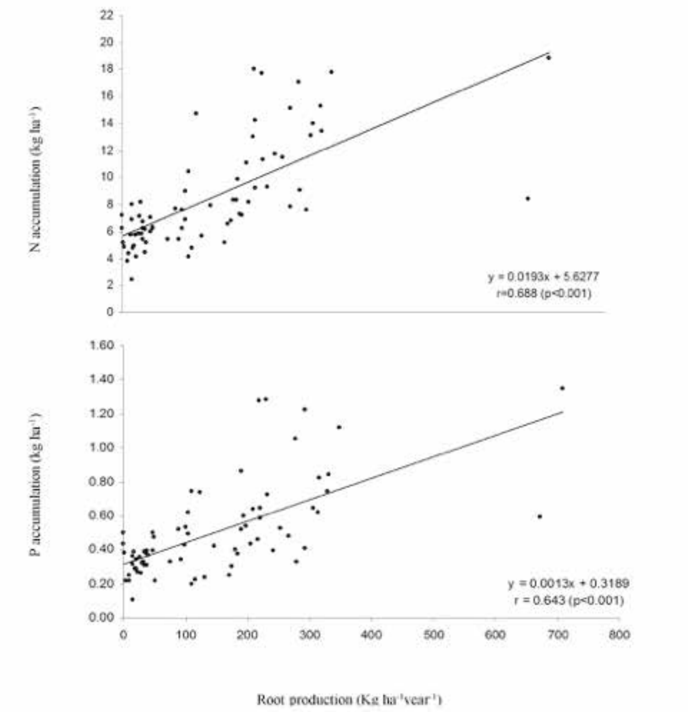
L23_O.09

Root biomass and nutrient (N&P) turnover in traditional agroforestry sytems of Northeast India

Deb S.[1] (sdeb@tripurauniv.in), Arunachalam A[2], Das A. K.[3]

[1] *Forestry and Biodiversity Department, Tripura University, Agartala, Tripura, India*; [2] *Krishi Bhawan, Indian Council for Agricultural Research, New Delhi, India*; [3] *Ecology and Environmental Science, Assam University, Silchar, Assam, India*

The importance of roots in nutrient dynamics of traditional agroforestry system was studied in two ethnic communities *viz*., `Kalitas' (Harmutty village) and `Nyishis'(Nirjuli and Doimukh village) of northeast India. Root biomass was studied by soil corer method. The study shows that within the investigated soil profile maximum fine roots were in the top 0-10 cm soil profile and coarse roots in the 20-30 cm depth. Good management practice (indigenous use of cowdung and other biofertilizers) by the farmers of Harmutty village in traditional agroforests resulted in greater fine root biomass. The fine and coarse root biomass showed significant increase or decrease with the climatic variables. The study of root turnover of different diameter classes of roots showed that larger diameter fine roots have longer expectances than the smaller diameter fine roots. This fine and coarse root turnover varied with site quality, root size and species composition in traditional agroforestry systems. Fine roots play an important role by accumulating detritus and redistributing nutrient in to the soil profile (Persson, 1990). N accumulation of fine and coarse roots was higher than P accumulation and the rate of N and P accumulation in fine roots decreased with increasing soil depth, due to limited input of organic matter. Nonetheless, proper recycling of plant detrital matter may help in the sustainable nutrient management of the soil *per se*.



Relationship between root production and nutrient accumulation in traditional agroforestry system

Keywords: Biomass, Productivity, Nutrient, fine roots, coarse roots.

References:

1. Persson, In: Nutrient cycling in Terrestrial Ecosystems,1990, Harrison, 198-217

L23_O.10

Response of Commiphora seedlings to mycorrhizal inoculation, soil fertility, and moisture deficit

Birhane E.[1] (emiru.birhane@mu.edu.et), Damtew A.[1], Tesfay A. T.[1], Bongers F.[2], Kuyper T. W.[3]

[1] *Land Resource Managment, Mekelle UNiversity, Mekelle, Tigray, Ethiopia*; [2] *Forest Ecology and Management, Wageningen University, Wageningen, Netherlands*; [3] *Soil quality, Wageningen University, Wageningen, Netherlands*

In dry ecosystems where silvo-pasture is the common farming system, seedling growth and survival are limited by access to moisture and nutrients. Arbuscular mycorrhizal (AM) fungi are known to increase seedling establishment and survival through enhancement of nutrient and moisture availability. Arbuscular mycorrhizal fungi are regular component of rhizosphere micro-flora in natural ecosystem and are necessary for sustainable plant soil systems by establishing symbiotic associations with most land plants and form mycorrhizae. Keeping in view the importance of these environment friendly micro-organisms and understanding how mycorrhizas operate in natural systems helps to improving the quality of plants in our gardens and landscapes while minimizing the need for fertilizer and water. We used a greenhouse experiment to determine the interactive effect of AM, water deficit and soil fertility on the biomass, growth, nutrient availability, and root colonization of seedlings of *Commiphora myrrh*, tree species that dominate large areas of dry forest in the Horn of Africa. A full factorial design was used: with and without AM, top and subsoil, and four levels of water deficit. AM increased the biomass of *Commiphora myrrh* seedlings. AM increased the allocation of biomass to shoots in *C. myrrh* seedlings. The seedlings had higher nutrient levels when mycorrhizal under water deficit conditions. *C. myrrh* seedlings responded positively to decreased moisture deficit. Rich soil condition favoured the growth of the seedlings. Colonization increased with decreased moisture in *C. Myrrh* seedlings. Rich soil positively affected colonization of the species. AM increased the biomass growth of *C. myrrh* seedlings through increased nutrient levels and colonization. The increased performance of mycorrhizal plants indicates that mycorrhiza is a major component of the adaptive strategy of seedlings in the dry deciduous ecosystem. For successful rehabilitation efforts, seedlings need to be mycorrhizal. Inoculating seedlings with AM in the nursery enables to increase survival, growth and escape browsing in the field where grazing is a major problem in an agro-pastoral system.

Keywords: arbuscular mycorrhiza, dry deciduous woodland, water deficit, soil fertility, C. myrrh.

References:

1. Augé, R. M. 2001. Mycorrhiza, 11, 3-42.
2. Birhane, E., Sterck, F. J., Fetene, M., Bongers, F. & Kuyper, T. W. 2012.Oecologia, 169, 895-904
3. Haselwandter, K. & Bowen, G. D. 1996. Forest ecology and management, 81, 1-17.
4. Van der Heijden, M. G. 2004.Ecology letters, 7, 293-303.

L23.P.01

Arbuscular mycorrhiza fungi spore density and root colonization in a dry Afromontane forest in northern Ethiopia

Birhane E.[1] (emiru.birhane@mu.edu.et), Fisseha K.[1], Taye G.[1], Aynekulu E.[2], Norgrove L.[3], Meles Hadgu K.[4]

[1] *Land Resource Managment, Mekelle University, Mekelle, Tigray, Ethiopia*; [2] *Soil quality, ICRAF, Nairobi, Kenya*; [3] *Bern University of Applied Sciences, Zollikofen, Switzerland*; [4] *ICRAF, Addis Ababa, Ethiopia*

The abundance and distribution of arbuscular mycorrhizal fungi (AMF) in forest soils depends upon environmental conditions and habitat disturbance. We investigated the effect of three plant communities and soil properties on the AMF spore density and root colonization and soil properties in a dry Afromontane forest. Soil and root samples were collected from 65 permanent plots of 50 m x 50 m, assessed for AMF spore density and root colonization from four sides of each tree plant, and replicated three times for dominant woody species across two soil depths. Analysis of soil chemical properties and determination of soil carbon stock were conducted across two soil depths. All three-plant communities were colonized by AMF. Juniperus procera-Maytenus senegalensis community (Jupr-Mase) and Cadia purpurea-Opuntia ficus indica community (Capu-Opfi) had the highest and lowest AMF spore density and root colonization respectively. Pterolobium stellatum-Celtis africana community (Ptst-Ceaf) did not show significant difference with Jupr-Mase and Capu-Opfi. The top soil (0-25 cm) had significantly ($p < 0.05$) higher AMF spore density but lower root colonization percentage than the sub-soil (25-50 cm). We also found significant correlation ($p < 0.05$) between soil carbon and spore density. Plants in Jupr-Mase community were suitable hosts for AMF and had higher soil carbon stock due to low disturbance and dense tree cover. Conserving remnant dry Afromontane forest have great role on harboring AMF and increased soil carbon stock which is important in increased soil carbon and climate change mitigation.

Keywords: AMF, Plant Community, Carbon Stock, Root colonization, Spore density.

References:

1. Brundrett M, Bougher N, Dell B, Grove T, Malajczuk N (1996) ACIAR Monograph 32
2. Birhane, E., Aregawi, K., & Giday, K. (2017). Journal of Arid Environments, 142, 1-10

L23.P.02

Mycorrhizal networks and nitrogen fluxes between *Pterocarpus officinalis* and Taro in swamp forests of Guadeloupe

Galiana A.[1] (antoine.galiana@cirad.fr), Geoffroy A.[2], Sanguin H.[3], Bâ A.[4]

[1] *LSTM, CIRAD, Le Lamentin, Martinique*; [2] *LSTM, University of Antilles, Montpellier, France*; [3] *LSTM, CIRAD, Montpellier, France*; [4] *LSTM/LBPV, University of Antilles, Pointe-à-Pitre, Guadeloupe*

Swamp forests of *Pterocarpus officinalis* (jacq.) form remarkable monodominant forest stands growing on temporarily or permanently flooded soils in mangrove hinterland areas, along rivers and in wet depressions in the mountains of the Caribbean and Guiana regions. In Guadeloupe, smallholder farmers traditionally cultivate flooded Taro (*Colocasia esculenta* (L.) Schott) monocultures under the canopy of *P. officinalis* stands in the swamp forests. Taro corms and unrolled leaves are commonly consumed in Guadeloupe. The understorey culture of Taro is conducted without pesticides and fertilizers, which could be partly due to the net input of nitrogen into the soil by *P. officinalis* through its ability to fix atmospheric nitrogen. Furthermore, the mycorrhizal networks could favor the transfer of fixed nitrogen from *P. officinalis* to the intercropped Taro. Taro cultivation is conducted during the dry season to facilitate their planting between mature *Pterocarpus* trees and their harvest when the marshy soils are dewatered. The sampling of roots and leaves on Taro and two cohorts of *P. officinalis* (mature trees and seedlings) were made during the dry season in two swamp forest sites located at Gosier (approx. 0.1 ha in area) and Belle-Plaine (approx. 0.5 ha in area) in the island of Grande-Terre, Guadeloupe. The arbuscular mycorrhizal (AM) fungal community was compared between Taro and two cohorts of *Pterocarpus*, by using pyrosequencing of partial 18S rDNA gene. We also compared natural abundance of 13C and 15N contents in leaves of the two cohorts of *Pterocarpus*, Taro and surrounding non-nitrogen-fixing plant species, in order to estimate what proportions of N and C were transferred to Taro. Of the 210,676 sequences, 37,631 sequences were assigned to a total of 215 OTUs belonging to the orders of Glomerales, Paraglomerales, Archeosporales and Diversisporales. A low AM fungal community membership was observed between *P. officinalis* and *C. esculenta*. However, certain AM fungal community taxa overlapped between both plants, notably predominant *Funneliformis* OTUs, suggesting a potential common AM network. The isotopic analyses did not show any direct link between the mycorrhizal status of both associated species and the transfer of N and C between *P. officinalis* and Taro. The proportion of N derived from atmospheric fixation in *P. officinalis* varied according to the study site, from about 80 to 95% in adult trees and from 50 to 80% in young seedlings while we estimated that 35% of fixed N was transferred from *Pterocarpus* seedlings to Taro in mixed stands of both species. The implementation of experiments under controlled conditions are needed to demonstrate the possible role of mycorrhizal networks in the transfer of nutrients between *P. officinalis* and Taro.

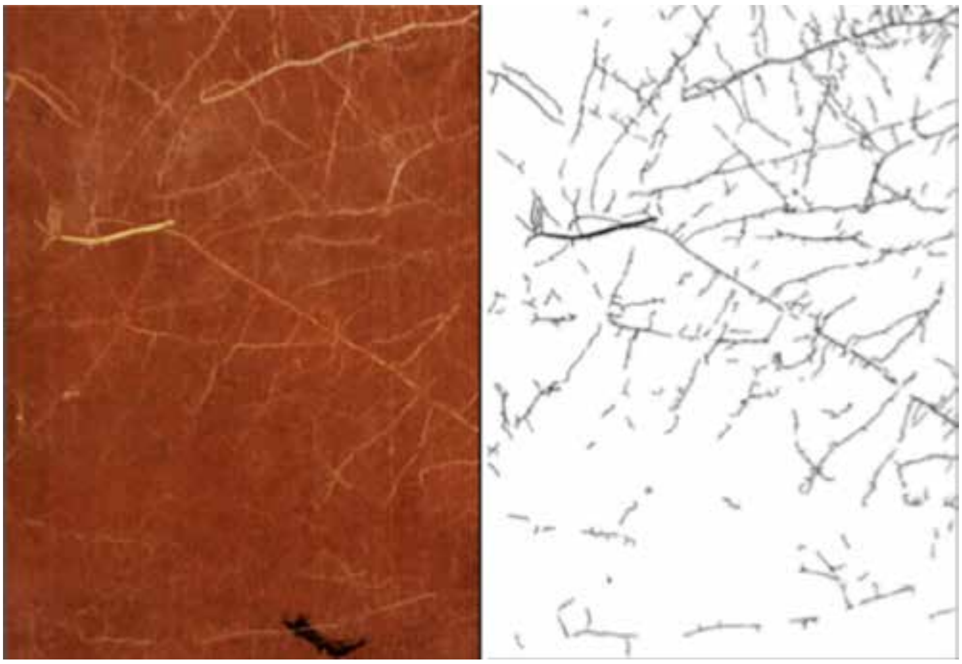
L23.P.03

AutoRootDraw - Using machine learning to develop auto root drawing model for field root images.

Maeght J.-L.[1] (jean-luc.maeght@ird.fr), Do Q. H.[2], Larmande P.[3], Hoang T. T.[2], Tai D. T.[2]

[1] *EcoBio, IRD SFRI, Hanoi, Vietnam*; [2] *ICTLab, USTH, Hanoi, Vietnam*; [3] *IRD USTH, Hanoi, Vietnam*

Background and aims
Most studies on root development are based on root images analysis with rhizotrons sources to study root turnover, which essential for understanding ecosystem carbon and nutrient cycling on large situation including agroforestry system. Yet extracting data from field root images requires intensive effort and was large time consuming even with semi automatic root software drawing. Our aim was to develop real automatic root drawing model capacity using machine-learning capacity.
Methods and results
Images are renamed and re-organized in the proper structure for the convenience of training and testing process. We apply CNN (Convolution neural network) in field roots images segmentation, by training the neural network using pairs of one image of roots and one ground-truth image which was drawn by human for determining the position of roots. After the training process, the model is able to convert images of roots to outputs similar to ground-truth images created by human with a valuable accuracy. We use cross validation to control the result form the model. After being process, these output images will be used to compute the length and diameter of the plant-roots using IJ_Rhizo open software it is freely available from (www.plant-image-analysis.org/ software/IJ_Rhizo)
Conclusions
For now, AutoRootDraw© has reached the capacity to identify, draw and analyse roots using the predictions of the network. We expect to provide a portable version to run the model.



Images from scanner in field (left) and Automatic roots Drawing result (right)

Keywords: Auto Root Draw, Machine learning, Rhizotron, Roots Images, Data extraction.

L23.P.04

Autumn photosynthetic activity and root system visualisation: Case study of hybrid Poplar NE-49 and European ash

Majewski R.[1] (robert.majewski@vukoz.cz), Weger J.[2], Barták M.[3], Valenta J.[4], Tàbořik P.[4], Čermák J.[1]

[1] *Forest Botany, Dendrology and Geobiocenology, Mendel University, Brno, Jihomoravský Kraj, Czech Republic*; [2] *Phytoenergy, Silva Tarouca Research Institute, Průhonice, Středočeský Kraj, Czech Republic*; [3] *Experimental Biology, Masaryk University, Brno, Jihomoravský Kraj, Czech Republic*; [4] *Applied Geophysics, Charles University, Prague, Středočeský Kraj, Czech Republic*

Solitary and boundary trees in parks, gardens as well as in agroforestry alley cropping stands are exposed to action of environmental abiotic factors more than trees growing within a group formation e.g. inside the forest stand and short rotation coppice plantations. Each part of these edge or solitary trees is otherwise affected concerning various sides of the crown. When from the densely overgrown stand side, the trees create own microclimate, towards an opened space they are not protected. On the exposed side they suffer less from spatial competition by neighboring trees and they have more space for development of crown and root systems. This process begins from the edge trees which create the buffering zone. The external factors gradient is being decreased by ecotone, which alleviates the abiotic influence. However, inside the forest, the competition for nutrients, water and solar radiation exists. The goal of the work was to compare the physiological activity of the semi–solitary and solitary tree along with the investigation of the irregular morphological differences.
The research was performed in the Michovka research area of the Silva Tarouca Research Institute for Landscape and Ornamental Gardening in Průhonice. The studied trees were European Ash Fraxinus excelsior cv. Atlas which grows on the agroforestry plantation edge and solitary hybrid Poplar Populs maximoviczii × Populus × berolinensis clone NE-49, which were in 200 m distance to each other (Weger and Bubeník, 2012). The field measurements were performed on both trees using Electrical resistivity tomography (ERT), as well as Dipole electromagnetic profiling, Gas exchange measurements, Sap flow sensors, Stem decay investigation by non – destructive acoustic testing, along with biometrical parameters investigation. The ERT measurement were performed using the Wenner – Schlumberger electrode configuration with the spacing of 30 cm and two profiles for each tree in NS and EW directions. With CMDExplorer, we investigated the soil apparent resistivity changes in three depths in distance roughly up to 7 m from the trees (Mareš et al. 2004, Hagrey, 2007). Gas exchange measurement were used for the evaluation of net photosynthetic rate (Pn) in the bottom part of the crown. Each hour, the measurement was repeated on random leaves for each geographical direction. Sap flow sensor was placed on northern side of each tree breast height, the transpiration rate was recorded each minute (Čermák et al. 1984).
Early morning Pn started about the same time in both trees, however, the increase in Pn was faster in solitary tree upon sunrise. The solitary tree terminated the photosynthetic activity earlier than the semi – solitary one.
In case of the solitary tree, root system is fully developed and it creates uniform circle – like shape. However, in semi – solitary tree root system is congregated in an unoccupied area and shows tendency to grow towards south in triangle shape in this particular study.

Keywords: Root system, Photosynthetic activity, European ash, Poplar.

References:

1. Čermák, J., et al., 1984, Oecologia, 64: 145–151
2. Hagrey, S.A., 2007, Journal of Experimental Botany, Vol. 58, No. 4, pp. 839–854
3. Mareš, S., et al., 2004, Book of Abstracts: Near Surface 2004 – 10th European Meeting of Environment
4. Weger, J., Bubeník, J., 2012, Acta Pruhoniciana 100: 51– 62

L23.P.05

The Edaphic Environment: Impact of Olive Trees on the soil beneficial interaction between Durum Wheat roots and Am Fungi

Panozzo A.[1] (nn.panozzo@gmail.com), Desclaux D.[2], Huang H.[2], Duponnois R.[3], Prin Y.[3]

[1] *Department of DAFNAE, University of Padova, Legnaro (PD), Italy*; [2] *INRA - DiaScope unit, Mauguio, Domanine de Melgueil, France*; [3] *LSTM, UMR 113 CIRAD, IRD, University of Montpellier II, Montpellier, France*

It is said that trees improve soil fertility. It might be due to biological interactions with micro-organisms and especially with arbuscular mycorrhizal fungi. Is-it the case with olive trees in south of France?
The field experiments were conducted in South of France at INRA DiaScope experimental unit. Durum wheat was sown in 3 conditions: (AF) yearly pruned olive orchard, (AF+) never pruned olive orchard, (C) open field.
Mycorrhizal analysis was performed on 6 durum wheat cvs. For each treatment and cv, 3 replicates of 90 root fragments were analyzed at the LSTM lab.
All the root fragments coming from AFs treatments were colonized, while 96.4% for C. The intensity of AMF colonization, thus the % of the root fragment length being colonized, was significantly higher in AFs treatments (+51% compared to C), as the arbuscular abundance in the root system (+74% compared to C).
A wide variability was observed among genotypes within the same treatment. The intensity of AMF colonization ranged from 11% to 57% in C, and from 55% to 74% in AF. The genotype showing the highest intensity of AMF colonization and arbuscular abundance in AF had the lowest values in C.
AM fungi are known to be an essential component of sustainable agricultural ecosystems (Jeffries et al. 2003). Olive trees seem to play the role of permanent reservoir of AMF diversity, available to associated cereals. Arbuscular mycorrhizal (AM) fungi help the understorey crop to catch soil nutrients (Wahbi et al. 2016).

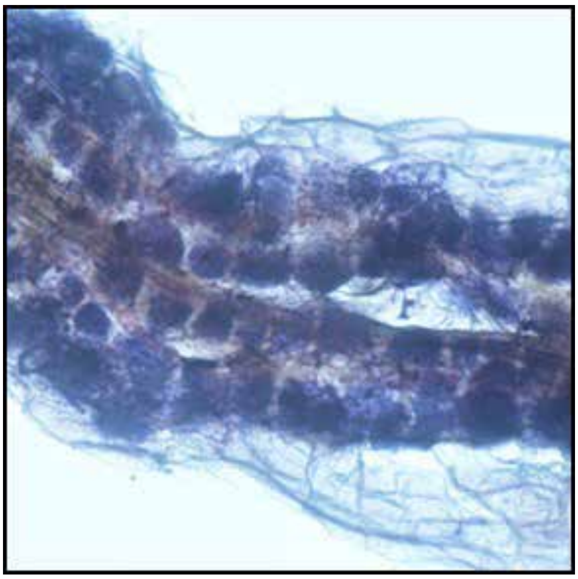


Figure 1. Photo of arbuscules in AF durum wheat roots.

Keywords: Olive tree, AMF, root colonization, soil fertility.

References:

1. Jeffries et al. 2003, Biol. Fertil. Soils, 1-16.
2. Wahbi et al. 2016, APPL SOIL ECOL, 91-98

L23.P.06

How agricultural practices affects the presences and the diversity of mycorrhizae in agroforestry systems

Parizel A. (alexandre.parizel@agroforesterie.fr)

Association Française d'Agroforesterie, Auch, France

Mycorrhizae represent a core part of agricultural systems, improving their resilience thanks to mutual benefits (mycorrhizal fungi protecting the plants, cross-feeding, etc.). Mycorrhizae are a powerful lever to keep an agricultural system resilient, functional and productive in a context of climate change. In that way, knowledge about the impacts of agricultural practices on mycorrhizae in agricultural systems are very useful.
The French Agroforestry Association (AFAF) is part of a project that compared the effect of agricultural practices (cover crop, tillage, herbicide application, etc.) on the diversity and the presence of mycorrhizae in temperate corn-walnut based agroforestry and monoculture systems (both corn and walnut tree separated in different systems, in biological or conventional systems). The first results of the project show a strong impact of several agricultural practices on mycorrhizae populations. Based on these first conclusions, the French Agroforestry Association is now processing the results to transfer the information to farmers. The information provided should help and guide farmers to organize and manage their systems in a sustainable way encouraging the mycorrhizae establishment and diversity.

Keywords: Myccorhizae, Agroforestry, Practices.

L23.P.07

Root Traits on Rewetted Peatlands Agroforestry in Central Kalimantan: A Preliminary Study

Tata H.[1] (hl.tata@gmail.com), SittiNuroniah H.[1], Rahayu S.[2], Pambudi S.[2]

[1] *Silviculture, Forest Research & Development Center, Bogor, West Java, Indonesia*; [2] *Ecological Modelling Unit, World Agroforestry Center SEA Regional, Bogor, West Java, Indonesia*

Plant traits are defined as any phenological, morphological, physiological, reproductive or behavioral characteristics of a species that can be quantified by measured at individual level. Trees, which grow naturally on peat swamp forests, have aerenchyme roots those enable them to absorb oxygen in the hydric soils. Recently, rewetting and revegetation are two important approaches in peatland restoration in Indonesia. However, there is lack of scientific understanding on the vegetation response on peat swamp or wet peatlands. A study of plant functional traits has just started to assess characters of anatomy, morphology and physiology of several trees species grown in wet and rewetted peatlands. The objective of the study is to understand the attributes of plant train in response to rewetted peatlands. Semi-permanent sample plots have been established purposively in three conditions of peatlands restoration, namely rewetted, rewetted and replanted peatlands, and intact (or very less degraded) peatland, in Central Kalimantan. Plants those from natural regeneration and rehabilitation were counted, measured and identified. Further investigation on the anatomy, morphology and physiology of the root traits will be observed in the laboratory.

Aerenchyma roots of Dyera polyphylla on peatland agroforestry

Keywords: peatland restoration, aerenchyma root, plant trait, Indonesia.

References:

1. Kissling et al., 2018, Nature Ecology and Evolution, 1-11, doi:https://doi.org/10.1038/s41559-018-06

ABSTRACTS

Biophysics of agroforestry systems

The wonders of agroforestry's biophysics

- L24 -

Biophysical modelling of interactions in agroforestry

The geek session:
modelling biophysical interactions in agroforestry

Models are increasingly applied in agroforestry for scientific discovery, farmer decision support and policy advice. In the face of changing climate, such models must be able to project field, farm and food system performance across a wide range of environmental and socioeconomic conditions. However, modelling of agroforestry systems is still facing many challenges among which their complexity including interactions between various components, the large spatial domains covered by trees and crops in both horizontal and vertical directions, the long-life spans of trees and differences in their management. To add to the complexity, growth resources sharing between components of the systems occurs simultaneously above (light and water) and below (nutrients and water) for a range of outputs (including provisioning, supporting and regulating services), all of which should be simulated for a comprehensive understanding of the overall system impacts. Thus, the objectives of this session are) to provide the state of art on advances in agroforestry modelling on how system components interact considering the large number of interacting factors (soil, climate, species, management); b) to identify key lessons learnt on which to base decision support tools for key stakeholders; c) to identify needs for future agroforestry model improvements and gaps in knowledge for future research directions.

L24_O.01

Do agroforestry models overestimate photosynthesis and RUE of understory crops?

Rosati A.[1] (rosatiadolfo@gmail.com), Wolz K.[2], Murphy L.[3], Ponti L.[4], Gold M.[5]

[1] *CREA OFA, CREA, Spoleto, (PG), Italy*; [2] *Savanna Institute, Madison, Wisconsin, USA*; [3] *Cary Institute of Ecosystem Studies, Millbrook, New York, USA*; [4] *Centro Ricerche Casaccia, ENEA, Roma, Italy*; [5] *Center for Agroforestry, University of Missouri, Columbia, Missouri, USA*

The light distribution under trees and available for understory crops has been examined with biophysical agroforestry models of various levels of complexity (for a review see Malézieux et al., 2009). No model, however, predicts the exact light pattern available under the trees in each point in time and space, as this would require detailed knowledge of the spatial arrangement of leaves and large computing effort (Lamanda et al. 2008). By averaging in time and/or space, the light predicted by models is less variable than in reality. Under variable light, photosynthesis (and crop growth) is reduced compared to more uniform light (Poorter et al., 2016; Vialet-Chabrand et al., 2017). Here, we tested whether using the more uniform light patterns estimated with models significantly affects the estimation of photosynthesis and radiation use efficiency compared to using measured light patterns.
We measured the light pattern using PAR photosensors every minute for several days in 24 positions under chestnut orchard canopies of various ages and tree spacings. We also created a spatially explicit, ray-tracing canopy light model and used it to estimate the light pattern under the trees at a one-minute resolution. We then compared the measured and modeled light patterns at the minute scale, as well as with half-hourly, hourly, and daily averages. Finally, we used the measured, modeled, minutely, and averaged light patterns to estimate the daily photosynthesis of an understory wheat leaf using its photosynthetic light response curve. Despite calibrating tree porosity in the model to yield the same daily light total as measured with the sensors, the modeled light patterns under the tree canopies differed substantially from the measured one, being much more uniform. This was due to the fact that the model assumes a canopy of uniform porosity, while, in reality, sun rays pass through a complex heterogeneous canopy. Using the more uniform modeled light overestimated daily photosynthesis by about 40%, even when calculating photosynthesis using the light patter at a minute scale. Averaging light in time increased the overestimation even further. We conclude that, by predicting overly uniform sub-canopy light patterns, current agroforestry models likely overestimate photosynthesis and radiation use efficiency of understory crops. Finding ways to account for the actual variability in light patterns under trees could improve model predictions of understory crop performance.

Keywords: Photosynthetically active radiation, Modelling, Variable light.

References:

1. Malézieux et al. 2009. Agronomy for Sustainable Development 29, 43-62.
2. Lamanda et al., 2008. Agroforestry systems 72, 63-74.
3. Poorter et al., 2016. New Phytologist 202, 838-855.
4. Vialet-Chabrand et al., 2017. Plant physiology

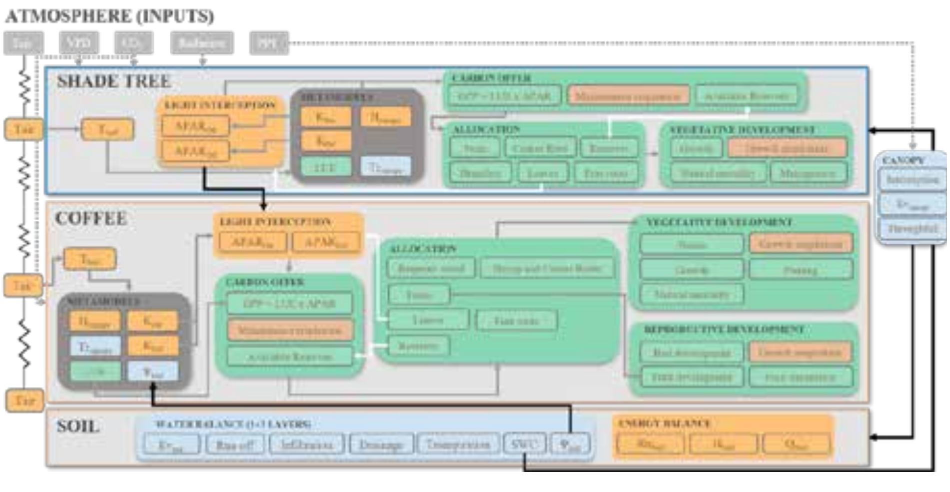
L24_O.02

DynA_Cof, a model for growth, yield, carbon, water, energy balances and ecosystem services of *Coffea* in agroforestry

Vezy R.[1] (remi.vezy@cirad.fr), le Maire G.[2], Charbonnier F.[2], Christina M.[3], Georgiou S.[4], Imbach P.[4], Hidalgo H. G.[5], Alfaro E. J.[5], Blitz-Frayret C.[6], Laclau J.-P.[2], Lehner P.[7], Robelo D.[7], Loustau D.[8], Roupsard O.[2]

[1] *AMAP, CIRAD, Montpellier, FRANCE*; [2] *ECO&SOLS, CIRAD, Montpellier, France*; [3] *AIDA, CIRAD, Montpellier, France*; [4] *CATIE, Turrialba, Costa Rica*; [5] *University of Costa Rica, San José, Costa Rica*; [6] *CIRAD, Montpellier, France*; [7] *Cafetalera Aquiares S.A, Turrialba, France*; [8] *ISPA, INRA, Bordeaux, France*

Agroforestry systems (AFS) are complex to model mainly due to the high spatial variability induced by the shade trees. Recently, the microclimate and light heterogeneity issue in AFS has been addressed using the 3D ecophysiological process-based model MAESPA (Charbonnier et al., 2013; Vezy et al., 2018). MAESPA surpassed the classical sun/shade dichotomy in AFS (Charbonnier et al., 2014) and provided continuous maps of e.g. available light, light-use-efficiency and canopy temperature within *Coffea* Agroforestry Systems (CAS).
A step further was to design a crop model for *Coffea* grown under agroforestry that would benefit from this continuum to estimate ecosystem services on the long term and under climate change scenarios. We designed DynA_Cof, a new process-based growth and yield model to compute plot-scale net and gross primary productivity, carbon allocation, growth, yield, energy, and water balance of CAS according to shade tree species and management, while accounting for fine-scale spatial effects using MAESPA metamodels (Figure 1). DynA_Cof satisfactorily simulated the daily plot-scale gross primary productivity (RMSE= 1.69 g_C m^{-2} d^{-1} on 1562 days) and the energy and water balances (RMSE: AET= 0.63 mm d^{-1}, H= 1.27 MJ m^{-2} d^{-1}, Rn= 1.98 MJ m^{-2} d^{-1}) compared to measurements from an eddy-flux tower in Aquiares (Costa Rica) and also the NPP for above and below-ground organs, coffee bean yield and shade tree wood production compared to a comprehensive database from this site.



Detailed DynACof model workflow. The air temperature is recomputed within the shade tree layer and Coffea layer canopy, and above soil surface using a series of resistances. The precipitation interception, evaporation and throughfall are all computed at plot scale. Carbon-related computations are coloured in green, energy-related in orange, and water-related in blue. Black arrows represent the interactions between layers, grey arrows the interactions within a layer, and white the retro-actions. VPD: vapor pressure deficit, PPT: precipitations, T: temperature, Ψ: water potential, LUE: light use efficiency, K: light extinction coefficient, Tr: transpiration, GPP: gross primary productivity, APAR: absorbed photosynthetically active radiation, Ev: evaporation, SWC: soil water content, H: sensible heat, Rn: net radiation, Q: heat storage.

Keywords: process-based, Coffea arabica, Erythrina, NPP, growth.

References:

1. Charbonnier, F., et al., 2013. AFM, 181: 152-169, https://doi.org/10.1016/j.agrformet.2013.07.010
2. Charbonnier, F., et al., 2014. World Congress on Agroforestry 2014, 1573, Delhi, India.
3. Vezy, R., et al., 2018. AFM, 253–254: 203-217, https://doi.org/10.1016/j.agrformet.2018.02.005

L24_O.03

A System Identification Approach to Process-Based Plant Growth Model Reduced-Order Parameter Estimation

Elevitch C. (cre@agroforestry.org), Johnson C. R.

Electrical and Computer Engineering, Cornell University, Ithaca, New York, United States

In order to describe underlying biophysical mechanisms, process-based plant growth models often contain an excessive number of parameters when only considering the accuracy of the model outputs. Regarding their influence on the model output, parameters of complex nonlinear plant growth models interact in ways that cannot be easily predicted based upon their roles in the component submodels describing biophysical processes. Consequently, parameter estimation in complex nonlinear plant growth models is often challenged by lack of a means to interpret the relative importance of parameters. In multi-crop models such as for agroforestry, increased model complexity due to interactions between crops and lack of data for novel crop combinations in varying environments further exacerbate the difficulties of discerning which parameters are important for estimation (Young 2012).
Our approach is based upon foundational system identification theory (Sjöberg et al. 1995, Ljung 1999) applied to a class of deterministic process-based predictive growth models. We evaluate the Hessian of the quadratic cost function to determine the relative importance of parameters to its curvature. Subject to a list of model requirements, the Hessian can be computed given input-output data and an estimated location in the parameter space provided by prior research into underlying biophysical processes and expert knowledge. Although system identification for plant growth models may be overlooked due to an assumed lack of data, this investigation illustrates that an input-driven predictive growth model can be parameterized using only environmental inputs and size data that are straightforward to collect.
The analysis method is presented as a procedure for determining a ranking of parameter importance that can be used by model developers to provide end users with guidance for parameter estimation given real data for novel crops and crop combinations. The procedure arrives at a reduced-order parameter space within which parameters can be uniquely identified entirely from input-output data. The procedure prioritizes (and allows the user to pick for identification) the parameters that will have the most impact on improving output prediction. Furthermore, when successful, reduced model outputs closely follow the outputs of the original system (with any feasible parameterization) when driven by any input in the input class. The procedure is demonstrated on the well-known Yield-SAFE predictive agroforestry growth model (van der Werf et al. 2007, Palma et al. 2017). The advantages of an input-output system identification approach may also carry over into field trial design or model structure revisions. Further, because model parameterization relies only on readily accessible model outputs, relatively low-tech data collection strategies may streamline approaches to on-farm participatory research.

Keywords: plant growth modeling, system identification, process-based models, reduced-order parameter space.

References:

1. Ljung 1999. System Identification: Theory for the User. Prentice Hall.
2. Palma et al. 2017. Deliverable 6.17 (6.2) AGFORWARD project.
3. Sjöberg et al. 1995. Automatica 31 (12): 1691–1724. https://doi.org/10.1016/0005-1098(95)00120-8
4. van der Werf et al. 2007. Ecol. Eng. 29 (4): 419–33. https://doi.org/10.1016/j.ecoleng.2006.09.017
5. Young 2012. Data-Based Mechanistic Modelling: Natural Philosophy Revisited? Springer.

L24_O.04

Land Equivalent Ratios for multifunctional agroforestry: a new version 5.0 of the WaNuLCAS model

van Noordwijk M.[1] (m.vannoordwijk@cgiar.org), Khasanah N.[1], Lusiana B.[1], Mulia R.[2]

[1] *World Agroforestry Centre (ICRAF), Bogor, Indonesia*; [2] *World Agroforestry Centre (ICRAF), Hanoi, Vietnam*

Evaluation of agroforestry options needs to explicitly relate plot-level processes to landscape (water and nutrient balances) and policy level (Sustainable Development Goals or SDGs) targets and goals (van Noordwijk 2017; van Noordwijk et al. 2018). Twenty years after the first release at an agroforestry meeting in Montpellier of the WaNuLCAS model (van Noordwijk and Lusiana, 1999), a version 5.0 will be presented. New features in this release of the model will include:

1) Lateral shading in response to direct and indirect light, using information from location and cloud cover and as such able to more fully evaluate climate change scenarios,
2) Soil carbon dynamics per Layer*Zone cell, rather than per zone, with explicit terms for biotic and abiotic exchange of all C pools,
3) Performance indicators for LERM that compare agroforestry options with monoculture reference scenarios for productivity, cash-flow, water balance terms, C, N and P balance terms, net soil loss; the first two refer to 'provisioning' services (SDG1&2), the others to 'regulating' services (SDG 6, 13 a.o.)
4) Expanded tree and crop libraries and existing validation studies.

A new application compares oil palm intercropping scenarios.

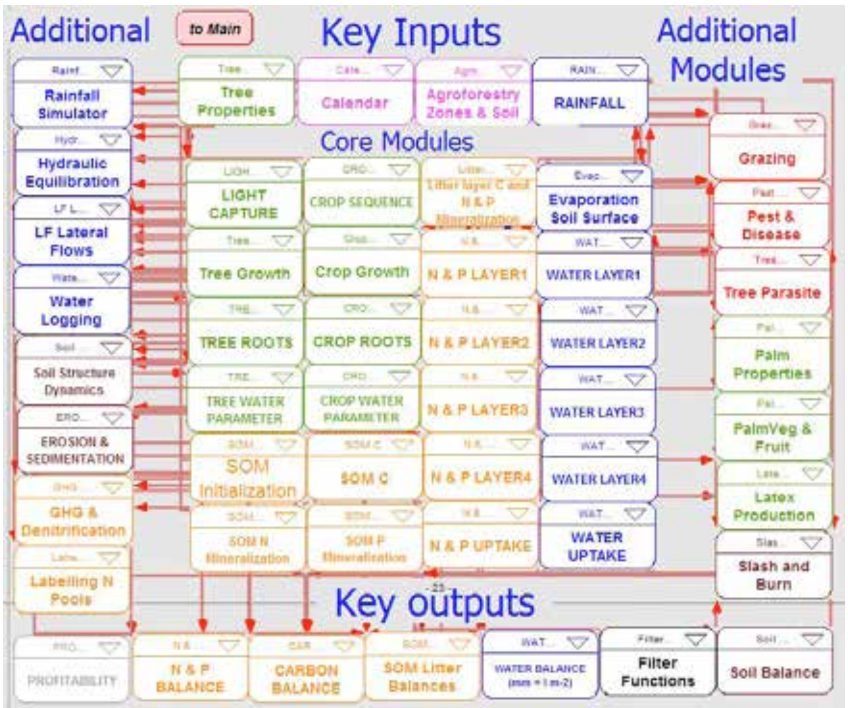


Figure 1. Sector map of WaNuLCAS 5.0

Keywords: Model, Process-based, Two-dimensional, Tree-Soil-Crop Interactions.

References:

1. van Noordwijk M, Lusiana B. 1999. Agroforestry Systems 43: 217-242.
2. van Noordwijk M. 2017. Agricultural Systems http://dx.doi.org/10.1016/j.agsy.2017.10.008.
3. van Noordwijk M et al. 2018. Curr Opin Environ Sustain 34, 33-42.

L24_O.05

Cutting through the complexity of biophysical models: Seeing the forest for the trees

Huth N.[1] (Neil.Huth@csiro.au), Holzworth D.[1], Smethurst P.[2]

[1] *Agriculture and Food, CSIRO, Toowoomba, Qld, Australia*; [2] *Land and Water, CSIRO, Hobart, Tas, Australia*

Modern farming systems models have built upon many years of work to develop robust, fit for purpose models for systems such as those incorporating agroforestry. However, these models have many parameters whose impact is not always known. Furthermore, agroforestry systems have many complex interactions that makes the value of different possible interventions difficult to identify.

Modern statistical and software approaches allow such issues to be untangled. Global Sensitivity Analysis has previously been used to inform plant breeding for different environments through ranking the value of individual plant traits for different geographical regions (Casadebaig et al, 2016). Similar approaches have been used to identify effective management options for minimising environmental impacts of oil palm whilst maintaining crop yields (Pardon et al, 2017).

These approaches have been formalised within the APSIM Next Generation modelling framework (Holzworth et al, 2014) in a way that makes these techniques accessible for the farming systems modelling community. APSIM provides a user interface that assists the user through the process of defining their analysis, ensuring efficient and effective sampling, and highlighting the impact of climate variability on the results of the sensitivity analysis. This functionality, and the availability of modern high performance computing capabilities will assist modellers in understanding hidden relationships within their models and the opportunities they provide.

In this paper, we demonstrate how these different sensitivity analysis techniques can be used to prioritise parameter optimisation or further research efforts such as targeted management interventions, beneficial Gene X Environment interactions or synergistic relationships within complex agroforestry systems.

Keywords: APSIM, Sensitivity Analysis, Biophysical Modelling, Farming Systems Analysis.

References:

1. Casadebaig et al, (2016) PLoS ONE 11: e0146385. https://doi.org/10.1371/journal.pone.0146385
2. Holzworth et al (2014) Env. Mod. & Soft., 62: 327-350. https://doi.org/10.1016/j.envsoft.2014.07.009
3. Pardon et al (2017) Field Crops Res., 210:20-32. https://doi.org/10.1016/j.fcr.2017.05.016

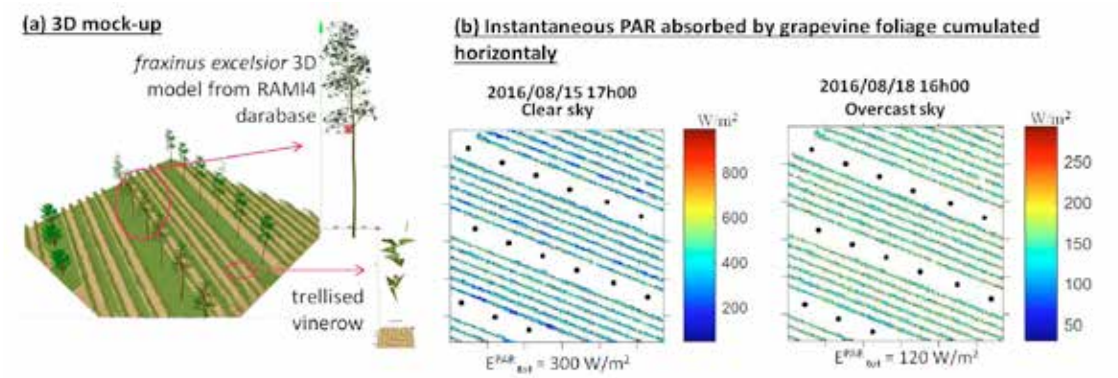
L24_O.06

What are the impacts of tree shade on the absorption of light by grapevine within alley-cropped vineyards?

Grimaldi J.[1] (juliette.grimaldi@inra.fr), Wang Y.[2], Chavanon E.[2], Lauret N.[2], Guilleux J.[2], Bustillo V.[2], Houet T.[3], Gastellu-Etchegorry J.-P.[2]

[1] *INRA UMR System, Montpellier, France*; [2] *CESBIO, Toulouse, France*; [3] *LETG-Rennes COSTEL - CNRS, Rennes, France*

Within modern agroforestry vineyards, light depletion from trees may impact both grape yield and berry quality for wine making. To target this question an alley-cropped vineyard was selected in Lagardere in South-Western France, under humid-continental climate. Based on drone-borne RGB and DSM images of this vineyard, several 3D numeric mock-ups of alley-cropped vinerows and their monocropped references were built [1]. Their radiative budgets were simulated in the photosynthetically active radiations (PAR) wavelengths using the 3D radiative budget model DART [2,3,4]. Simulations were run from April-15th (grapevine budburst) to September-12th (grapevine harvest) considering the succession of sunny and cloudy skies recorded at Lagardere in 2016.
According to our simulations, (i) under clear sky conditions, grapevine rows falling inside the shade of trees absorbed 20% to 40% of the PAR that is absorbed in full sun, depending on the tree leaf density, while (ii) under overcast conditions, no shade pattern appeared as most of the light irradiance is diffuse. Over the whole simulated time period, alley-cropped grapevine rows absorbed 90% to 85% of the cumulated PAR that is absorbed under monocropped arrangements, depending on tree heights.
This very new approach led to encouraging results in regards to agroforestry practices for grapevine cultivation and shall in the future be widened to other climatic contexts and vegetation arrangements.



Example of mock-up of agroforestry vineyard (a) and instantaneous radiative budget of grapevine in the PAR under either clear sky (left) or overcast sky (right)

Keywords: Vitis vinifera, agroforestry vineyards, radiative budget, DART, 3D modeling.

References:

1. Grimaldi J (2018) PhD thesis, Université Toulouse III Paul Sabatier
2. Gastellu-Etchegorry JP, Martin E, Gascon F (2004) International Journal of Remote Sensing 25:73–96.
3. Gastellu-Etchegorry J-P, Grau E, Lauret N (2012) Modeling and simulation in Engineering. pp 29–68
4. Gastellu-Etchegorry J-P, Lauret N, Yin T, et al (2017). IEEE Journal. 10:2640–2649.

L24_O.07

Modeling the adoption of agroforestry systems: Evidence from agent-based simulation

Carauta M. (m.carauta@uni-hohenheim.de), Mössinger J., Berger T.

Land Use Economics, Universität Hohenheim, Stuttgart, Baden-Württemberg, Germany

One of the major challenges that our society faces nowadays is to eradicate hunger and poverty while making agriculture and food systems sustainable. Integrated agricultural production systems (IAPS) are a promising strategy to tackle these challenges since it can improve productivity and increase resilience to climate change (Gil et al., 2017; Garrett et al., 2017).

The objective of this study is to evaluate agent-based modeling approaches on different IAPS realities to (1) identify potential outcomes from current modeling approaches, (2) summarize data availability and modeling limitations and, (3) debate the future potential of agent-based IAPS simulation.

The first case study evaluated the adoption of IAPS in the Brazilian state of Mato Grosso (Carauta et al. 2017), where large-scale commercial farms employ highly dynamic double-crop systems. Aiming to reduce greenhouse gas (GHG) emissions from the agricultural sector, the Brazilian government established the low-carbon agriculture plan. The plan offers the farmers preferential credit lines to shift their monoculture systems to IAPS in order to prevent soil erosion and stop deforestation.

The second case study evaluated the economic potential of Acrocomia (*Acrocomia ssp.*) adoption by family-based peasant farming systems in the district of San Pedro del Paraná in Paraguay. Acrocomia is a multipurpose palm tree, and its fruits can be processed to fuel, food and fodder. An earlier study shows that Acrocomia has the potential to be a viable cash crop alternative for smallholders (Mössinger et al. 2015).

We employed an integrated assessment (IA) approach that captures socio-economic and biophysical constraints at farm-level and simulates farmer decision-making, agricultural land-use, and policy response. The main component is the agent-based software package MPMAS (Mathematical Programming-based Multi-Agent Systems). In the first study, MPMAS was combined with MONICA (Model for Nitrogen and Carbon in Agro-ecosystems), which was used to estimate crop yield responses of different cultivars, nitrogen fertilization rates, soil types, and climatic conditions. In the second study, a participatory modeling approach was conducted with intensive household interviews, group discussions, and interactive modeling sessions with farmers. In addition, a multi-period planning problem was implemented to evaluate long-term investment decisions adequately.

The results of our agent-based simulations indicate that the implemented IA approach can capture region-specific economic incentives and improve the decision-making of smallholder family farmers. Further, our policy analysis at regional level underlines the importance of policy recommendation which takes into consideration farmer heterogeneity and decision-making rather than simulated average responses that may mislead policymakers to introduce interventions which are only beneficial for average farms but ineffective in a heterogeneous region.

Keywords: Policy Impact, Impact Assessment, Integrated Agricultural Production Systems, Agent-based model, Participatory modeling.

References:

1. Carauta et al., 2017, Reg Environ Change, 675
2. Garrett et al. , 2017, Agricultural Systems, 136
3. Gil et al., 2017, WIREs Clim Change, 8:e461
4. Mössinger et al., 2016, Proceedings of the XX ICABR

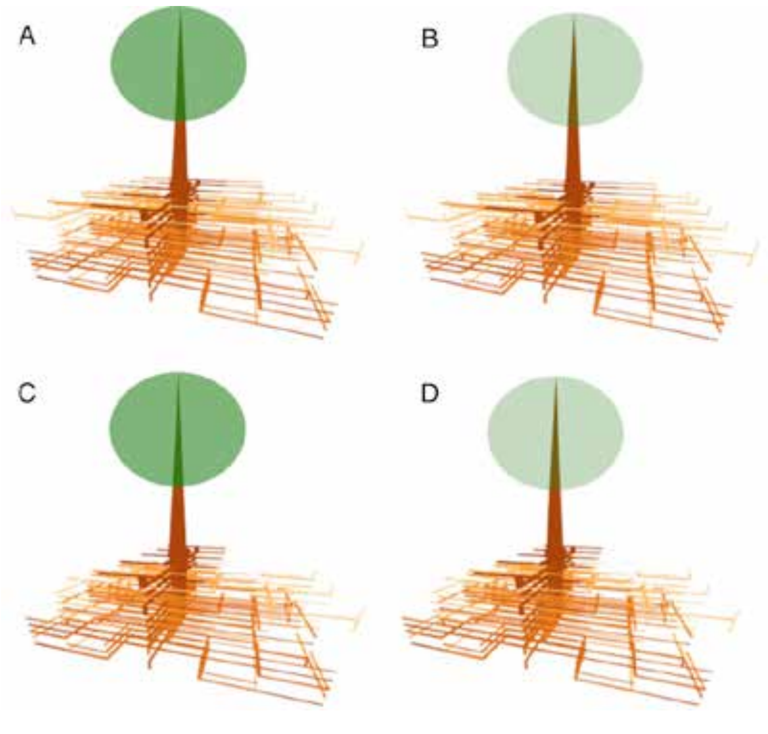
L24_O.08

Using the Hi-sAFe model to test the effect of tree root and branch pruning with different crop management options

Inurreta Aguirre H. D.[1] (inurreta.daniel@gmail.com), Wolz K.[2], Dupraz C.[2], Gosme M.[2]

[1] *INIFAP, Vera Cruz, Mexico*; [2] *UMR SYSTEM, INRA, Montpellier, France*

Agroforestry systems, even simple ones such as two-strata alley cropping systems, present almost infinite possibilities for the design of the system combined with the crop and tree management options. Simulation models can be useful tools to quickly test a large number of combinations in order to test only the most promising systems in the field. Here, we tested the effect of tree root and branch pruning in an alley cropping system with hybrid walnut in the Mediterranean climate, with two contrasting dates of sowing of durum wheat. The results showed that branch pruning (removal of 50% of the branches) had a much stronger effect than root pruning (pruning at 1m depth, 2m from the tree line) not only on crop yield, but also on soil water content. These effects depended on the date of sowing and soil depth: branch pruning increased yield with the normal date of sowing (November), but decreased it when sowing of the crop was delayed until December, and increased deep soil water content but decreased topsoil water content. A field experiment with the same treatments (but not all combinations) showed the same patterns of crop yield, but pointed to possible improvement of the model concerning tree water extraction.



The 3D nature of the Hi-sAFe agroforestry model allows to run virtual experiments, for example an experiment comparing the effects of tree root (C-D vs A-B) and branch pruning (B-D vs A-C), for different crop sowing dates.

Keywords: modelling, root pruning, branch pruning, crop yield, competition.

L24_O.09

Variation in ecosystem service values with respect to land use/cover changes in agroforestry landscape

Temesgen H.[1] (habte023@yahoo.com), Wei W.[2], Xiaoping S.[2], Yirsaw E.[1], Bekele B.[3], Kindu M.[4]

[1] *Natural resources management, Dilla University, Dilla, Southern Region, Ethiopia*; [2] *Land Management, Nanjing Agricultural University, Nanjing, Jiangsu, China*; [3] *Natural resources management, Assosa Agricultural College, Assosa, Benishangul, Ethiopia*; [4] *Remote Sensing Working Group, Technical University of Munich, Munich, Germany*

An ancient agricultural form of forestland management, *agroforestry* is a way of life and survival strategy in southern Ethiopia. Human pressure in a rugged and fragile landscape can cause land use/cover changes that significantly alter ecosystem services. Yet, estimating the multiple services obtained particularly from agroforestry systems is seldom attempted. A combined approach of geospatial technology, cross-sectional field investigations, and natural capital economic valuation was used to develop Ecosystem Service Valuation (ESV) model (as indicated in the figure) to estimate changes in ESV between 1986 and 2015. Over 120 values were mainly sourced from Ecosystem Service Valuation Database and allied sources to establish the value coefficients via benefit transfer method. Our 1848 km2 area with eight land use categories yielded entirety annual ESV of $129 x 106 in 1986 and $147 x 106 in 2015, which is 14.2% ($18.3 million) *increment* in three decades. These show the overall relative resilience of the Gedeo-Abaya agroforestry landscape. Yet, losses are experiential with natural vegetation classes whose area and/or value coefficients are too small to offset the increased value due to expansion of agroforestry and wetland/marshy which have the largest cover share and high economic value, respectively. Appreciating the unique features of agroforests, we strongly recommend its economic value to be studied as a separate biome for further valuation accuracy improvement.

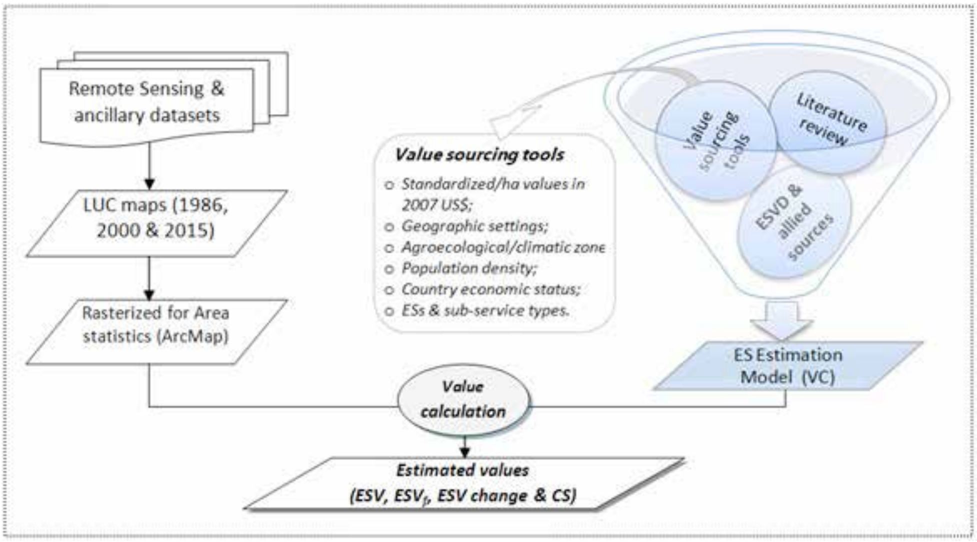


Fig Schematic methodological flow

Keywords: ecosystem services, ecosystem service valuation, agroforestry, Gedeo-Abaya, Ethiopian rift.

References:

1. MEA 2005. World Resources Institute, Washington, DC.
2. Temesgen, et al. 2018. Environ Monit Assess. 2018. 190: 16
3. de Groot, et al. 2012. Ecosystem Services, 1, 50-61.
4. Costanza et al. 1997. Nature, 387, 253
5. Kindu et al. 2016. Science of The Total Environment, 547, 137-47.

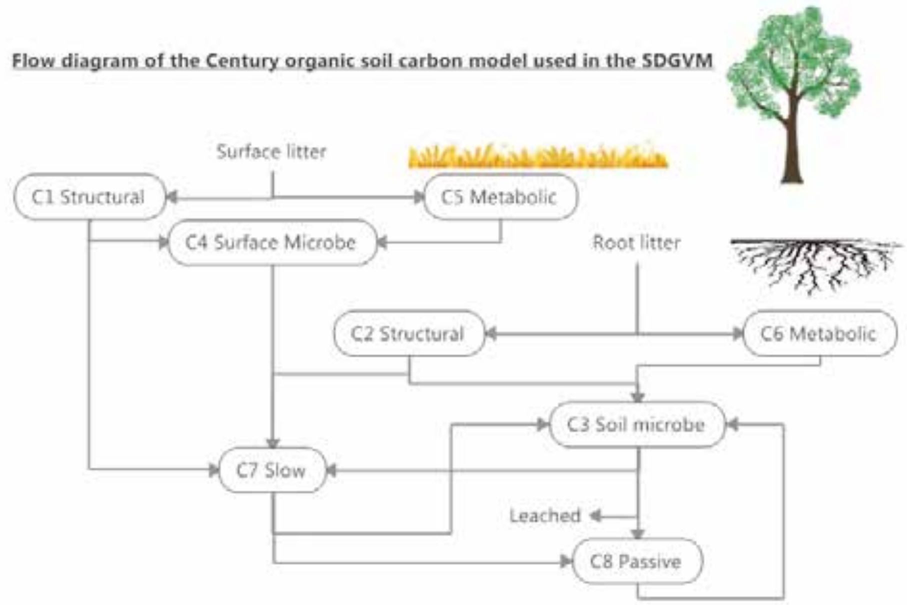
L24_O.10

Dynamic modelling of potential carbon removal and sequestration by agroforestry: A UK perspective

Felton M.[1] (m.a.felton@reading.ac.uk), Quaife T.[2], Clark J.[3], Lukac M.[1]

[1] *Agriculture, University of Reading, Reading, Berkshire, United Kingdom*; [2] *Meteorology, University of Reading, Reading, Berkshire, United Kingdom*; [3] *Geography and Environmental Sciences, University of Reading, Reading, Berkshire, United Kingdom*

Background
Actions on UK agricultural greenhouse gas emissions have failed to achieve national reductions over the last decade, threatening the UK's capability to meet national 4th and 5th carbon budgets and therefore requiring transitional change in the sector. Agroforestry represents a powerful option for transitional change in UK agricultural practice, offering very high potential for delivering both carbon sequestration and other environmental/public goods whilst maintaining food production.
Aims
To explore the potential for national-scale carbon removal and sequestration by adoption of agroforestry practices on UK agricultural land, under present and future climates.
Methods
We use a global dynamic vegetation model (SGDVM) with climate model data to simulate potential changes in carbon dynamics and above- and below-ground carbon storage for different levels of agroforestry implementation in the UK.
Results
Substantial increases in total UK carbon storage are modelled from agroforestry vs. mono-cropping over an 80-year term, particularly in aboveground stocks. Rising atmospheric carbon dioxide levels increase this gain.
Conclusion
The results support agroforestry on UK cropping land as an option for significant carbon removal, though long-term sequestration depends crucially on the fate of above-ground carbon stocks. Improving soils mapping and topography in the model could identify UK regions with highest potential for soil carbon sequestration.



Flow diagram of the Century organic soil carbon model dynamics used in the SDGVM

Keywords: agroforestry, soil carbon, dynamic vegetation model, carbon dioxide, silvoarable.

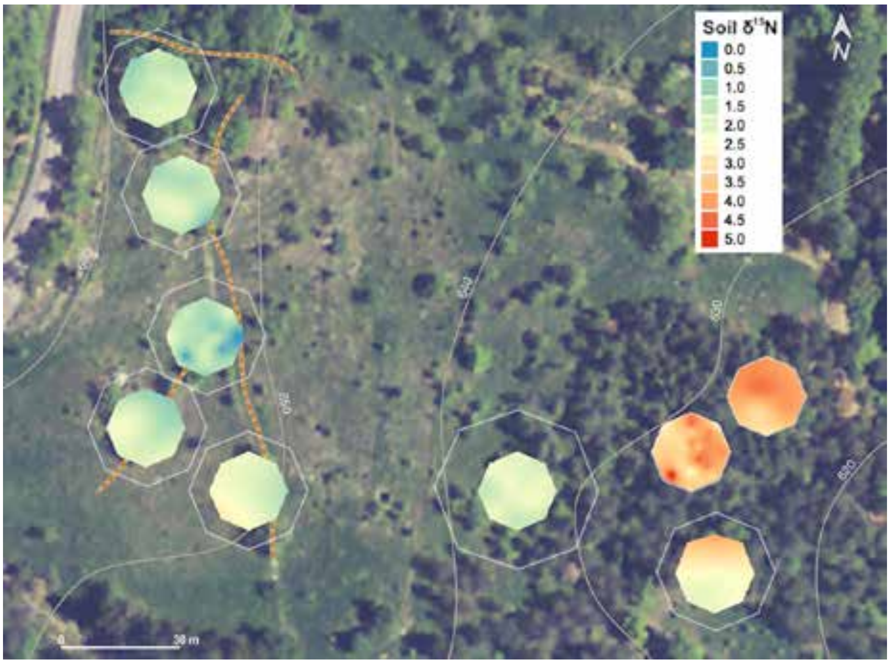
L24.P.01

Mapping ecological relationships: Stable isotopes spatial distribution to understand mechanisms underlying agroforestry

Ciolfi M. (marco.ciolfi@ibaf.cnr.it), Chiocchini F., Russo G., Paris P., Lauteri M.

CNR - IRET, Porano, Italy

Stable isotopes are known tracers of biogeochemical pathways and are widely used in eco-physiology as indicators of carbon sequestration, water and nutrients assimilation, soil nutrients depletion and geographic origin of the consumer goods. In the last decade, the merging of IRMS (Isotope Ratio Mass Spectrometry) and geostatistics has given rise to the discipline of the so-called *Isoscapes*(*Iso*topic land*scapes*): spatial distribution maps of the relative abundance of stable isotopes, referred to an established standard (West et al. 2010).
Agroforestry systems are characterised by the presence of trees outside forest as scattered single trees or small bunches in pastures or as tree hedgerows between crop fields. The presence of trees enrich the rhizosphere ecosystem, likely improving the resilience of the whole system. By means of stable isotopes geostatistics we can map primary assimilation processes ($^{13}C/^{12}C$, Brugnoli and Farquhar 2000), fertilizers or manure supply ($^{15}N/^{14}N$) and water uptake ($^{18}O/^{16}O$). The time and space variability of the stable isotopes distribution can also give a clue on the biocenosis relationships - e.g. trees/fungi symbiotic exchange of nutrients. Such complexity, which is typical of forest ecosystems, is largely loosen in intensive crop systems. Stable isotopes mapping provides a method of investigation of the degree of the *forestry-ness* in an agroforestry systems, especially for what concerns the soil management.



Spatial distribution of nitrogen isotope composition (δ15N ‰) values in soil across nine truffle producing plots within a pine plantation in central Italy

Keywords: Stable isotopes ratios, Isoscapes, Ecophysiology, Spatial Analysis, Geostatistics.

References:

1. Brugnoli E, Farquhar G.D. (2000) Advances in Photosynthesis, vol.9 ch.17 pp.99-434 Kluwer Ac. Pub.
2. West J.B. et al. (2010) Isoscapes, Springer. DOI 10.1007/978-90-481- 3354-3

L24.P.02

Extending the multi-agent modelling platform MAELIA to support land conversion to agroforestry systems

Clivot H.[1] (clivot.hugues@hotmail.fr), Cuntz M.[2], Therond O.[1]

[1] *UMR LAE INRA - Université de Lorraine, Vandoeuvre/Colmar, France*; [2] *UMR Silva INRA - UL - AgroParisTech, Nancy, France*

Background
European policies are encouraging the development of agricultural practices such as agroforestry, which are promoting both provisioning and regulating ecosystem services. To help decision support, there is a need to develop tools able to evaluate the environmental, economic and social impacts of converting existing agricultural land to agroforestry. The MAELIA platform (Multi-Agents for Environmental norms Impact Assessment http://maelia-platform.inra.fr/) has been developed to handle interactions between agricultural activities, agricultural landscape dynamics and the management of natural resources at the landscape level. MAELIA is currently able to simulate the development, yield, gross margins, and workload of arable crops and grasslands and their interactions with water, nitrogen and carbon dynamics in soils.
Objectives
The aim of this work is to extend the functionalities of MAELIA a) to simulate growth of trees and their biophysical interactions with intercropping crops and grasslands, and b) to implement management strategies in agroforestry systems.
Methods
Growth of trees and their temporal and spatial interactions with crops regarding competition for light and water will be implemented into MAELIA at a daily time step. A light response curve will be adopted to simulate carbon assimilation, which will also be regulated by water availability (Granier et al., 2007) and temperature (Sitch et al., 2003). Allometric relationships will be used to allocate biomass in trees and hence describe tree growth. Water dynamics in the soil-plant-atmosphere system will be described similar to the BILJOU water balance model (Granier et al., 1999), considering competition between plants for soil water. Light under the canopy will be simulated by implementing the CanSPART radiative transfer model (Haverd et al., 2012).
Information on management strategies in agroforestry systems will be collected to parameterize the decision rules that allow simulating the dynamics of technical operations applied by farmers (Murgue et al., 2016). These data will also be used to parameterize the economic module of MAELIA.
Calibration and validation of the platform will be performed using 1) an in-depth analysis of biophysical processes from an instrumented experimental site, and 2) data on a subset of processes from 6 other field sites to encompass diverse pedoclimatic conditions and plant associations.
Expected results and perspectives
Robust representation and simulation of plant growth and water fluxes in temperate agroforestry systems are expected from MAELIA after implementation of the above biophysical processes. The environmental and socio-economic impacts of scenarios regarding introduction of alley cropping systems in a French temperate region will then be assessed. Ongoing developments in MAELIA will allow in the future to address further issues related to carbon and nutrient cycling in agroforestry systems.

Keywords: Multi-agent platform, Integrated assessment and modelling, Biophysical processes, Landscape-scale, Temperate systems.

References:

1. Granier et al., 1999, Ecol. Model. 116, 269–283, 10.1016/S0304-3800(98)00205-1
2. Granier et al., 2007, Agric. For. Meteorol. 143, 123–145, 10.1016/j.agrformet.2006.12.004
3. Haverd et al., 2012, Agric. For. Meteorol. 160, 14–35, 10.1016/j.agrformet.2012.01.018
4. Murgue et al., 2016, Land Use Policy 54, 339–354, 10.1016/j.landusepol.2016.02.020
5. Sitch et al., 2003, Glob. Change Biol. 9, 161–185, 10.1046/j.1365-2486.2003.00569.x

L24.P.03

An ontological approach to data management in agroforestry

Conde Salazar R.[1] (raphael.conde_salazar@cirad.fr), Liagre F.[2], Mougenot I.[3], Perez J.[4], Stokes A.[1]

[1] *UMR AMAP, INRA, Montpellier, France*; [2] *AGROOF, Anduze, France*; [3] *UMR ESPACE-DEV, University of Montpellier, Montpellier, France*; [4] *UMR AMAP, IRD, Montpellier, France*

Data from field observations acquired in partnership with several categories of actors (foresters, farmers, breeders, etc.) as part of agroforestry experiments have been accumulating for many years now. The management and reuse of this data is made difficult by the multiplicity of media and formats used and by the diversity of the actors and their language. In addition, agroforestry studies require systemic approaches to better understand for example, how to better manage a site in response to climate change, pests and soil pollution. This necessity can only be tackled by linking up with other fields of knowledge such as climatology, zoology or soil science.

To help the agroforestry community in the exploitation and sharing of their data, and in order to report on the evolution and effectiveness of the developments they have performed, we propose as a first objective, to set up a knowledge model (an ontology) dedicated to agroforestry. This ontology will serve as the basis for capitalizing and sharing data in agroforestry.

A second objective is to link agroforestry data with other data sets from diverse knowledge areas concerning the environment and regional territories. For example, an agroforester should have the opportunity to easily compare the selling price of standing timber in his/her region for different tree species that they wish to plant on a given site.

The dual challenge of sharing and interconnecting data in agroforestry brings us closer to what is currently practiced within the "semantic web" with different tools and methods to promote the sharing of open and linked data sources. Semantic web technologies provide standard procedures for describing and accessing resources on the web. The linked data is exploited and enriched by technologies such as RDF, SPARQL, OWL and SKOS. We reuse semantic web standards and exploit a range of terminological ontologies to provide an open and flexible knowledge model that can reflect the complexity of data already collected in agroforestry. This new model will be able to connect to other knowledge models already present on the Web. Agroforestry expertise linked to other expert areas on the web will facilitate the creation of decision support tools and thus provide new solutions to agroforestry practice.

Keywords: agroforestry, structural modelage, ontology, semantic web.

L24.P.04

How resilient are crop-tree intercropping in comparison to mono-cropping systems to the effects of climate change?

Deryng D. (deryng@zalf.de)

ZALF, Muencheberg, Germany

Agricultural systems are particularly sensitive to climatic conditions, and anthropogenic climate change threatens future agricultural production and food security. Progress in the global quantification of climate impacts on agricultural production have improved substantially over the last decade, as a result in part to the development of global agriculture and land use datasets, which have enabled the development and evaluation of global crop modelling tools, and also due to several international modelling intercomparison efforts such as ISIMIP (www.isi-mip.org) and AgMIP (www.agmip.org), which have provided a necessary framework for characterising the cascade of uncertainties spanning climate scenarios and crop responses across the world.

Nonetheless, large scale agricultural modelling tools have focused on the most economically important crops in the world and have yet to represent the variety and complexity of agricultural systems prevalent in many low-latitude countries. Subsistence and semi-subsistence cropping systems, involving multiple cropping management practices, are central to securing food to small farmers in these regions, and have yet to be taken into account in climate impacts assessments. Furthermore, the agricultural sector in low-income countries represents the biggest share of the national economy but remains one of the most vulnerable and exposed sectors to the effects of climate change, and urgently needs tailored scientific information to support the identification of sustainable, productive, equitable and resilient land use and agricultural management options.

Designed to better inform vulnerability assessments and adaptation planning targeted at small low input cropping systems in the tropics and sub-tropics, this work will present an extension of the global agro-ecosystem model PEGASUS (Predicting Ecosystems Goods and Services Using Simulations) in order to simulate the productivity of crop-tree inter-cropping systems and implication for ecosystem services at the landscape and potential feedback to the climate system, taking into account the physiology of traditional and indigenous crops and trees.

Keywords: Adaptation, Vulnerability Assessment, Global agro-ecosystem model, Ecosystem services, Climate Change.

References:

1. Deryng et al, 2016, NCC, pp.786–790 doi: 10.1038/nclimate2995
2. Deryng et al, 2014, ERL, 034011
3. Deryng et al, 2011, GBC, doi:10.1029/2009GB003765
4. Rosenzweig et al, 2014, PNAS, pp.3268–3273 doi:10.1073/pnas.1222463110
5. Leakey, 2018, Food Security, pp.505–524 doi:10.1007/s12571-018-0796-1

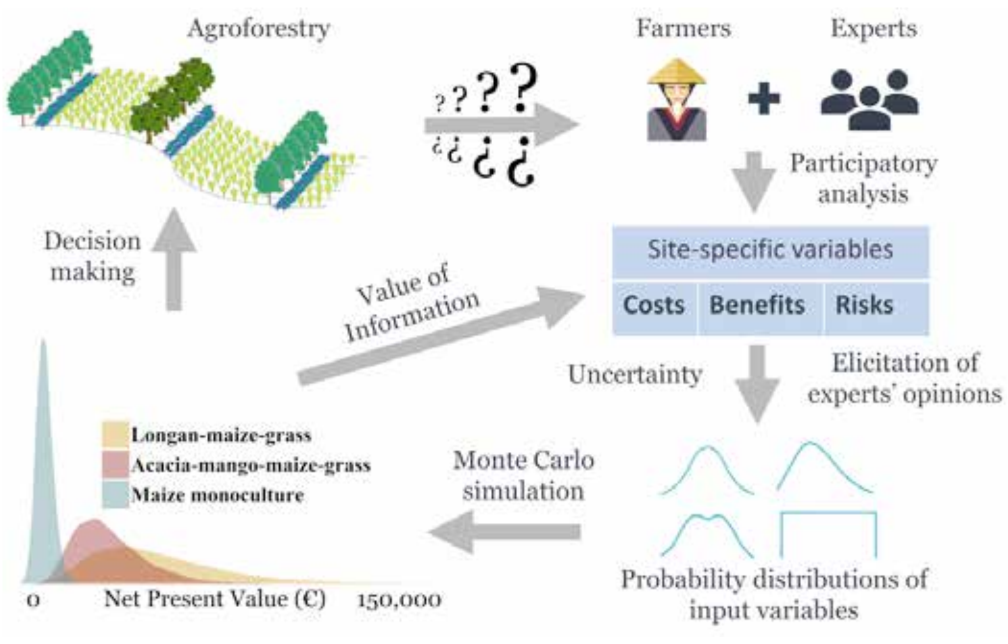
L24.P.05

Uncertainty analysis in agroforestry planning: A case study in Northwest Vietnam

Do H.[1] (dohoa1190@gmail.com), Whitney C.[2], Luedeling E.[2]

[1] *ARTS, University of Bonn, Bonn, Germany*; [2] *INRES - Horticultural Sciences, University of Bonn, Bonn, Germany*

Agroforestry may benefit many farmers of Northwest Vietnam, but it is often difficult to anticipate which of many possible options promises the greatest returns on investment. We applied holistic modelling approaches to provide ex-ante assessments of Net Present Values for seven agroforestry interventions promoted by the World Agroforestry Centre in the mountains of Northwest Vietnam. The region faces serious soil erosion and land degradation due to unsustainable cropping systems, such as maize monoculture on steep slopes. Model results show that these monocultures may be attractive to farmers in that they provide relatively early incomes without lags, yet annual profits decrease over time. All agroforestry systems, on the other hand, return substantial profits in the long term. However, the high costs of establishment and maintenance reduce economic returns in the short term, with many systems generating net losses during the first few years. Initial financial incentives to compensate for short-term economic losses may be needed to promote the adoption of agroforestry. Value of Information analysis revealed key uncertainties (i.e. discount rate, crop yield and crop price). Further information about these variables should be collected to reduce uncertainty about which agroforestry option promises the greatest financial returns.



Decision analysis for agroforestry intervention in Northwest Vietnam

Keywords: decision analysis, holistic model, risks and uncertainties, agroforestry.

References:

1. Luedeling E, Shepherd K, 2016. Solutions 7(5), 46-54.
2. Luedeling E, 2015. Frontiers in Environmental Science 3, article 16, 1-18.
3. Luedeling E, Goehring L, 2018. R package version 1.103.8.
4. R Core Team, 2018. R Foundation for Statistical Computing.

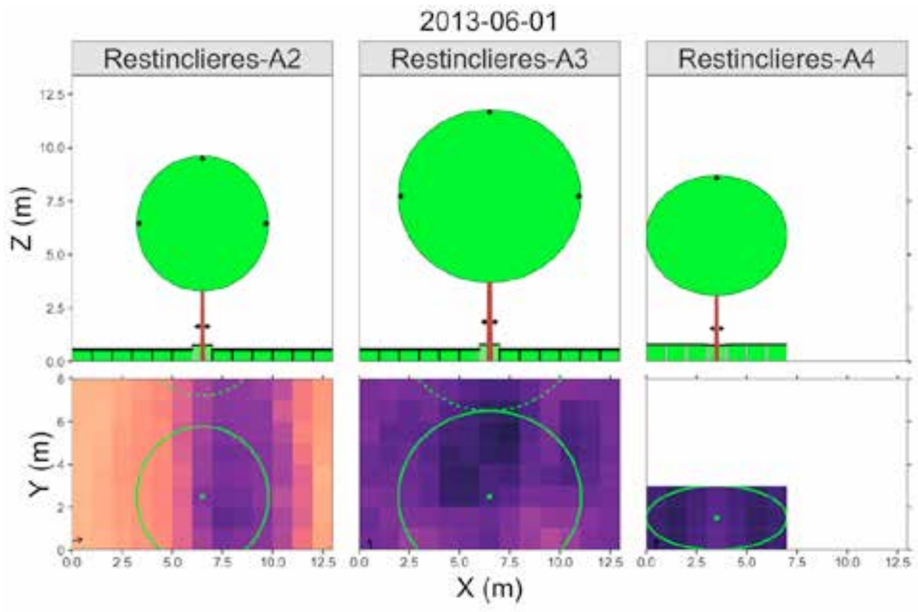
L24.P.06

Theory and description of the 3D Hi-sAFe agroforestry model

Dupraz C.[1] (christian.dupraz@inra.fr), Wolz K.[1], Lecomte I.[1], Talbot G.[1], Vincent G.[2], Mulia R.[3], Reyes F.[1], Gosme M.[1], Van Noordwijk M.[3]

[1] *UMR System, INRA, Montpellier, France*; [2] *UMR Amap, IRD, Montpellier, France*; [3] *Icraf, Bogor, Indonesia*

Hi-sAFe is a mechanistic, biophysical model designed to explore the interactions within agroforestry systems that mix trees with crops. Hi-sAFe has been under development since 2002 via the Silvoarable Agroforestry for Europe (SAFE) project (Dupraz et al. 2005) and was partially described by Talbot (2011). The model couples the pre-existing STICS crop model (Brisson et al. 1998) to a new tree model. Trees and crops compete in 3D for light, water and nitrogen at a daily time step. Modelled system geometry can be custom built using a grid of square cells and flexible boundary conditions, permitting the simulation of isolated trees, tree lines, stand edges, and a wide range of agroforestry patterns. An opportunistic tree growth module (Mulia et al. 2010) accounts for the impact of resource availability on tree root architecture. Monoculture crop and tree systems can also be simulated, enabling calculation of the land equivalent ratio of agroforestry systems. Hi-sAFe is a novel tool for elucidating daily interactions for light, water, and nitrogen in agroforestry systems. Its 3D and spatially explicit form is key for accurately representing many competition and facilitation processes. Hi-sAFe is available online free of charge. A suite of tools for building, running, and analyzing Hi-sAFe simulations is also available via the *hisafer* R package.



A snapshot of one day of three Hi-sAFe simulations. The top row illustrates a horizontal projection of the modelled scene. The bottom row shows a top-down view of the scene, with cell color proportional to shade by the tree on the crop (darker colors indicate more shade).

Keywords: Competition; Facilitation; Roots; light; water; nitrogen.

References:

1. Brisson N. et al, 1998, Agronomie, 18:311–346, doi: 10.1051/agro:19980501
2. Dupraz C. et al, 2005, Synthesis of the SAFE project, http://www.montpellier.inra.fr/safe/english
3. Mulia R, et al, 2010, Plant Soil 337:77–92. doi: 10.1007/s11104-010-0502-3
4. Talbot G, 2011, Ph.D. University of Montpellier, http://tel.archives-ouvertes.fr/tel-00664530

L24.P.07

Sensitivity analysis of the water balance in the WaNuLCAS model: a case study using cocoa-based agroforests in Cameroon

Fayolle S.[1] (stolian.fayolle@cirad.fr), Justes E.[1], Metay A.[2], Saj S.[3]

[1] *UMR SYSTEM - CIRAD, Montpellier, France*; [2] *UMR SYSTEM - Montpellier SupAgro, Montpellier, France*; [3] *UMR SYSTEM - CIRAD, Kourou, French Guiana*

In various regions of the world, climate change is predicted to induce modifications of the rainfall regime which, in turn, are to probably prompt changes in agricultural land-uses. In Central Cameroon, where cocoa cultivation is already carried out in sub-optimal rainfall areas, rainfall changes could threaten this currently crucial source of revenue. Yet, local cocoa growing systems include many complex agroforestry systems (AFS) that may not respond similarly to rainfall variability and drought than less diversified or monospecific cocoa plantations (Jagoret *et al*., 2017). The impact of climate change on such AFS and their resilience is debated in the recent literature (Abdulai *et al*., 2018) and needs to be investigated.
Modelling could significantly contribute to the understanding of the main processes governing AFS functioning and be of great use to check for climate change effects on these processes. However, the relevance of simulated results greatly depends on model performance and modelling AFS remains today a scientific challenge. Therefore, few models are currently available. Yet, the WaNuLCAS model has proven to be efficient at modelling AFS particular crop-tree systems (Van Noordwijk and Lusiana, 1999) albeit it has not been extensively used for tree-tree systems. Furthermore, cocoa AFS often exhibit diverse structural parameters (functional type, height and age of cocoa or associated trees) which may greatly alter WaNuLCAS' outputs (Coulibaly *et al*., 2014). We thus carried out a sensitivity analysis for evaluating the WaNuLCAS functioning and its ability to represent the change in water fluxes in cocoa AFS.
WaNuLCAS was parameterised with soil and plant data collected in a previous study in Cameroon from 144 AFS distributed among three sites (Saj *et al*., 2017). The dataset contained information on the: i) density of cocoa and associated trees, ii) their DBH and basal area, iii) date of cocoa stand establishment, and iv) soil features. Weather data were retrieved from Nasa's "TRMM" survey. We performed a sensitivity analysis of WaNuLCAS v4.01 to analyse the effects of structural parameters on water balance. The tested parameters were: i) density of trees, ii) soil characteristics, and iii) farmers' management practices. Values of the parameters were changed up to 50% of the measured range. We analysed the water fluxes simulated, such as cocoa and associated trees transpiration, soil evaporation, drainage, and run-off.
The work is on-going and final results shall be available for the WAF congress. Preliminary results indicate that WaLNuCAS is sensitive to rainfall variability and could be further used for analysing water fluxes of cocoa AFS under climate change scenarios. These results will allow determining the parameters and variables to be measured in priority in a future field experiment.

Keywords: WaNuLCAS, Water budget, Cocoa, complex systems, Sensitivity analysis.

References:

1. Abdulai et al., 2018. Glob. Change Biol. 24, 273–286. https://doi.org/10.1111/gcb.13885
2. Coulibaly et al., 2014. Agrofor. Syst. 88, 13–28. https://doi.org/10.1007/s10457-013-9651-8
3. Jagoret et al., 2017. Agron. Sustain. Dev. 37. https://doi.org/10.1007/s13593-017-0468-0
4. Saj et al., 2017. Int. J. Agric. Sust. 15, 282-302. http://dx.doi.org/10.1080/14735903.2017.1311764
5. Van Noordwijk and Lusiana, 1999. Agrofor. Syst. 43, 217-242.

L24.P.08

WISDOM: a biophysical and economic systems model for short rotation coppice (SRC) agroforestry management

Greene C.[1] (c3greene@uwaterloo.ca), Nguyen T.-H.[2], Davies E.[3], Dyck M.[4], Blank M.[5], Krygier R.[5]

[1] *Environment Resources and Sustainability, University of Waterloo, Waterloo, Ontario, Canada*; [2] *Civil Engineering & Applied Mechanics, McGill University, Montreal, Québec, Canada*; [3] *Civil and Environmental Engineering, University of Alberta, Edmonton, Alberta, Canada*; [4] *Renewable Resources, University of Alberta, Edmonton, Alberta, Canada*; [5] *Canadian Forest Service, Natural Resources Canada, Edmonton, Alberta, Canada*

Short rotation coppice (SRC) systems are excellent tools for managing treated, nutrient-rich, domestic wastewater residuals, soil carbon, and providing economically viable sources of sustainable wood fibre. However, SRC systems are complex, with numerous interactions between climate, nutrient inputs, soil physicochemical properties, crop establishment and growth, bioenergy, carbon offset credits, environmental regulations, and economics. A method is thus required to simulate such interactions. This paper proposes “WISDOM”, a comprehensive decision-support model for SRC systems. WISDOM can be used to aid stakeholders and decision-makers in long-term planning for environmentally- and economically-sustainable SRC plantations. It can also be used to identify how alternative management decisions affect system behavior – biomass growth, soil properties, and economic returns, for example – through the development of “what-if” scenarios. Model validity was tested with eight years of historical data from a case study in Alberta, Canada. For instance, statistical test results between simulated and observed values using the Nash-Sutcliffe efficiency were 0.98, 0.90, 0.86, and 0.68 for biomass production, tree height, soil electrical conductivity, and irrigation application, respectively. Additionally, three different climate and nine yield-harvest economic scenarios were run to predict different aspects of SRC system and project life cycle assessment outcomes 20 years into the future.

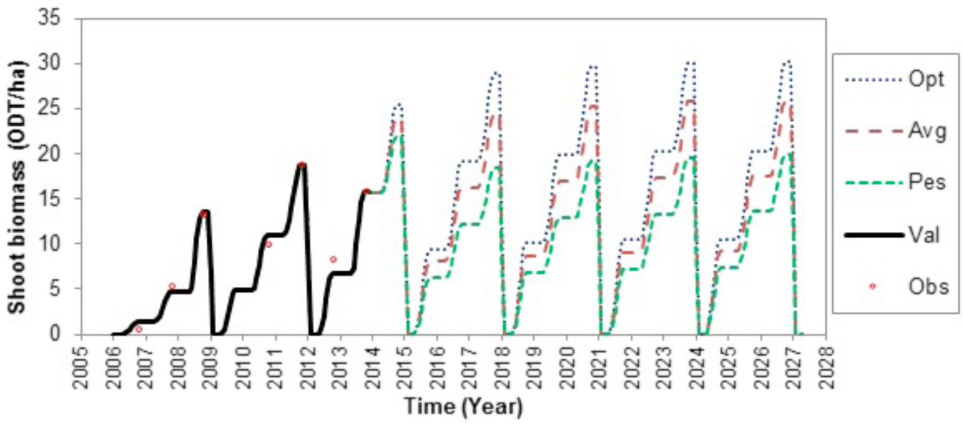


Figure 1: Prediction of biomass production for the complete 7-rotation cycles: optimistic (opt), average (avg), and pessimistic (pes) based on validated (val) results and observed (obs) values from 2006-2013

Keywords: System dynamics, decision support tool, waste to resources, biofuel, WISDOM.

References:

1. Dimitriou et al, 2011, IEA Bioenergy, Task43
2. Heller et al, 2003, Biomass Bioenergy,147-165
3. Langeveld et al, 2012. Bioenergy Research, 621-635
4. Buchholz et al, 2010. Bioenergy Research, 85-95
5. Volk et al, 2011, Asp.Appl.Biol., 67-74

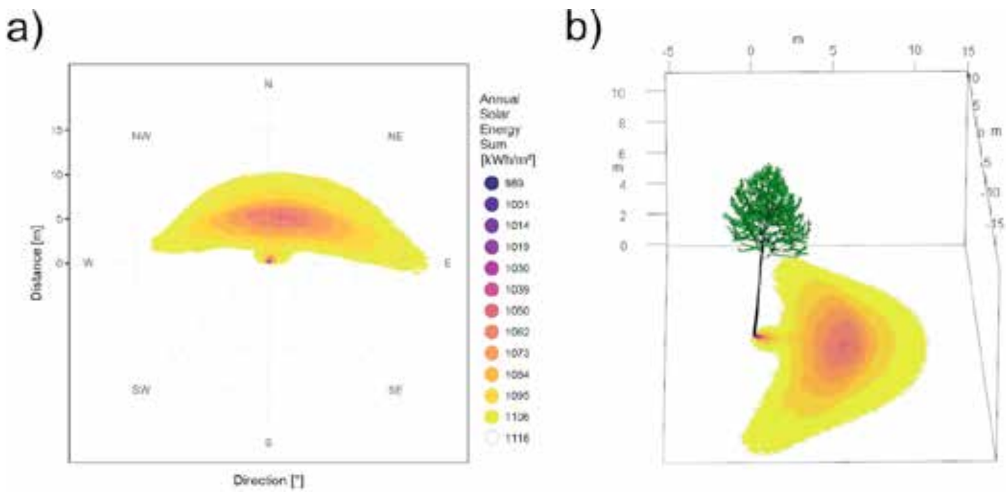
L24.P.09

The dark side of agroforestry: Modelling shadow projections based on 3D data

Morhart C. (christopher.morhart@iww.uni-freiburg.de), Rosskopf E., Nahm M., Kahle H.-P.

Chair of Forest Growth, Albert-Ludwigs-University Freiburg, Freiburg, Germany

Background
Agroforestry systems (AFS) represent complex landuse systems as they imply the cultivation of trees and agricultural crops. Since supply with radiation energy is fundamental for the growth of trees as well as of crops, estimations of the spatial and temporal variation of solar irradiation available at different parts of AFS are of particular interest regarding optimized management.
Materials and Methods
We use 3D point cloud data of single trees collected with a terrestrial laser scanner to develop vector-based models of these trees. To model the shadow cast by the trees and to quantify the resulting loss of solar radiation energy on the ground, we use factual weather data of solar irradiance, obtained from the German Meteorological Service (Deutscher Wetterdienst, DWD).
Results
The novelty of this approach is to use 3D data of trees to compute shadow projections at increased temporal and spacial resolution. The model provides shadow projections in time intervals of 10 min for a raster grid of 10 cm x 10 cm cell size (see Fig. 1).
Conclusion
Using factual climate data enables us to model the radiation regime around a given tree in a realistic manner. The derived results can help to plan AFS more efficiently and to optimize their planting design, taking the expected light reduction into account for choosing the best tree/crop combinations and spatial arrangements.



(a) Annual solar radiation distribution below the modelled tree along the compass directions, the outer circle (grey line) representing a radius of 15 m around the tree stem; (b) 3D visualization of the model tree and distribution of the reduction in direct annual solar radiation energy.

L24.P.10

EcoYield-SAFE: maintaining a parameter-sparse approach in modelling ecosystems processes and dynamics

Palma J.[1] (joaopalma@isa.ulisboa.pt), Graves A.[2], Crous Duran J.[1], García de Jalón S.[3], Oliveira T.[1], Paulo J.[1], Ferreiro-Domínguez N.[4], Moreno G.[5]

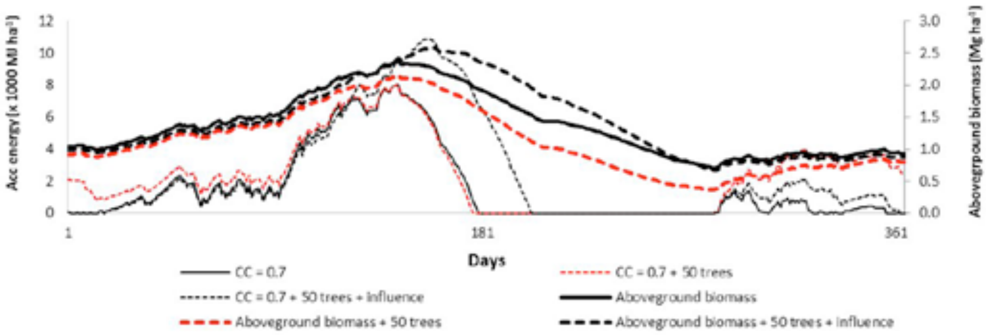
[1] *Forest Research Center, Instituto Superior De Agronomia, Lisboa, Portugal*; [2] *Cranfield University, Cranfield, United Kingdom*; [3] *Basque Centre for Climate Change (BC3), Leioa, Spain*; [4] *Crop Production and Project Engineering, University of Santiago de Compostela, Lugo, Spain*; [5] *INDEHESA, Unversity of Extremadura, Plasência, Portugal*

New agroforestry systems have been proposed across Europe as land use alternatives in the last decades. The systems involves the combination of perennial woody elements, agricultural understory (e.g. wheat, pasture), potentially used by a livestock component. Experimental designs that can combine different alternatives are difficult to implement in the field due to time and cost requirements, and therefore, models can be key tools to explore those alternatives.

In the last decade, the Yield-SAFE model has been used to estimate long term-productivity of silvoarable systems. However, new challenges have arisen and the model has been improved in order to capture new components of the agro-ecosystem dynamics.

This paper summarizes four areas of new developments with the EcoYield-SAFE model which can be categorized into: 1) Improved availability of climate inputs using the CliPick tool; 2) improved description of the microclimate experienced by crops, pasture and livestock within the tree canopy, 3) the addition of new outputs to enable prediction of the carrying capacity of a grass understorey and the impact of agroforestry systems, where appropriate, on fruit and bark production (e.g. cork), and 4) the integration of a soil carbon module adapted from RothC.

The improvement of the model kept its simplistic concept and tried to keep the algorithms as simple and general as possible to ease the calibration for a wider audience.



Example of assessment of tree effects on pasture production during a year in a mature agroforestry system (montado) in southern Portugal with 50 tree/ha, while considering tree influence on micro-climate and 0.7 livestock units/ha energy demand. Note the increase number of days with available energy for grazing

Keywords: Ecosystem approach, livestock, energy, provisioning ecosystem services, regulating ecosystem services.

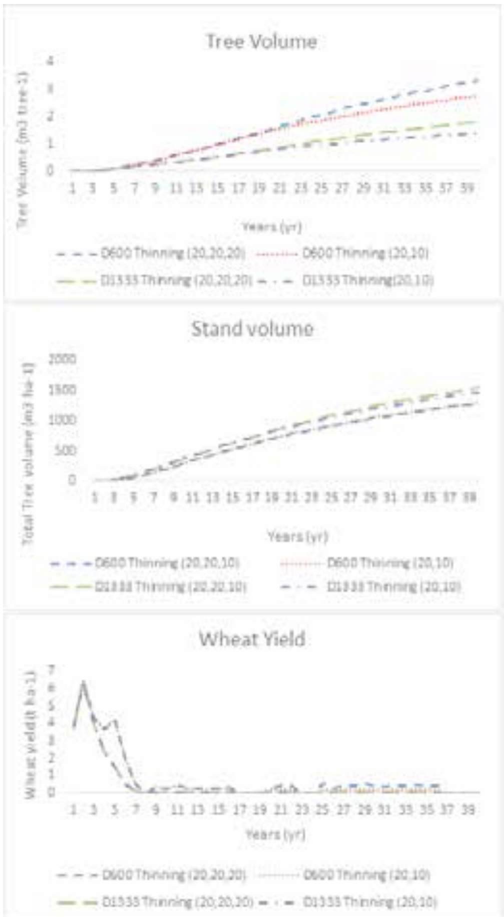
L24.P.11

Yield safe: wheat production under Pinus Radiata

Pérez López C.[1] (mrosa.mosquera.losada@usc.es), Mosquera Losada M. R.[2], Ferreiro Domínguez N.[2]

[1] *Agroforestry, Universidad de Santiago de Compostela, Lugo, España*; [2] *Produc. vegetal y proyecto de ingeniería, Universidad de Santiago de Compostela, Lugo, España*

Silvoarable practices are a type of agroforestry systems that allows combining a crop with a Woody component. Tree layout designs considering distribution but also density modify the productivity of both components. Yield safe was used to compare two tree densities of a Pinus radiate stand considering the productivity of the tree and of wheat. Low initial tree density (600 trees ha-1) aiming at high value timber production was compared with high initial density (1333 trees ha-1) aiming at to produce a higher volume per hectare. Two different thinning were programmed being the first the extraction of 20% of the trees in years 10, 15 and 20 and the second a 20 and a 10% in years 10 and 15. Stand volume was reduced when low tree density were implemented compared with high tree density, while the contrary happened with the tree volume and diameter. Tree diameter was higher when 20:20:20 thinning program was carried out in both tree densities, being the effect more noticeable when low tree density was evaluated.
Wheat maximum production peak was found in the third year being the reduction of wheat production more steadily in high densities than in low densities as expected. However, in all treatment's wheat production was negligible from the 7th year of the simulation. Thinning increased wheat production but the tree density selected is too high to make the seeding profitable.



Keywords: Silvoarable, density, thinning, volume, yield.

L24.P.12

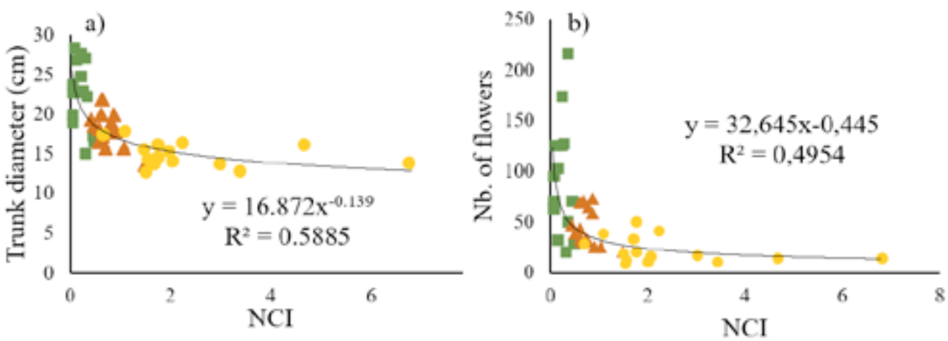
A neighbourhood analysis to characterize competition in a multi-stratum agroforestry system of timber and fruit trees.

Pitchers B.[1] (benjamin.pitchers@inra.fr), Do F. C.[2], Lauri P.-É.[1]

[1] *INRA, Montpellier, France*; [2] *IRD, Montpellier, France*

The growing agroforestry with apple in Mediterranean climate (GAFAM) project looks at the growth and development of apple trees in a multi-strata agroforestry system where walnut trees planted in 1995 forms the upper stratum, three-year-old apple trees the intermediate stratum and sainfoin the herbaceous stratum. Analysing multi-species, multi-stratum agro-systems using a qualitative variable, i.e. 'treatments', is often not satisfying when looking at the heterogeneity within each 'treatment'. Inspired by forest ecologists we developed a neighbourhood competition index (NCI) that combines season-dependant canopy shading and distance-dependent competition model. For $i = 1, \dots, n$ neighbours within a maximum radius (R=15 meters) of the target tree the net competitive effect of the neighbours on the target tree is given by equation [1].
Where PAR is the sum of the photosynthetically active radiation reaching the crown of the target tree during the growing season (t0…t) and CSA the cross section area at breast height of the neighbour *i*.
We correlated the trunk diameter of the target trees with the NCI (Figure 1a). The NCI we calculated explained 59% of the variation of the target trees trunk diameter. We then used the NCI to analyse other data like the number of flowers per apple tree (Figure 1b). Our preliminary results will be discussed in the context of the relationships between apple tree architecture and flowering in fruit-tree based agroforestry systems.

$$[1] \quad \mathrm{NCI} = \frac{1}{\sum_{t0}^{t} PAR} \times \sum_{i=1}^{n} \frac{\mathrm{CSA_i}}{\mathrm{distance_i}}$$



[1] Equation used to calculate the NCI. a) Correlation between the trunk diameter and our newly calculated NCI of 45 3-year-old apple trees across a range of walnut-apple. b) One example of data analysis using the NCI. Here we correlated the number of flowers per tree for 45 apple trees with the NCI. NB: increasing NCI values means increasing competition.

Keywords: Agroforestry, Apple tree, Competition, Neighbourhood competition index, Mediterranean climate.

References:

1. Canham et al., 2004, Canadian Journal of Forest Research, 778-787, doi: 10.1139/X03-232
2. Fichtner et al., 2017,Ecology Letters, 892-900, doi: 10.1111/ele.12786
3. Canham, 1988, Ecology, 1634-1688, doi: 10.2307/1941664
4. MacFarlane, 2017, Functional Ecology, 1624-1636, doi: 10.1111/1365-2435.12865

L24.P.13

Carbon Enrichment Not Fully Explained by Tree Litter or Animal Manure Inputs in a Simulated Faiderherbia-Maize Parkland

Smethurst P.[1] (Philip.Smethurst@csiro.au), Dilla A.[2], Huth N.[3]

[1] *CSIRO, Hobart, TAS, Australia*; [2] *University of Tasmania, Sandy Bay, TAS, Australia*; [3] *CSIRO, Toowoomba, QLD, Australia*

Faidherbia albida is an N-fixing tree native to many countries across a wide range of sub-Saharan Africa, including Ethiopia. Several researchers recorded higher concentrations of C under tree canopies than in adjacent crop-only areas, and speculated that differences were due to a tree effect. Conversely, others indicate that natural regeneration of trees was favoured on pre-existing fertile microsites. To quantify potential influences on soil C, we simulated five decades of a Faidherbia-maize parkland system in the Central Rift Valley of Ethiopia. Soil C was measured in 2015, and maize yield in 2015 and 2016. Simulations were conducted with the APSIM Agroforestry model. Soil parameters were tuned to achieve a good fit of soil C and maize grain yield in the crop-only treatment. Factorial combinations of zero or high annual additions of tree litter and manure were simulated. Soil C (0-20 cm) increased under trees without litter or manure additions, explaining 0-45% of observed increases in the three radial tree zones (Fig. 1). High litter inputs explained a further 25-80% increase, with a further contribution from manure.

As high manure and litter input rates simulated were higher than could be expected in this heavily pollarded and low-stocked system, we suspect that the tree-effect is due to a combination of these and other previously hypothesised mechanisms. This simulation approach appears useful, but better quantification of actual pools and fluxes of C is needed.

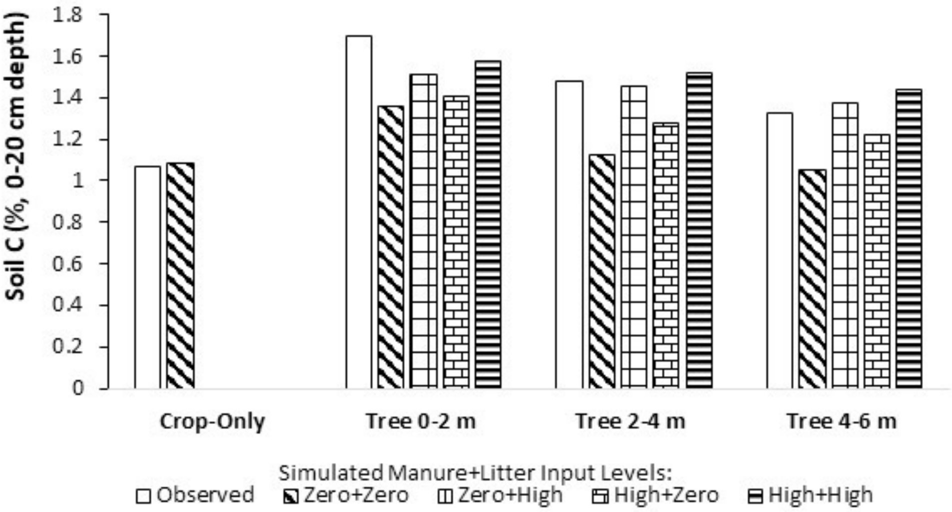


Fig. 1. Observed soil C compared to simulated concentrations with four combinations of manure and litter inputs

Keywords: Model, organic matter, long-term, Ethiopia, microsites.

References:

1. Dilla et al 2019 Agroforestry Systems in press
2. Smethurst et al 2017 Agricultural Systems 155:70-77

L24.P.14

Plot-Scale Biophysical Modelling of Tree-Crop Interactions Using APSIM

Smethurst P.[1] (Philip.Smethurst@csiro.au), Huth N.[2], Dilla A.[3]

[1] *CSIRO, Hobart, TAS, Australia*; [2] *CSIRO, Toowoomba, QLD, Australia*; [3] *University of Tasmania, Sandy Bay, TAS, Australia*

Demand for predictability of wood, food and livelihood outcomes of agroforestry options prompts a need to incorporate trees into plot-scale-biophysical and farm-scale livelihood models. The ICRAF project 'Scaling Trees for Food Security' aims to develop and apply this capability, and make it available for further use. The APSIM modelling framework was chosen for plot-scale-biophysical modelling because of its use in various contexts of food production around the world. However, this model lacked a two dimensional capability that could grow adjacent crops and trees interacting above- and below-ground. In two phases, the project is developing and applying this capability using the APSIM Next Generation framework. Phase 1 involved a proxy tree model used in linear (tree row) or circular (single tree or parkland) configurations in which tree behaviour in relation to competition for light, water and nutrients was user-defined. Phase 2 involves replacing the tree proxy with 'active' tree options that respond to environment, management and genotype. Eucalyptus, gliricidia and oil palm are the tree models currently available, along with wheat, maize, potato and several other crop or pasture models. During phase 1, adequate simulations in a range of contexts were achieved: Gliricidia-Maize (Kenya and Malawi; Fig. 1), Faidherbia-Maize (Ethiopia) and Eucalyptus-Wheat (Australia). We are now proceeding to release the proxy model for public use, and to develop the active tree capability.

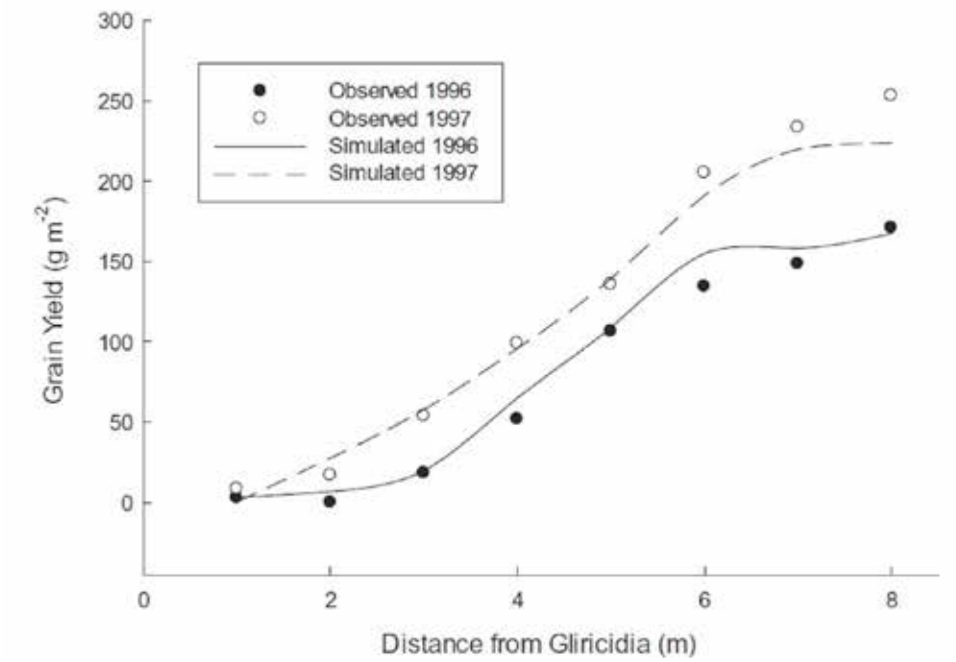


Fig. 1. Observed and simulated maize grain yield in relation to distance from gliricidia at Machakos, Kenya.

Keywords: competition, water, nitrogen, alley cropping, intercropping.

References:

1. Smethurst et al. 2017 Ag. Sys. 155:70-77

L24.P.15

Sap flow prediction model in cocoa trees under different agroforestry arrangements in western Colombian Amazonia

Suárez Salazar J. C.[1] (ju.suarez@udla.edu.co), Casanoves F.[2], Melgarejo L. M.[3], Di Rienzo J. A[4], Armas C.[5], Ngo Bieng M. A.[6]

[1] *Universidad de la Amazonia, Caqueta, Florencia, Colombia*; [2] *CATIE, Turrialba, Costa Rica*; [3] *Universidad Nacional de Colombia, Bogota, Colombia*; [4] *Universidad Nacional de Cordoba, Cordoba, Argentina*; [5] *Estación Experimental de Zonas Áridas, Almeria, España*; [6] *CIRAD, UR Forêts et Sociétés, Turrialba, Costa Rica*

Background

In the current context of adaptation to and mitigation of climate change, water use in agriculture is a critical issue. Specifically in relation to water use, agroforest systems are considered as a sustainable strategy, as the presence of shade trees above crops induces adequate microclimatic conditions that result in an improved water use status. Indeed the presence of shade trees reduces soil evaporation through a reduction in radiation, wind speed, temperature and an increase in air humidity. Therefore, understand and predict water use in agroforest systems is of a key importance when assessing the environmental impacts of agroforestry practices nowadays.

Aim

The aim of this study is to quantify, compare and model sap flow of cacao trees growing under different shade intensities and its relationship with the microclimatic characteristics generated by these shade intensities. The work is applied to cacao agroforests in the Colombian Amazonia, giving the importance of cacao cropping systems in the world in general, and especially in Colombia within its post conflict context.

Material and Methods

For that purpose, we measured sap flow in three plots with different shade intensities in agroforest systems in the Colombian Amazonia, at the Macagual Center of Investigation – University of Amazonia. We used Sap Flow Meter sensors set up in three random cacao trees in each plot. The sap flow measures was recorded during two weeks within the dry season, with a data recording system that stored a measure every 10 minutes. Shade trees composition and structure were characterized in each plot, along with environmental variables related to sap flow variation, mainly: radiation, humidity, temperature, and vapor pressure deficit.

We then built a mixed linear model that predicted sap flow as a function of the climatic variables measured, and we assessed its predictions compared to the measured values of sap flow using the best (AIC/BIC) models for sap flow and a validation dataset.

Major results and Conclusions

The statistical model we built was able to simulate sap flow variations in each plot during the day, but also sap flow variation between the plots. We simulated real situations of hydrological behavior specific to the cultivation of cocoa under different agroforestry arrangements. Particularly, it predicted the hydraulic redistribution of cacao trees in agroforestry arrangements, as well as nocturnal transpiration in monocultures under the environmental conditions, that we put in evidence for the first time in the region of the Colombian Amazonia. In this sense, hydraulic redistribution may play a fundamental role in the water balance of the cacao plant. This model could be an useful tool for managing and predicting cacao tree water use as a function of the microclimatic conditions in the different agroforest systems in the Colombian Amazonia.

L24.P.16

Generation of configurable and extensible, multiscale models for dynamic simulation of complex agroforestry systems

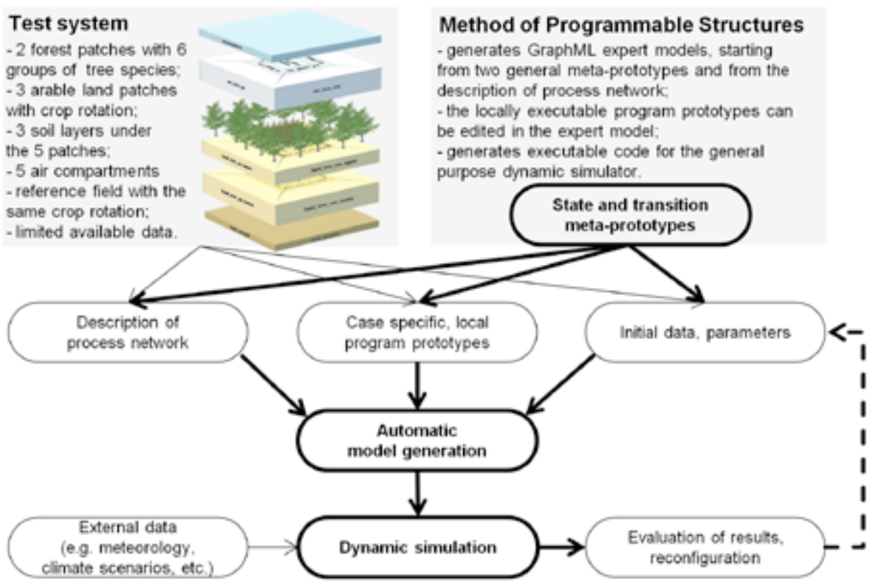
Varga M.[1] (varga.monika@ke.hu), Rásó J.[2], Keserű Z.[2], Csukás B.[1]

[1] *Institute of Methodology, Kaposvar University, Kaposvar, Hungary*; [2] *Department of Plantation Forestry, Forest Research Institute – NARIC, Püspökladány, Hungary*

Planning and operation of agroforestry systems, affected by changing external conditions, require flexible dynamic models of interacting processes [1,2,3]. The objective of this work is to apply the recently developed methodology of Programmable Structures [4,5] for dynamic simulation of an example agroforestry in Földes, Hungary.

In our non-conventional modeling methodology the structure and the building elements of processes are mapped onto a computable code, directly, without any specific mathematical apparatus. The multiscale, time- and event-driven Programmable Structures can be generated and simulated automatically. The general part of the related framework is highlighted by bold lines in the Figure.

In agroforestry models we generate specific state elements in various compartments (e.g. leave, branch, bole, main root, fine root, xylem and phloem for trees, or organic residues, humus, inorganic solid and solution for soil parts). Typical examples for transition prototypes are photosynthesis, evapotranspiration, growth, respiration, nutrient uptake, etc. in plants; evaporation, precipitation, diffusion, demineralization, etc. in soil. In the lowest level we calculate the dynamic balance of C, O, H, N, P and other optional atoms, considering the characteristic stoichiometries. According to the temporary results, Programmable Structure seems to be a feasible approach to generate dynamic models of medium complexity, with relatively limited data demand.



Keywords: agroforestry modeling, multiscale model, dynamic simulation, model generation, Programmable Structure.

References:

1. van der Werf et al. 2007. Ecological Engineering, 29(4): 419-433.
2. Artru et al. 2017. European Journal of Agronomy, 82(Part A): 60-70.
3. Van Noordwijk et al. 2011. WaNuLCAS version 4.0, World Agroforestry Centre, 224 p.
4. Varga and Csukas. 2017. AIChE Annual Meeting, Computing and Systems Techn. Division. Paper 448e.
5. Varga and Csukas. 2017. Ecological Modelling, 364:25-41.

L24.P.17

Calibration of the 3D Hi-sAFe agroforestry model for hybrid walnut

Wolz K. J. (wolzkevin@gmail.com), Dupraz C., Lecomte I., Gosme M., Reyes F.

UMR-SYSTEM, INRA, Montpellier, France

Hi-sAFe is a 3D biophysical model designed to explore the interactions between tres and crops in agroforestry systems. Utilization of any tree species within Hi-sAFe requires parameterization and calibration of the model for that tree species. We carried out these three steps for hybrid walnut (*Juglans regia x nigra*). Data used for parameterization and calibration came from the literature and long-term experimental plots at the Restinclières Estate near Montpellier in Southern France (Inurreta-Aguirre et al. 2018). The three plots included two alley cropping systems of hybrid walnut and durum wheat (*Triticum durum*) and a pure forestry system of hybrid walnut with a natural ground cover. A total of 21 Hi-sAFe tree inputs were unable to be parameterized directly and were included in the model calibration. Optimal parameter values were searched for using a multi-objective evolutionary algorithm (MOEA) similar to the NSGA-II algorithm (Deb et al. 2002). The root mean square errors of the measured vs. modeled diameter at breast height (DBH) in each plot were used as objective functions to minimize. The final Pareto optimal front of the MOEA contained a diversity of tree parameter sets. Accuracy of modeled crop relative yield in the A2 plot was used as a final criterion to select the best parameter set. These calibrated Hi-sAFe parameters for hybrid walnut can be used to confidently explore hybrid walnut agroforestry systems across pedoclimatic and management conditions.

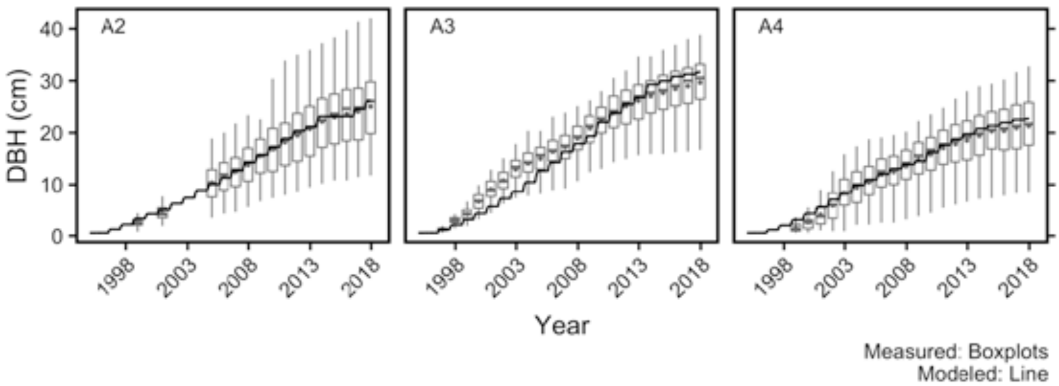


Fig. 1 Measured vs. modeled DBH of hybrid walnut in two agroforestry systems (A2 and A3) and one pure forestry system (A4) in Southern France. Boxplots show the range of measured data for individual trees each year. Lines show Hi-sAFe model predications after model calibration.

Keywords: alley cropping, silvoarable, model, genetic algorithm, optimization.

References:

1. Deb K, Agrawal S, Pratap A, Meyarivan T (2002) IEEE Trans Evolutionary Computation 6:182–197.
2. Inurreta-Aguirre HD, Lauri P-É, Dupraz C, Gosme M (2018) Agrofor Syst 1–14. doi: 10.1007/s10457-018-

L24.P.18

Modeling the contribution of ecological agriculture for climate change mitigation in Côte d'Ivoire

Worou O. N.[1] (n.worou@cgiar.org), Kone A. W.[2], Tondoh J. E.[2], Guei A. M.[3], Edoukou F. E.[4]

[1] *ICRISAT, Bamako, Mali*; [2] *UFR des Sciences de la Nature, Université Nangui Abrogoua, Abidjan, Côte d'Ivoire*; [3] *UFR d'Agroforesterie, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire*; [4] *Centre de Recherche en Ecologie, Abidjan, Côte d'Ivoire*

The use of crop models is motivated by the prediction of crop production under climate change and for the evaluation of climate risk adaptation strategies. Therefore, in the present study the performance of DSSAT 4.6 was evaluated in a cropping system involving integrated soil fertility management options that are being promoted as ways of adapting agricultural systems to improve both crop yield and carbon sequestration on highly degraded soils encountered throughout middle Côte d'Ivoire. Experimental data encompassed two seasons in the Guinea savanna zone. Residues from the preceding vegetation were left to dry on plots like mulch on an experimental design that comprised the following treatments: (i) herbaceous savanna-maize, (ii)10 year-old of the shrub *Chromolaena odorata* fallow-maize (iii) 1 or 2 year-old *Lalab pupureus* stand-rotation, (iv) the legume *L. pupureus* -maize rotation; (v) continuous maize crop fertilized with urea; (vi) continuous maize crop fertilized with triple superphosphate; (vii) continuous maize crop, fertilized with both urea and triple superphosphate (TSP); (viii) continuous maize cultivation. The model's sensitivity analysis was run to figure out how uncertainty of stable organic carbon (SOM3) can generate variation in the prediction of soil organic carbon (SOC) dynamics during the monitoring period of two years, within the first soil layer and to estimate the most suitable value. The observed variations were of 0.05 % in total SOC within the short-term and acceptable dynamics of changes were obtained for 0.80% of SOM3. The DSSAT model was calibrated using data from the 2007-2008 season and validated against independent data sets of yield of 2008-2009 to 2011-2012 cropping seasons. After the default values for SOM3 used in the model was substituted by the estimated one from sensitivity analysis, the model predicted average maize yields of 1 454 kg ha-1 across the sites versus an observed average value of 1 736 kg ha-1, R2 of 0.72 and RMSE of 597 kg ha-1. The impact of fallow residues and cropping sequence on maize yield was simulated and compared to conventional fertilizer and control data using historical climate scenarios over 12 years. Improving soil fertility through conservation agriculture cannot maintain grain yield in the same way as conventional urea inputs, although there is better yield stability against high climate variability according to our results.

Keywords: conservation agriculture, sensitivity analysis, climate, DSSAT, West Africa.

References:

1. Koné AW, Edoukou EF, Gonnety JT, N'Dri ANA, Assémien LFE, Angui PKT, Tondoh JE Can the shrub Chromol
2. Yéo WE, Goula BTA., Diekkrüger B, Afouda A (2016) Vulnerability and adaptation to climate change
3. Yang JM, Dou S, Yang JY, Hoogenboom G, Jiang X, Zhang ZQ, Jiang HW, Jia LH (2011) Crop-soil nitrogen
4. Soler CM, Bado VB, Traore K, Bostick WM, Jones JW, Hoogenboom G, 2011 Soil organic carbon dynamics
5. Lal R (2015) Restoring soil quality to mitigate soil degradation. Sustainability 7: 5895-5895 doi:10

ABSTRACTS

Open Session

- L25 -
Open Session

All that you always wanted to know about agroforestry, but never dared ask

Agroforestry is much more than what was included in the 32 parallel sessions. Feel free to submit here any proposal that do not fit properly in the thematic sessions. If a new topic of high interest emerges, we may turn it into a full session. We are well aware that many topics are missing in the thematic sessions: specialty agroforestry systems (such as bamboos, rattan, silkworm production, and many more), agroforestry systems dedicated to energy production, allelopathy effects in agroforestry, and many more. This session is open to all your suggestions, feel free to open our eyes on all aspects of agroforestry.

L25_O.01

From Agroforestry to Agrivoltaism : an extension of the mixture concept

Dupraz C.[1] (christian.dupraz@inra.fr), Sourd F.[2], Gosme M.[1], Nogier A.[2]

[1] *UMR System, INRA, Montpellier, France*; [2] *Sun'R, Paris, France*

What is the best strategy to produce both food and energy from agricultural land? Agroforestry (AF)? Monocrops? We explore a new option, agrivoltaism (AV). AV systems combine crops with photo-voltaic panels to produce both food and energy. Usually, crops, forests and photo-voltaic plants are separated in different land units. The Land Equivalent Ratio is the sum of the relative yield of the crop (crops in AV versus monoculture) and the relative production of electricity (AV plant versus standard photovoltaic plant). Measured LERs for AV and AF systems were surprisingly high : 1.2 to 1.5 in AF and 1.3 to 1.6 in AV. Dynamic AV use moving panels on trackers, and allow to provide light to the crop when the needs are high, or shade when the crop is under water stress. They can also help alleviating frost or hail damage. Both AF and AV systems appear to be very efficient in resource use. The level of complexity involved in the two systems is different : in AF systems, the trees are a living component that induce a dynamic shade pattern, a growth in size year after year and competition for water and nutrients with the crops. In AV systems, solar panels produce a stable and predictable shading pattern and do not compete for below-ground resources. Mixed AF-AV systems (Agrivoltafor systems?) are possible when small trees are grown under the panels. Such three layers systems (crop, tree and panels) are considered for fruit trees such as apple or peach trees in South France.

Prototypes of agri-voltaic systems combining fixed (right, with vegetable growing, Montpellier) and mobile (center and left, with vineyards, Tresserre) solar panels. A 4 m clearance allows easy mechanization of the system with conventional machinery. Mobile panels can be dynamically aligned with the sun to provide high irradiation to the crop (center).

Keywords: mixed systems, solar panels, joint production, Land Equivalent Ratio.

References:

1. Dupraz C et al, 2011, Renewable Energy, 36: 2725-2732
2. Sun'R, 2018, https://sunagri.fr/en/agrivoltaics/1056-2/
3. Valle B et al, 2017, Appl Energy, 206:1495-1507

L25_O.02

Agroforestry on post-mining restoration: a multispecies and multifunctional approach

Asmara D. H.[1] (degi.asmara.1@ulaval.ca), Allaire S.[2], Van Noordwijk M.[3], Khasa D. P[1]

[1] *IBIS, Université Laval, Quebec City, Quebec, Canada*; [2] *Soils and Agro-Environmental Engineering, Université Laval, Quebec City, Quebec, Canada*; [3] *World Agroforestry Centre, Bogor, West Java, Indonesia*

Forward-looking restoration paradigm which focuses on enhancing ecosystem services and increasing resilience is believed to be the best environmentally sustainable practice in ecological restoration (Choi et al., 2008, Ecoscience 15:53–64). Accelerating land restoration with similar principles of agroforestry concept can be beneficial for expected increase in the demand for land and food (Vieira et al., 2009, Restor Ecol 17:451–459). Agroforestry has great potentials for providing numerous ecosystem services, including: soil conservation, land rehabilitation, ground water-table stabilization, and phytoremediation of soils contaminated with heavy metals and other pollutants (Atangana et al., in: Tropical Agroforestry, 2014). The challenges with restoration on degraded post-mining land are the low productivity of soil and high potential contaminants. Herein we evaluated the potential phytobial remediation by testing a mixture of woody and herbaceous species, microsymbiont and biochar amendments, and growth spacing conditions.

The experiments with agroforestry multispecies and multifunctional approaches were conducted using greenhouse and field trials. The field trails were established on gold post-mining sites in the Abitibi-Témiscamingue region, Northwest Quebec, Canada, on two types of waste materials: fine tailing and waste rock. We used a mixture of tree species (*Alnus crispa, Picea glauca, Populus tremuloides, Salix arbusculoides*) and herbaceous species (*Avena sativa, Festuca rubra,* and *Trifolium repens*). The biochar amendment and microbial inoculation were applied on both greenhouse and field trials. The plant growth performance was assessed after three months for the greenhouse trials and two growing sessions for the field trials. An additional greenhouse experiment with Nelder plot design (Nelder, 1962, Biometrics 283–307) was also conducted to assess the tree species interaction.

The microclimate was found to be the most significant factor on plant survival and growth. The higher plant density and species selection with various leaf forms were shown to be affecting the microclimate. The uncertainty effect of microbial inoculation between the greenhouse and field trials on the plant's growth performance was also suspected as the result of differences in macro and microclimate conditions. Biochar's effect on soil albedo and temperature is more important in the studied climate and may hinder its impact on other soil properties. We suggest putting emphasis on microclimate modification to facilitate the phytoremediation design. Among different plantation techniques, the nucleation method (Corbin et al., 2012, For Ecol Manag 265:37–46) with the incorporation of agroforestry principles should be considered to accelerate the remediation and succession processes. The plantation method in patches (nucleation) is expected to generate an improved micro-environment that facilitates the ecosystem's recovery with minimum implementation costs.

Keywords: agroforestry, restoration, phytoremediation, multispecies, microclimate.

References:

1. Choi et al., 2008, Ecoscience 15:53–64
2. Vieira et al., 2009, Restor Ecol 17:451–459
3. Atangana et al., in: Tropical Agroforestry, 2014
4. Nelder, 1962, Biometrics 283–307
5. Corbin et al., 2012, For Ecol Manag 265:37–46

L25_O.03

Agroforestry and Food Security of Households in Selected Upland Farming Communities in the Philippines

Landicho L.[1] (ldlandicho@gmail.com), Cabahug R. E.[2], Baliton R.[3], Paelmo R.[4], Visco R.[3], Abadillos M. A.[2], Cosico R. S.[2], Castillo A. K.[2]

[1] *Institute of Agroforestry, University of the Philippines Los Banos, College, Laguna, Philippines*; [2] *Institute of Agroforestry, University of the Philippines Los Banos, College, Philippines*; [3] *Institute of Renewable Natural Resources, University of the Philippines Los Banos, College, Philippines*; [4] *Institute of Crop Science, University of the Philippines Los Banos, College, Philippines*

The agricultural sector in the Philippines is the major stakeholder in food production, and is dominated by smallholder farmers in the upland farming communities. Can the farmer-producers consume their own produce? Is food available and accessible among them? Can the production systems produce food enough for households and community? Can these production systems withstand climate change? These are the basic questions that were addressed by the study in the three upland farming communities in Luzon, Philippines, involving 215 farmer-respondents. The food security potentials of different production systems were analyzed based on food stability, availability, accessibility, and utilization. Each variable was measured through several indicators. The corresponding mean scores are scaled as (<1) means food is not available, stable, accessible, or utilized; while a higher score (1.5-2) means the opposite or highly available, stable, accessible, or utilized. A mean score in between (1-1.49) means moderate indicators. The food security status in the study sites were then computed by adding up the scores in each of the four measures/indicators divided by the total number of indicators (4). The food security score was measured using the following scale: (7.00 – 8.00 high level of food security; 6.00 – 6.99 moderate level of food security; 5.00 – 5.99 low level of food security; and, <5.00 food insecure). Most of the upland farmers in the three communities were small-income earners, as their estimated annual farm income ranges from PHP 10,000–20,000. Landholdings were small— farm size ranged from 1 to 3 ha, although 70 percent of the farmers owned the land they tilled. Most of the farms had a topography ranging from rolling to steep slope, which was prone to soil erosion. Furthermore, the areas, which were mostly rainfed, were vulnerable to changing rainfall patterns brought about by climate change. Four types of production systems were present in the upland communities—monocropping, relay cropping, multiple cropping, and agroforesty. Around 64 percent adopted agroforestry planted with a combination of short, medium, and long terms crops. Results revealed that farm households engaged in agroforestry had the highest food mean score (1.82) in terms of food availability (year-round availability of food in the household); food stability or the capacity of the farming system to withstand natural calamities (1.58); food utilization (1.94, or the consumption of the farmers' produce within and outside the community; and food accessibility or farmers' ability to access basic food items either in their own backyard or nearby markets (1.53). The smallholder farmers engaged in agroforestry production systems have the highest food security score of 7.14 based on the four indicators. Therefore, this paper argues that the practice of agroforestry provides potentials for ensuring food security of smallholder farmers in the upland farming communities in the Philippines.

Keywords: food availability, food accessibility, food utilization, food stability, smallholder farmers.

L25_O.04

Eliciting Children's culture: Sustainable hunting in backyard agroforests by budding trappers in the Congo Basin

Dounias E. (edmond.dounias@ird.fr)

UMR5175 CEFE, IRD, Montpellier cedex 5, France

In the modern Western world, children are mostly considered as "adults to be" and the educational system is accordingly conceived as a one-way process from "adults who know" to "children who learn". Proximate consequences of such conception of the place of children within the society are to consider them as fragile and dependent consumers. This western view of childhood has for long oriented research and development actions considering children as inactive household members and overlooking them as actors and potential informants.

In reality, children among indigenous peoples and local communities (IPLCs) in the intertropical regions generally have an access to a specific range of presumably "wild" resources that are generally of lesser importance for adults. As almost exclusive harvesters of these resources, children detain their own sphere of knowledge and know-how with two utmost consequences: (1) they coordinate among them an independent and horizontal educational channel, in which adults seldom intervene; and (2) they are actively involved into a reciprocal transmission process along the vertical educational channel that interconnects them with adults: they are depositories of traditional ecological knowledge that adults no longer mobilize. In addition to the acquisition of skills that are required prior to the passage into adolescence, children also "produce" knowledge to be shared among themselves with their peers, a knowledge that is now commonly referred to as "children's culture".

This presentation wishes to explore the role of agroforests as an overlooked playground for the expression of children's culture among the most nature-dependent peoples. Garden hunting practiced by children in the backyard agroforests throughout the Congo Basin is a striking example. Kids detain a sphere of trapping knowledge, which is technically speaking highly diversified, and which they manage on their own. The intervention of adults is minimal since this form of trapping takes place in proximity of the safe homestead. The assembling of these traps combines recreational and educative purposes as it prepares budding trappers for adulthood. The bushmeat captured in the vicinity of villages is generally consumed as snack food by children; it incidentally makes up a valuable part of their diet in its own right. Children should not be viewed only as the final beneficiaries of a tradition that should be preserved by any means; they also hold in their hands a corpus of knowledge and know-how that adults no longer care about, and that still could ensure a reliable portion of meat procurement for domestic consumption.

Keywords: Backyard Agroforests, Children, Hunting, Knowledge, Congo Basin.

References:

1. Dounias & Aumeeruddy-Thomas 2017. AnthropoChildren 2017(8). DOI : 10.25518/2034-8517.2799
2. Dounias 2016. Ecology & Society. 21(1). DOI : 10.5751/ES-07946-210123
3. Dounias 2010 The Open Complementary Medicine Journal 2010(2). DOI: 10.2174/1876391X01002010031

L25_O.05

Farmers' values sustain forest gardens

Melvani K. (Kamal.Melvani@cdu.edu.au), Myers B., Stacey N.

RIEL, Charles Darwin University, Darwin, NT, Australia

Tropical forest gardens (FGs) are ancient, tree-dominant land uses that continue to be adopted and maintained in Sri Lanka because farmers value them. Why and what farmers value about FGs will aid the global search for resilient agricultural models which increase food production and improve farmers' livelihoods (Food and Agriculture Organsation, 2016) in the face of climate variability (Esham et al., 2017), shrinking natural resources (Food and Agriculture Organisation, 2018) and increasing animal and insect pest impacts (Marambe et al., 2015). We investigated the context of valuation, farmers' values for land and crops, stressors that impacted livelihoods and farmers' responses to stressors. Data were collected with 85 farmers from nine locations in the Intermediate zone of Sri Lanka (average annual rainfall 1750-2500 mm) using semi-structured and open-ended interviews. Values were categorised and aligned with the Total Economic Value framework (Pascual et al., 2010). Forest gardens were: mainly inherited, already planted with long-term crops (tree or perennial) and cultivated thereafter with short-term crops (annual and semi-perennial). Farmers developed FGs with material and technical support from government and NGOs. New expertise and ancestral knowledge guided landscape designs using long- and short-term crops. The selection and maintenance of crops was attributed to Direct or Indirect values that farmers held or gained from them. Direct included: Utility (floristic diversity - plants and crops, food, income, fuelwood, timber, medicine, aesthetic) and Environmental values (eg. shade, cool environment, water quality, soil fertility and moisture retention), while Indirect incorporated Intrinsic (tranquillity, pride, contentment), Option (potential timber, fuelwood) and Bequest (land) values. Income, food and floristic diversity were the most highly ranked values. Farmers were stressed by climate variability, animal and insect pests, and labour scarcity, and adopted various adaptation strategies in response. Most farmers opted to cultivate long-term crops as their response strategy to all stressors because they provided: income, food, fuelwood, timber and environmental benefits over time, and the option of converting timber to cash in an emergency. Long-term crops were also resilient to rainfall variability and required less labour. In contrast, short-term crops served immediate household needs for food, medicine and cash but were vulnerable to multiple stressors. Sri Lankan farmers value FGs because they provide multiple benefits in the present and for the future. Although their main response strategy was the cultivation of long-term crops, farmers, as had their ancestors, cultivate a portfolio of long- and short-term crops to satisfy all their livelihood needs and reduce risk. Forest gardens provide potential for farmers in other tropical countries challenged by similar stressors and warrant consideration in global agricultural planning.

Keywords: Forest gardens, Values, Sri Lanka.

References:

1. Esham, M., et al. (2017). Environment, Development and Sustainability, doi: 10.1007/s10668-017-9945
2. Food and Agriculture Organisation. (2018). http://www.fao.org/3/I9535EN/i9535en.pdf
3. Food and Agriculture Organisation. (2016). http://www.fao.org/publications/sofa/2016/en/
4. Marambe, B., et al. (2015). In W. L. Filho (Ed.), Handbook of Climate Change Adaptation
5. Pascual, U., et al. (2010).In P. Kumar (Ed.), The economics of ecosystems and biodiversity (TEEB)

L25_O.06

The potential of introducing multipurpose trees in the rural landscapes of KwaZulu-Natal, South Africa

Tshidzumba R. P.[1] (phillipmgf@yahoo.com), Pokwana S.[1], Chirwa P. W.[1], Babalola F. D.[2]

[1] *Plant and Soil Sciences, University of Pretoria, Pretoria, Gauteng, South Africa*; [2] *Forest Resources Management, University of Ilorin, Ilorin, Kwara State, Nigeria*

Trees are a common feature in the landscape around the world and provide important environmental, social and economic services to the people (Garrity, 2004). This study assessed the potential benefits of introducing multipurpose trees on farmlands and homesteads in three communities of Harding-Weza region in KwaZulu Natal Province of South Africa. Quantitative data was collected from households through administration of structured questionnaire, while focus group discussion (FGD) was used to interview key members of the communities. Chi-square test of independence was employed to understand the relationship between Kwabasa, Mkhoba and Ngubelanga communities regarding their perception on the importance of trees. The study revealed that the respondents from KwaBasa (69.1%), Mkhoba (85.4%) and Ngubelanga (93.4%) strongly valued the importance of trees in their livelihood. Moreover, there was statistically significant relationship ($p < 0.001$) between study communities regarding their perceptions on the significance of integrating trees in their farming practices. While the majority of respondents had no knowledge of any agroforestry practices, focus group discussions revealed that interest in planting trees depended on cultural beliefs and myths. Specifically, FGD participants in both Mkhoba and Kwabasa strongly indicated that planting of Avocado trees in homesteads was associated with subsequent death to household males, while planting it in communal land was regarded appropriate. In contrast, participants in Ngubelanga community preferred to plant the same avocado trees in their homesteads. Majority of the respondents (90-100%) in Kwabasa, Mkhoba and Ngubelanga showed interest in growing fruit trees including peach, orange and apple in their homesteads. It is concluded that communities were interested to plant fruit trees in the homesteads but mostly preferred the communal land. However, there was need for government, private companies and non-governmental organizations to actively promote the culture of planting and establishment of multipurpose trees in the rural areas in order to improve the livelihoods and conservation of indigenous trees species.

Keywords: Agroforestry practice, Tree planting, Livelihood, Landscape, Multipurpose trees.

References:

1. Garrity, 2004. Agrofor Sys 61:5–17
2. Krejcie, Morgan. 1970. Edu and Psy Measurement, 30(3): 607–610
3. Tshidzumba et al. 2018. SFJFS. 1-9 DOI:10.2989/20702620.2018.1463190

L25_O.07

Species Richness, Cultural Importance and Prioritization of Wild Spices for Conservation in Benin (West Africa)

Kafoutchoni K. M.[1] (k.medard@gmail.com), Idohou R.[2], Egeru A.[3], Salako K. V.[1], Agbangla C.[4], Adomou A. C.[5], Assogbadjo A. E.[6]

[1] *Faculty of Agronomic Sciences, Laboratory of Biomathematics and Forest Estimations (LABEF), Abomey-Calavi, Bénin*; [2] *Faculty of Agronomic Sciences, Laboratory of Biomathematics and Forest, Abomey-Calavi, Bénin*; [3] *RUFORUM, Kampala, Uganda*; [4] *Faculty of Science and Techniques, Laboratoire de Génétique Moléculaire et, Abomey-Calavi, Bénin*; [5] *Département de Biologie Végétale, Herbier National, Abomey-Calavi, Bénin*; [6] *Faculty of Agronomic Sciences, Laboratory of Applied Ecology, Abomey-Calavi, Bénin*

Spices have always been used for their flavor-enhancement characteristics and for their medicinal properties. In Benin, scientific research on spices is scarce, despite their importance in the local population's daily needs. This study investigated the diversity of wild spices and documented the associated traditional knowledge that can be used for their valuation, domestication and sustainable management in the Sudano-Guinean Zone of Benin. Data were collected during field expeditions using semi-structured interviews in ten localities across the three phytodistricts of the zone. Species richness and Shannon's diversity index were estimated using species accumulation curves. Use-report (UR), Cultural Importance [1], Use value (UV) index [2], and Informant consensus factor (*F*ic)[3] were used to assess traditional knowledge on wild species, their local importance, and informants agreement among sociolinguistic groups.Priority wild spices were finally identified using an approach combining eight criteria (native status, economic value, ethnobotanical value, global distribution, national distribution, in-situ and ex-situ conservation status, legislation, and threats assessment) in four prioritization methods (point scoring procedure, point scoring procedure with weighting, compound ranking system, and binomial ranking system) [4]. A total of 14 species, belonging to 12 genera and 9 families were inventoried. The most prominent families were Zingiberaceae (21.43%), Annonaceae (21.43%) and Rutaceae (14.29%). More than 200 specific uses were reported, with the Tchabè people holding the greatest level of knowledge (70 uses; UR=5.70±0.33). The culturally most important spices differed among sociolinguistic groups. Most of the informants agree on the use of the species among (*F*ic:0.72-0.98) and across the considered use-categories (*F*ic:0.88-0.99). The highest UV were registered for *Aframomum alboviolaceum*(UV=0.93), *Lippia multiflora* (UV=0.76) and *Aframomum angustifolium* (UV=0.18). Overall, people perceived wild spices as declining due to agriculture, grazing and drought. Five species; *Aframomum alboviolaceum, Lippia multiflora, Monodora tenuifolia, Xylopia aethiopica,* and *Zanthoxylum zanthoxyloides* were the most prioritized for conservation. This study provides information relevant for theimplementation of conservation and domestication actions of wild spices in Benin. Priority species could be integrated into traditional agroforestry systems (e.g. home gardens). However, for this to be effective, further research should be undertaken on morphological and genetic diversity, and propagation methods of priority wild spices.

Keywords: biodiversity, quantitative ethnobotany, prioritization, accumulation curve.

References:

1. Tardio J, 2008, Economic Botany, 24–39.
2. Rossato SC, 1999, Economic Botany, 387–395.
3. Heinrick M, 1998, Social Science & Medicine, 1859–1871.
4. Magos Brehm J, 2010, Biodiversity Conservation, 2715–2740

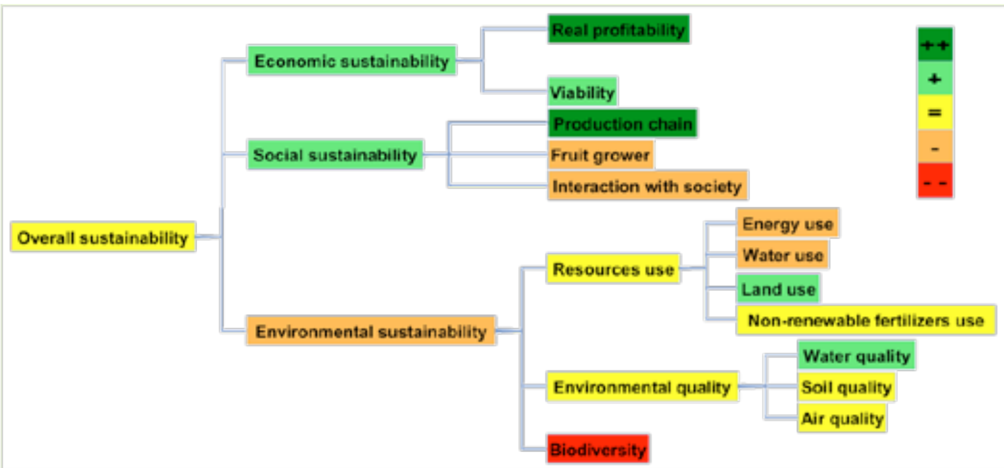
L25_O.08

DEXiAF: a new *ex-ante* assessment tool for co-designing sustainable agroforestry systems

Alaphilippe A.[1] (aude.alaphilippe@inra.fr), Warlop F.[2], Mezière D.[3], Augis A.[4], Vaskou C.[1], Castel L.[5], Grandgirard D.[4]

[1] *UERI Gotheron, INRA, St-Marcel-Lès-Valence, France*; [2] *GRAB, Avignon, France*; [3] *UMR System, INRA, Montpellier, France*; [4] *Unilasalle Beauvais, Beauvais, France*; [5] *CA26, Chambre d'agriculture de la Drôme, Etoile-sur-Rhône, France*

The design of optimal temperate agroforestry systems is a real challenge, particularly because of their multi-species and multi-production characteristics, but also because of the lack of references about these complex cropping systems.
Once agroforestry system prototypes have been designed, their global sustainability shall be assessed in order to identify the most promising system or the improvement possibilities before planting, while avoiding technical and economical failures. The tool (named DEXiAF) has been developed for such purpose. It is an expert knowledge-based tool to rank the sustainability of agroforestry prototypes (excluding livestock). It was developed with the DEXi software and is based on a decision tree subdividing the decisional problems of sustainability assessment into simpler units, referring to the three dimensions of sustainability.
DEXiAF can be used i) as a dashboard to determine strengths and weaknesses of the evaluated system; ii) to assist advisors and farmers in defining and optimizing the prototypes to be planted and iii) for training purpose allowing to discuss options.
The different steps of the tool development (structuration, aggregation, test), as well as the common framework defined to assess the sustainability of agroforestry systems will be presented. Two case studies (fruit-tree-vegetable system and arable crop-timber trees system) will illustrate the potential of this tool. A discussion on opportunities for improvement will be proposed.



DEXiAF used as a dashboard: dark green colored criteria represents strenght, while red criteria weakness of the evaluated system.

Keywords: ex ante assessment, sustainability, agroforestry system, prototype, co-design.

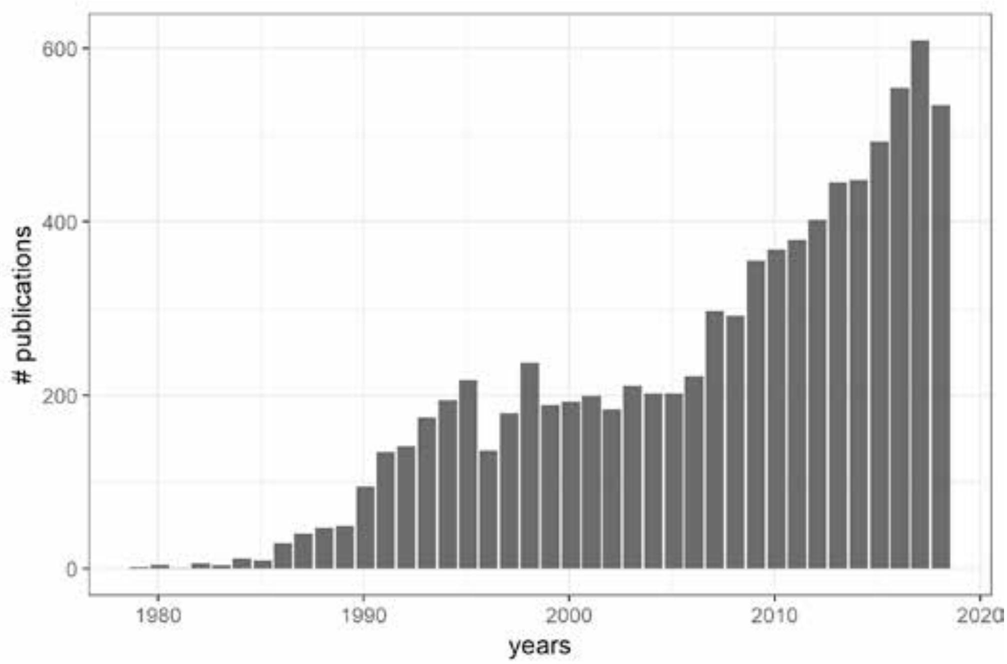
L25_O.09

Mapping the structuration of topical communities in Agroforestry research. A scientometric overview

Ollivier G. (guillaume.ollivier@inra.fr)

INRA, UR 0767 Ecodéveloppement, Avignon, France

Despite the long research history of Agroforestry, few papers have analyzed the overall pattern of its knowledge development (Nair, 1996; Montambault & Alavalapati, 2005; Barisaux, 2017). In this communication, we analyze the development of this scientific domain since its appearance in the Web of Science database (1979).
We first build a comprehensive lexical query on forms of agroforestry. This generates a corpus of 11902 records from 1979 to 2018. Then, we apply scientometric analysis to highlight the overall dynamic of scientific communities, specialties and research fronts.
We found that agroforestry first follows an irregular dynamic, with a steady growth since 2005 (fig below). Characterizing the main actors at various scale, we show that collaborations follow a densification pattern since the 1990s resulting in an increasingly cohesive international research community.
Then, we focus on the topics, characterized by a diversification pattern. To pinpoint major trends of agroforestry, we then analyze the structuration of topics by discriminating them according to their centrality/marginality and also to their dynamic (hot or cold trends). Through this mapping, and beyond descriptive statements, we also discuss the issue of links between science, society and policy. We particularly focus on the evolution of studies about economic and institutional determinants of diffusion and adoption and more recently on transition studies toward agroforestry.



Distribution of publications on agroforestry over time

Keywords: scientometrics, topic modeling, agroforestry research.

References:

1. Barisaux M., 2017. Bois et Forets, 5-17
2. Montambault J. & Alavalapati J., 2005, Agroforestry Systems, 151-161
3. Nair P.K.R., 1996, The literature of forestry and agroforestry, 74-95

L25_O.10

Why farmers are not adopting agroforestry systems? *To a hazy future of our trees…*

Guillet P. (philippe.guillet@pl.chambagri.fr), Lemarié C.

Sarthe, Chambre d'agriculture Pays-de-la-Loire, Le Mans, France

Are agroforestry systems really spreading in France? In Sarthe at the West of France, our study (GIEE study), found on testimonies and field experiences, shows numbers of obstacles condemning the adoption of agroforestry systems. Based on these observations, we propose strategies to make agroforestry a common farming system.
To enhance understanding, we choose to classify obstacles which, in reality, are part of complex systems in constant evolution.
1) With the increase of farms 'surface and the decrease of labour units, hedges and trees maintenance is often seen as a huge work unprofitable. Moreover, agricultural practices and trees are often considered as incompatible.
2) As trees are disappearing, knowledge associated to agroforestry systems is dissolving gradually. We notice that agroforestry awareness can't replace trainings. Indeed, among our students, our colleagues, our farmers and our institutions who really knows how to manage an agroforestry system?
3) Global study of one farm is often forbidden because of advisors 'specialization. Indeed, many advisors can be advising the same farmer without sharing their knowledge. In this process, it is not crops or livestock which is forgotten but trees. On the contrary, transversality and complementarity of advisors could inverse trees' loss.
4) In an advisor's life, filling in a grant application is complicated (example: 8.2). Though, when the creation of agroforestry systems is late because of an incomplete file, it makes farmers stop believing in the funding process. Moreover, lots of agroforestry systems can't be subsidised because they haven't the characteristics required.
Then, we propose some strategies to promote the adoption of agroforestry systems to farmers.
1) Training is fundamental. If agroforestry is in people mind, they may create an agroforestry system. Moreover, looking back, we observe that agroforestry trees are healthier when farmers have knowledge about trees management. Indeed, we need more initial and continuing education about agroforestry for students, advisors, farmers, regulators and politicians.
2) Scientific results can help understand agroforestry complexity. Yet, they need to be popularised to advisors who will transmit knowledge to farmers and students. Nevertheless, the ratio between the number of advisors and the number of farmers is very low. Is it sufficient?
3) Farmers' pride about their agroforestry systems is one of the most wonderful development levers. In Sarthe, we will begin next year an agroforestry group with proud farmers. First, they will have trainings, and then they will create their proper agroforestry system and communicate about it.
To conclude, agroforestry's development is surrounded by some risks. If nothing's done, agroforestry systems will often be a failure and knowledge will be loss by degrees. We have leverage actions to enhance the adoption and the success of agroforestry systems, so let's do them.

Keywords: Adoption, Obstacle, Agroforestry systems.

L25.P.01

Trees for life: Role of trees in livelihoods of toy makers in Karnataka, South India

Bhaskar D. (dhanya.b@apu.edu.in)

School of Development, Azim Premji University, Bangalore, Karnataka, Indi

Channapatna, in Ramanagaram district of Karnataka, is the centre of a famous wooden toy making industry that employs more than 5000 skilled craftspeople. *Wrightia tincotoria* or ivory wood is the major raw material for Channapatna toys that enjoy a Geographical Indication tag. Ivory wood's unique features including soft nature and lighter shade makes carving and dying easy. The toys are made completely using wood and natural colours and are considered non-toxic and ecofriendly.

Wrightia tinctoria is commonly found in agricultural lands in and around Channapatna. This is considered a good agroforestry species for intercropping (Orwa et al. 2009). Of late use of alternative species including pine and rubber wood are reported in the face of decline in the population of ivory wood (Ajith 2017). The toy making industry that had faced stiff competition from low-cost, plastic toys in the market a few years back, was revived thanks to interventions of state government and non-governmental organizations. Artisans who had migrated to cities in search of employment have now returned to Channapatna (Aggarwal et al. 2013).

Our research looked into the trend in the use of ivory wood in toy making craft and perceptions of stakeholders about the trees in the context of the recent bust and boom phases of the industry. We estimated the supply of this resource and use of alternative species in toy making craft through focus group discussions and semi structured interviews with stakeholders including craftsmen and women, saw mills and farmers who grow the trees in villages in Channapatna. The tree is of no local economic importance other than for toy making and hence changing social relations with this species was apparent with fluctuating fortunes of the industry. We further attempt to explore the sustainability of this tree resource in the context of present growth in market for the toys and consequent increasing demand from the crafts industry for this unique species.

Keywords: Wrightia tinctoria, ivory wood, wood craft.

References:

1. Aggarwal et al, 2013, Unasylva, http://www.fao.org/docrep/018/i3364e/i3364e08.pdf
2. Orwa et al., 2009. Agroforestree Database: a tree reference and selection guide version 4.0. World A
3. Ajith,2017, https://scroll.in/article/858249/crafting-joy-this-karnataka-village-has-been-making-wood

L25.P.02

Agroforestry Practice of Customary Community and Its Challenge in Indonesia

Budiman I.[1] (ibudiman99@gmail.com), Fujiwara T.[2], Pamungkas D.[3]

[1] *Laboratory of Forest Policy, Kyushu University, Fukuoka, Fukuoka, Japan*; [2] *Agro-environmental Science, Kyushu University/Faculty of Agriculture, Fukuoka, Fukuoka, Japan*; [3] *Silvicultur, FOERDA of Kupang Office, Kupang, East Nusa Tenggara, Indonesia*

Since the Constitutional Court Decision (CCD) was enacted in 2012, customary forest are no longer part of state forest, yet the rights forests. Customary forest can be owned by indigenous people through mechanism established by the government. In Indonesia, agroforestry practices also happen in customary forests or communal forests managed by indigenous peoples. This practice runs from generation to generation and is still ongoing in several regions in Indonesia. As a province with the densest population, West Java still has indigenous community, known as "Kampung Naga" village which maintains communal forests known as *hutan larangan* (taboo forest). In East Nusa Tenggara, Indonesia's southernmost province, there is "Mollo People" that still have traditional territories called *suf*. In both regions, traditional agroforestry practices are still carried out with different patterns. Agroforestry practices are carried out not only through traditional agroforestry systems (vegetables–perennial crops) in communal forest areas but also silvo pastur (forest crops-cattle) in the state forest area. Until now, the agricultural products obtained are still sufficient to meet household needs, which if there is residual harvest will be sold to the nearest market. The results of perennials are taken to meet the needs of communal needs of building materials without any compensation of money.

Picture 1. Agroforestry practice in Mollo People land

Keywords: customary forest, Kampung Naga, Mollo People, Suf, Hutan larangan.

References:

1. Neyra-Cabatac,Neyrma et al., 2012, Forest Policy and Economics Vol 22 (18-27)
2. Camacho, Leni D. et al., 2012, Forest Policy and Economics Vol 22 (3-8)
3. Shackleton, Charlie M Pandey, Ashok K, 2014, Forest Policy and Economics Vol 38 (1-7)
4. Kristiansen, Stein Sulistiawati, Linda,2016, Bulletin of Indonesian Economic Studies Vol 52(209-227)
5. Peluso, Nancy L, Vandergeest Peter, The Journal of Asian Studies, Vol. 60 (761-812)

L25.P.03

Sustaining Agroforestry Education, Research and Development: Initiatives from the PAFERN

Cabahug R. E.[1] (cabahug_weng@yahoo.com), Landicho L.[1], Abadillos M. A.[1], Cosico R. S.[1], Castillo A. K.[1], Ocampo M. T. N.[1], Ramirez M.. A. J.[1], Visco R.[1], Villancio V.[2]

[1] *Institute of Agroforestry, University of the Philippines Los Banos, Los Banos, Laguna, Philippines*; [2] *College of Agriculture and Food Science, University of the Philippines Los Banos, Los Banos, Laguna, Philippines*

The Philippine Agroforestry Education and Research Network (PAFERN) was formally organized in response to the urgent and pressing needs expressed by agroforestry institutions, particularly state colleges and universities in the Philippines; with the vision of a well-coordinated delivery of agroforestry education, research and extension services in the Philippines. Since its inception, PAFERN has already embarked on a number of project activities both at the national and international levels because of its technical expertise, track record and multidisciplinary character. Such project initiatives were mostly in partnerships and through the fund support of the Swedish International Development Cooperation Agency (Sida) via the Southeast Asian Network for Agroforestry Education (SEANAFE), Development Bank of the Philippines-Forest Project, World Agroforestry Centre (ICRAF), Department of Agriculture-Bureau of Agricultural Research, Energy Development Corporation, Asia-Pacific Network for Global Change Research, Center for International Forestry Research, among others.

PAFERN has implemented training programs on various aspects of agroforestry farm and enterprise development; collaborative agroforestry research and extension projects; provided technical assistance in the establishment, documentation, monitoring and evaluation of agroforestry demonstration farms/projects; organized policy forum and national and international agroforestry congresses of various themes relevant to the pressing issues and concerns in sustainable development; and in so doing, was able to directly reach-out partner communities, along with concerned local government and non-government institutions. PAFERN finds it important to have a venue for sharing recent and innovative agroforestry development initiatives, particularly prospects and challenges in addressing food security, ecological stability, poverty and cross-cutting issues in agroforestry promotion and development in the Philippines.

Apart from the aforementioned activities, one major role of PAFERN is on agroforestry curriculum development. This is very important to keep abreast of the current state of agroforestry education in the country, hence contribute towards advancement of agroforestry science and practice and in bridging the science-policy gap. Given its humble beginnings and experiences, PAFERN continue to draw inspiration from the active participation and strong commitment of its member institutions, sharing the mutual goal of promoting agroforestry for sustainable development.

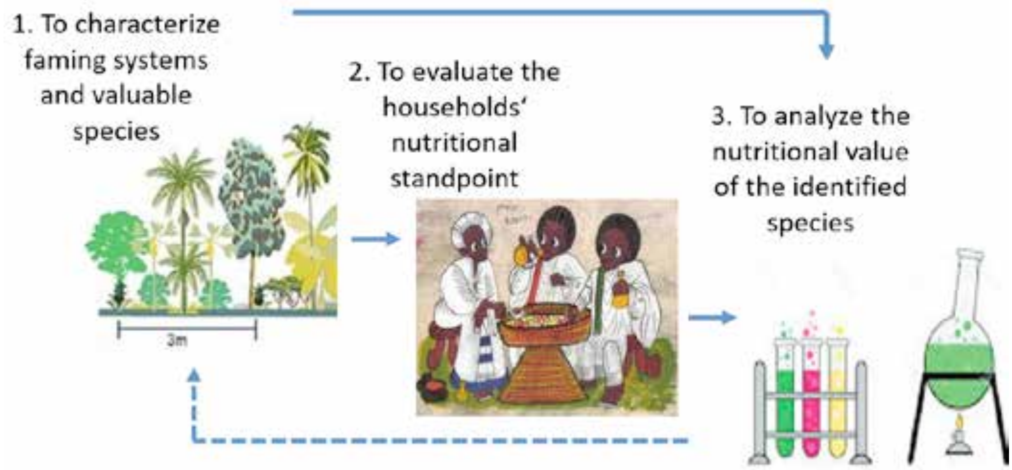
L25.P.04

Local solutions to local problems: nutritionally valuable species in southwestern Ethiopian agroforestry systems

Callo-Concha D.[1] (d.callo-concha@uni-bonn.de), M. Jemal O.[2], Seyoum Aragaw H.[3]

[1] *Ecology and Natural Resources Management, Center for Dev. Research (ZEF), Uni Bonn, Bonn, NRW, Germany*; [2] *Ethiopian Biodiversity Institute, Addis Ababa, Ethiopia*; [3] *Ethiopian Institute of Agric. Research, Jimma, Ethiopia*

The montane rainforests of southwestern Ethiopia are highly biodiverse and dominated by coffee-based agroforestry systems. Their socio-economic and environmental benefits are well documented, but their capabilities to provide food and nutrients remain largely unknown. Between 2015 and 2017 we assessed these agroforestry systems potential to satisfy the nutritional demands of rural householders in three steps: (i) the identification of agroforestry practices and nutritionally valuable species, (ii) the assessment of the nutritional status of rural householders; and (iii) the matching of the species nutritional value with the householders' demands. Methods included ethnography, botanical surveys, dietary and biometry assessments, and biochemical analyses. Three agroforestry practices were recognized, homegardens, multi-storey coffee systems and multipurpose trees on farmlands. 127 useful species were identified, out of which 55 were regularly cultivated and 25 edible but underutilized. Although more than 83% of households were food secure, 17% of children were chronically stunted and 50% of householders suffered of iron deficiency. Finally, the biochemical analyses of 12 of the underutilized species growing in the 'hunger season', showed that there are species capable to fill the householders unsatisfied demands of protein, pro-vitamin A and non-heme iron.



Three phases in the evaluation of agroforestry valuable species for locals householders' nutrition

Keywords: Nutrition, Underutilized species, Nutritionally valuable species, understory species.

References:

1. Callo-Concha, D., Jemal O., Seyoum H. 2019. Food Studies 9,1.
2. Jemal, O., Callo-Concha, D., van Noordwijk, M. 2018. Sustainability 10, 2722.
3. Jemal O. and D. Callo-Concha. 2017. ZEF working paper series 161. 46 p.

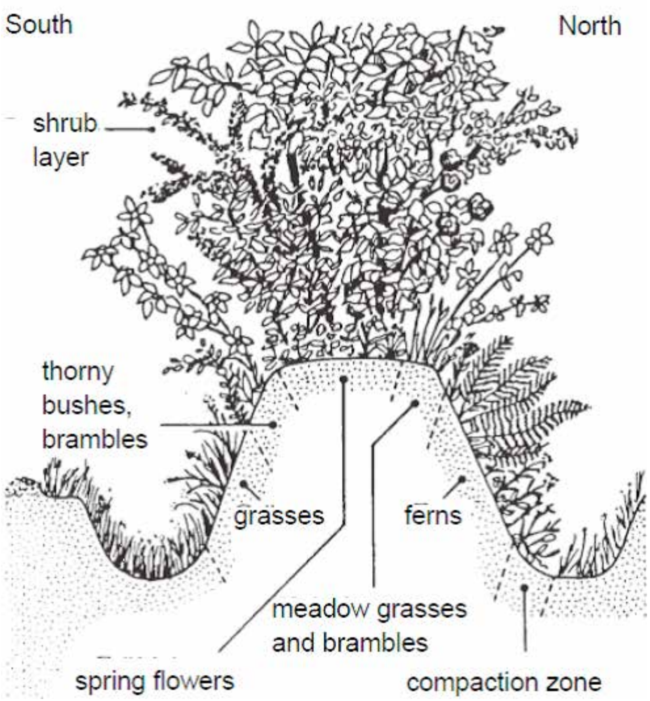
L25.P.05

A wide-spread traditional agroforestry system and modern agriculture in Germany's federal state Schleswig-Holstein (S-H)

Chalmin A. (anja.chalmin@gmx.de)

MSc. Agroforestry, Altenholz, Germany

'Knicks' - a traditional hedgerow agroforestry system, established from the mid-18th century onwards, became and remains a wide-spread and characteristic landscape feature in S-H, Germany's most northern federal state, situated between Northern and Baltic Sea.
'Knicks' - the name stands for a hedgerow system with manifold growth zones, consisting of man-made soil ridges covered with various combinations of trees, shrubs and herbs. Initially, the hedgerow system was established to mark plot boundaries, to ensure that livestock did not stray onto neighbouring land, and to provide products as fuel or fodder. The term 'Knick' derives from the German verb "knicken" and describes the process of bending branches downwards and sticking them into the soil to promote dense growth.
Nowadays, 2.9 km to 4.3 km of Knicks per km², form an important retreat and habitat for many plant and animal species in Germany's most sparsely wooded federal state. Well-maintained Knicks offer a remarkable ecological diversity; 7.000 animal species have been found in Knicks in S-H.
The poster clarifies the origin of the Knicks as well as their distribution and types. The second part details the supporting, regulating, cultural and provisioning ecosystem services provided by Knicks. The posters' last part describes the binding protection and maintenance measures from ecological and economical standpoints. The work is based on a thorough literature review and interviews with different stakeholders.



Knick sections (Source: MELUND (2008), adapted)

Keywords: Knicks, traditional agroforestry, ecosystem services, temperate agroforestry.

L25.P.06

Effect of alley cropping agroforestry on soil microbial communities

Clivot H.[1] (clivot.hugues@hotmail.fr), Petitjean C.[2], Genestier J.[1], Blaszczyk N.[1], Laflotte A.[3], Marron N.[2], Piutti S.[1]

[1] *UMR LAE INRA - Université de Lorraine, Vandoeuvre/Colmar, France*; [2] *UMR Silva INRA - UL - AgroParis Tech, Nancy, France*; [3] *Ferme expérimentale de la Bouzule ENSAIA, Champenoux, France*

In Europe, agroforestry systems are considered as a way to maintain higher levels of biodiversity and to produce greater biomass than conventional systems. Compared to monoculture, agroforestry systems may also enhance soil microbial functioning by increasing soil organic matter (SOM) content through the deposition of tree leaf litter, fine roots and crop residues. Short- and medium-term changes in SOM pools could alter both the diversity of microbial communities and their ability to synthesize several classes of enzymes that are the proximate agents of SOM decomposition. Studies focusing on soil microbial communities and on related ecological functions (such as carbon and nutrient cycling) in temperate agroforestry systems are still scarce.
The hypothesis of our study is that the quantity and the quality of organic matter inputs in agroforestry may increase microbial biomass and the decomposition of SOM compared to agricultural systems.
The study site is located on an agricultural field of the experimental farm of La Bouzule, in north-eastern France. Experimental plots have been installed during spring 2014 and associate nitrogen-fixing species (alder, alfalfa) to non-fixing species (poplar, cereals or perennial ryegrass). Agroforestry plots (poplar / alfalfa association, alder / cereals or perennial ryegrass association) are adjacent to agricultural control plots (pure alfalfa, pure cereals or perennial ryegrass). Alfalfa was sown in 2014 at the same time of poplar planting. For the second association, the rotation was spring wheat-wheat-triticale-ryegrass in the control plots. This pilot site is monitored in terms of biomass production and soil functioning since 4 years. An initial soil characterization (physico-chemical parameters) was performed in spring 2014. In 2015, 2016 and 2018, we investigated soil microbial biomass C and N (MBC and MBN), extractible organic C and N (EOC and EON) pools, inorganic N content and several enzyme activities related to C, N, S and P cycles. Soil samples were collected in the 0-15 cm layer, in the middle of inter-rows of each plot, which is repeated according to a three-block design. The initial characterization in 2014 showed a gradient of texture and organic carbon content along the three blocks. A significant effect of sampling date was observed on microbial parameters suggesting notably a strong influence of climatic conditions. After 4 years, the microbial biomass N was found to be significantly higher in agroforestry plots compared to agricultural plots with a stronger effect in alfalfa as inter-row crop compared to cereal-ryegrass. Concerning enzyme activities, we did not observe any significant difference at these early steps between agroforestry and agricultural systems. However, trends in differentiation can be observed for some N-cycling enzymes and suggest that potentially higher activities could be measured in agroforestry compared to agricultural plots in the next future.

Keywords: Microbial communities, Enzyme activities, Soil organic matter, N-fixing species, Temperate systems.

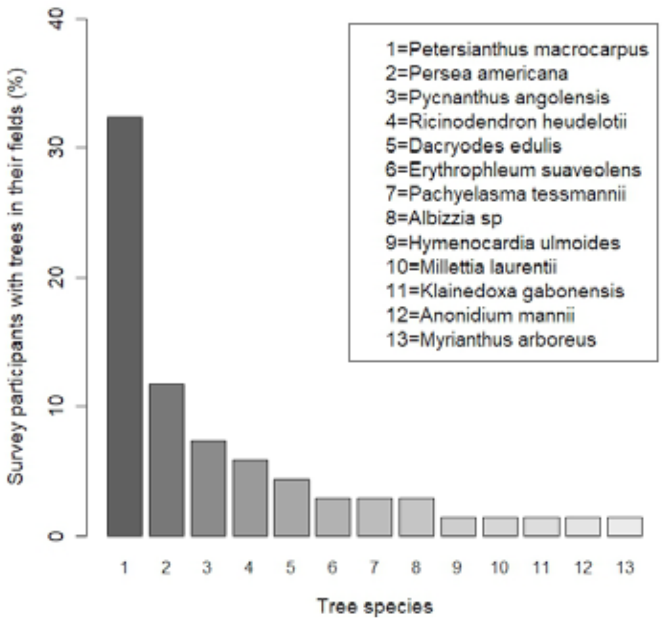
L25.P.07

Identification of trees outside the forests in the fields of Yangambi Biosphere Reserve in Congo DR

Diesse H.[1] (diessehermane@gmail.com), Bourland N.[2], Onautshu D.[3], Dhed'a B.[3]

[1] *Agronomy, University of Kinshasa, Kinshasa, Kinshasa, Congo - Kinshasa*; [2] *Royal Museum of Central Africa, Tervuren, Belgium*; [3] *University of Kisangani, Kisangani, Congo - Kinshasa*

This paper aims to: identify the trees present in the fields of Yangambi Biosphere Reserve (YBR), bring out the trees preferred by the farmers and which can make an object of reforestation, and identify the constraints related to the tree-crop association. For this, open and semi-open questions were administered to 68 farmers of the Losambila quarter in YBR. The survey was followed by inventories of trees in the fields. The results show that 51.4% of farmers investigates keep trees in their fields for different reasons (caterpillar production, fruit production, firewood, and protection against the sun). However, none of the surveyed farmers mentioned the reasons related to biodiversity or pharmacopoeia. In regards to trees left in the field, five species that have been frequently mentioned are by decreasing order: *Petersianthus macrocarpus, Persea amercicana, Pycnanthus angolensis, Ricinodendron heudelotii, Dacryodes edulis*. Deliberate planting of trees in the field is not practiced by farmers. On the other hand, assisted natural regeneration is practiced only for the preferred species (caterpillar host trees and fruit trees). Among the surveyed farmers, 85.2% think that the tree in the field has a negative effect on crops and the most important negative effect that has been mentioned is the creation of the shading (82.3%). So, taking into account the preference of farmers in projects to promote tree conservation in the open field is important for reforestation success.



Trees inventoried in the fields of the farmers surveyed

Keywords: Trees outside ofrest, Caterpillars trees, Regeneration, Yangambi Biosphere Reserve, Democratic Republic of the Congo.

References:

1. Boffa et al., 2005, Mountain Research and Development, 212-217
2. Ebuy et al., 2011, Journal of Tropical Forest Science, 125-132
3. Gbemavo et al., 2010, Tropicultura, 193-199
4. Carrière,S.M., 2002, Bois forêts des tropiques, 45-62
5. Ndayambaje et al., 2012, Small-scale For., 477-508

L25.P.08

Tracing 35 years of agroforestry development in the USA: Past, Present, Future

Gold M. (goldm@missouri.edu)

Center for Agroforestry, University of Missouri, Columbia, MO, United States

The past: Although practiced by landowners previous to 1980, there was no formal awareness or recognition of US agroforestry. There was no definition of temperate zone agroforestry, no defined practices, no underlying biophysical or socio-economic science, no academic courses or degree programs, no extension, no literature, no journal and no professional association.
The present: Post 1980, major advances occurred on every dimension of agroforestry. Agroforestry Systems journal launched in 1982, temperate agroforestry research was initiated in Canada and the US. The capstone event was 1989, the 1st North American Agroforestry Conference (NAAC), Guelph, Ontario. The 1990 "Farm Bill" established the USDA National Agroforestry Center. The 2nd NAAC, 1991, led to the formation of the Association for Temperate Agroforestry.
Post 1993, huge advances in temperate agroforestry in the US and Canada. A formal temperate zone agroforestry definition was published and five recognized agroforestry practices were described and defined. The foundations for the science underlying both biophysical and socio-economic dimensions of agroforestry were laid. The first North American temperate zone agroforestry textbooks were published, Universities initiated agroforestry courses and offered short duration training programs.
In the past decade, the depth, breadth and pace of agroforestry progress has accelerated. The USDA Natural Resources Conservation Service formally recognized temperate agroforestry practices in their Environmental Quality Incentives Program (EQIP) cost share programming helping promote agroforestry through national policy. An agroforestry knowledge infrastructure began to take share in the form of regional agroforestry working groups, the establishment of formally recognized online graduate certificate and MS degree programs, and the creation of numerous extended duration training programs designed to train educators and landowners. Importantly, both the NGO sector and the private sector started to engage with landowners about agroforestry, including formation of multiple specialty crop and livestock cooperatives supported by increasingly robust financial decision support tools.
The future: Looking forward to 2050, a rapid expansion of agroforestry practices will be deployed on the US agricultural landscape. The agroforestry knowledge infrastructure will have matured to support a tipping point of rapid growth and development. The private sector will heavily invest and engage with landowners to deploy diversified agroforestry practices across the temperate zone landscape. Nurture capital will fund long-term perennial-based agroforestry practices. A trained cadre of "Professionally Certified Agroforesters" will work with landowners adopting agroforestry. Finally, an "Agroforestry Certified" label will gain market and consumer recognition and landowners will receive a price premium for "Agroforestry Certified" products.

Keywords: Knowledge Infrastructure, History, Science, Education, Tipping Point.

L25.P.09

Evaluation of Ultisol areas with agroforestry, pasture, eucalyptus and native forest applying multivariate statistical

Guidolini J. F.[1] (janaguidolini@gmail.com), Pissarra T. C. T.[2], Abdo M. T. V. N.[3], Costa R. C. A.[2], Cordeiro Júnior P. S.[3]

[1] *Centro Sistema Terrestre, INPE, São José dos Campos, SP, Brazil*; [2] *Departamento de Engenharia, UNESP, Jaboticabal, SP, Brazil*; [3] *DDD, APTA, Pindorama, SP, Brazil*

Soil is fundamental for agriculture and environment and its improperly use can lead to degradation. Multivariate statistic is accurate for interdependent relations of soil and management. Cluster Analysis was applied to compare agroforestry, pasture, eucalyptus and native forest and samples collected at 0-20cm and 20-40cm, 2014, Pindorama-SP,Brazil.Analyses: pH, CEC, H+Al, sum of bases, Ca, Mg, organic matter, total organic carbon, P and K in areas: A1-pasture: *Panicum maximum* until 1997, then *Brachiaria decumbens,* animal allowed until 2010, no fertilization, herbicide (2011/2014); A2- *Eucalyptus citriodora planted* 1979, spacing 2.00 x 3.00m, no fertilization; A3- Agroforestry System, forest species interspersed with rubber tree and annatto, weed control with plow, plantation in furrows, spacing 3.5 x 2m, no crop between rows; A4- Atlantic native forest. Native forest, pasture, eucalyptus and agroforestry were grouped based on similarity. Cutting in the linkage distance (LD) 7.0 at 0-20cm and 8.0 at 20-40cm results four groups: G1- eucalyptus, G2- forest, G3- AFS and G4- pasture evidencing soil fertility difference between groups. Cutting LD of 21 (0-20cm) and 18.5 (20-40cm) results in two groups: G1- eucalyptus, G2- forest, AFS and pasture, evidencing soil fertility similarity between agroforestry and native forest when compared to eucalyptus. Cluster analysis was efficient to verify the similarities and difference on soil fertility between each area studied.

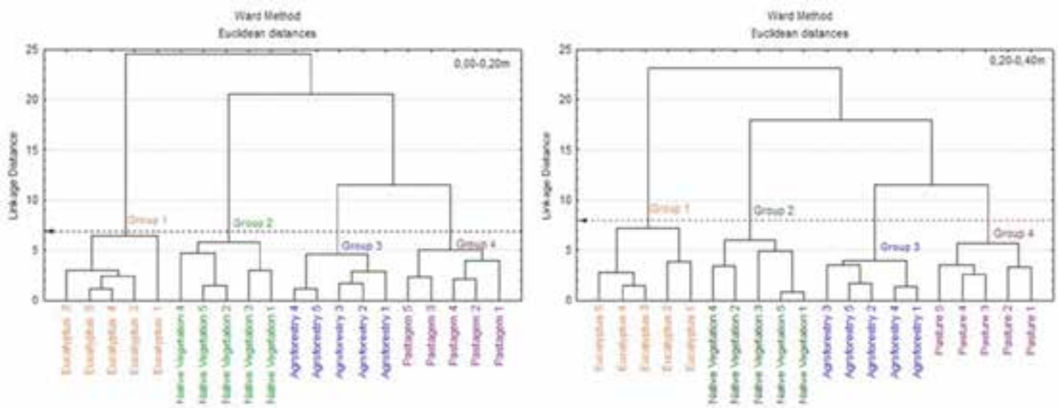


Figure 1: Cluster analysis to verify the similarities and differences between Red-Yellow Ultisol areas

Keywords: Cluster analisys, soil attributes under AFS, Atlantic forest soil.

References:

1. Iwata et al. (2012). Rev. Bras. Eng. Agr. Amb.v. 16, n. 7, p.730-738
2. Quinkenstein, A. et al. (2009). Environmental Science & Policy, [s.l.], v. 12, n. 8, p.1112-1121
3. Udawatta, R. P.; Gantzer, C. J.; Jose, S. (2017). Soil Health And Intensification Of Agro-ecosytems

L25.P.11

Knowledge exchange and communication of Agroforestry research for rural livelihoods improvement in Nigeria

Osundun S.[1] (osundunsuliyat@yahoo.com), Onilude Q.[2], Julius J.[3]

[1] *Forestry and Wood technology, Federal University of Technology Akure, Akure, Ondo, Nigeria*;
[2] *Environmental Modeling and Biometrics, Forestry Research Institute of Nigeria, Ibadan, Oyo, Nigeria*;
[3] *Forest economics, Forestry Research Institute of Nigeria, Ibadan, Oyo, Nigeria*

This study evaluated agroforestry research communication in Nigeria with major reference to diverse channels with which results of research are disseminated to selected farmers in Ibarapa zone of Agricultural Development Programme of Oyo state based on a survey amongst 200 farmers. Forty household heads (farmers) from five villages were sampled through a multi-stage sampling technique. Information collected includes socio-demographic characteristics, medium of communication between the farmers and researchers, information on trials of research breakthrough and methodologies used in communicating the research results. Results showed that majority of the farmers practice agroforestry (71.3%), Non timber forest products (12.5%), animal rearing (5.8%) and combination of all (10.4%). Results revealed lack of feedback from the farmers to the researcher as 60.5% of farmers do not respond back. Also, most medium of communication was through extension programme (16.1%) while the least was through the internet with 3.8%. The perception of farmers about on-farm trees varied. Factors contributing to the failures of agroforestry research communication between the farmers and researchers in the study area were also analyzed. The result of multiple regression model revealed that socio-demographic variables were all significant at 5% probability level. Recommendations towards enhancing agroforestry research communication for rural livelihood improvement were suggested.

Forest tree species growing on maize farmland

Keywords: knowledge exchange, agroforestry research, communication, Nigeria.

L25.P.12

Structure of agroforestry systems in the agricultural landscape of Southern Moravia region (case study Břeclavsko)

Pástor M.[1] (michalpastor65@gmail.com), Martiník A.[2], Blažejová A.[2]

[1] *Forest Research Institute, National Forest Centre, Zvolen, Slovakia*; [2] *Faculty of Forestry and Wood Technology, Mendel University in Brno, Brno, Czechia*

Agroforestry systems in Southern Moravia region represent traditional land use systems with a high environmental and cultural value. This region also has a strong potential for establishment of modern agroforestry systems. The research was conducted in the cadastre of the Hrušky village (area 1591 ha), which lies in the southernmost part of the Southern Moravia region about 8 km east of the Břeclav town. In terms of both the Czechia and Central Europe, this area has the highest degree of ploughing (around 77 %). Forest lands, including also windbreaks, form only 1 % of the cadastre area. The main aim of our study was to monitoring and inventorying of agroforestry systems during the summer season 2018. The following agroforestry systems were identified: solitary trees, shrubs linear communities, windbreaks, small-scale forests, short rotation coppice plantations of poplars, multifunctional orchards and lines of fruit trees. The most widespread agroforestry systems were the multifunctional windbreaks. This agroforestry system was established in 50 – 60´s of 20th century. Total length of windbreaks is about 10 km. The most common tree species composed these systems were *Quercus* spp., *Populus* spp., *Ulmus minor*, *Juglans nigra*, and *Acer negundo*. At present, their status and functionality are inadequate due to the long-term lack of stand (tree) care. Appropriate cultivation measures to improve their condition can be recommended: thinning, trees restoring and partial reconstruction.

In the central part of the windbreak was used to plant black poplar (Populus nigra L.), which is currently already overmature

Keywords: mapping, windbreaks, solitary trees, small-scale forests, short rotation coppice plantations of poplars.

L25.P.13

Innovations in the Extra-Virgin Olive Oil (EVOO) value chain in Central Italy

Pisanelli A. (andrea.pisanelli@cnr.it), Consalvo C., Russo G., Lauteri M., Paris P.

IRET, National Research Council, Porano, Italy

It is recognised that several constraints such as the lack of knowledge and expertise of farmers, land users and policy makers concerning agroforestry systems establishment and management hamper the adoption of agroforestry systems (Camilli et al. 2017). AFINET project acts at EU level in order to direct research results into practice and promote innovative ideas to face challenges and solve practitioners' problems. AFINET proposes an innovative methodology based on the creation of a European Interregional Network, linking different Regional Agroforestry Innovation Networks (RAINs). RAINs represent different climatic, geographical, social and cultural conditions and enclose a balanced representation of the key actors with complementary types of expertise (farmers, policy makers, advisory services, extension services, etc.). The Italian RAIN is focused on the Extra-Virgin Olive Oil (EVOO) value chain, with the main aim to promote agroforestry management of local olive orchards. Olive trees are still managed traditionally, often in marginal sites, with minimal mechanization and relatively low external inputs such as chemical treatments in comparison to other crops. The presence of permanent crops (olive trees) guarantees a partially tree cover reducing hydrogeological risk. Soil management usually keeps natural grassing reducing soil carbon emission and increasing soil fertility (Bateni et al. 2017). Intercropping with cereals and/or fodder legumes and livestock can also be practiced in olive orchards, increasing the complexity of the olive tree multifunctional system. Moreover, olive orchards can be managed as agroforestry systems since they can be intercropped with arable crops (cereals, legumes) and/or combined with livestock (sheep, poultry). The RAIN process, involving local stakeholders, highlighted the main bottlenecks of the EVOO value chain related to communication and dissemination of knowledge, technical and management aspects, market and policy. In order to contrast bottlenecks and exploit opportunities of the olive oil supply chain, the identified innovations are: i) adoption of best practices: testing and experimenting innovative agroforestry systems introducing different crop/animals species and varieties; ii) improve the management of the olive orchards: encouraging and increasing the organic production; iii) valorisation of olive processing residues: identifying and testing innovative products (bio-materials, olive paste as example); iv) arise the awareness among consumers: educating people about the benefits of olive oil consumption, creating networks among stakeholders, improving marketing and commercialization. Creating a Bio-district, defined as a geographical area where farmers, citizens, tourist operators, associations and public authorities enter into an agreement for the sustainable management of local resources, emerged a powerful tool to implement the innovation in the local EVOO value chain.

Keywords: Best practices, Participative approach, Communication.

References:

1. Bateni Camilla, Ventura Maurizio, Tonon Giustino, Pisanelli Andrea (2019): https://doi.org/10.1007/s10457-019-00367-7
2. Camilli, F., Pisanelli, A., Seddaiu, G. et al. Agroforest Syst (2018) 92: 849. https://doi.org/10.1007/s10457-017-0127-0

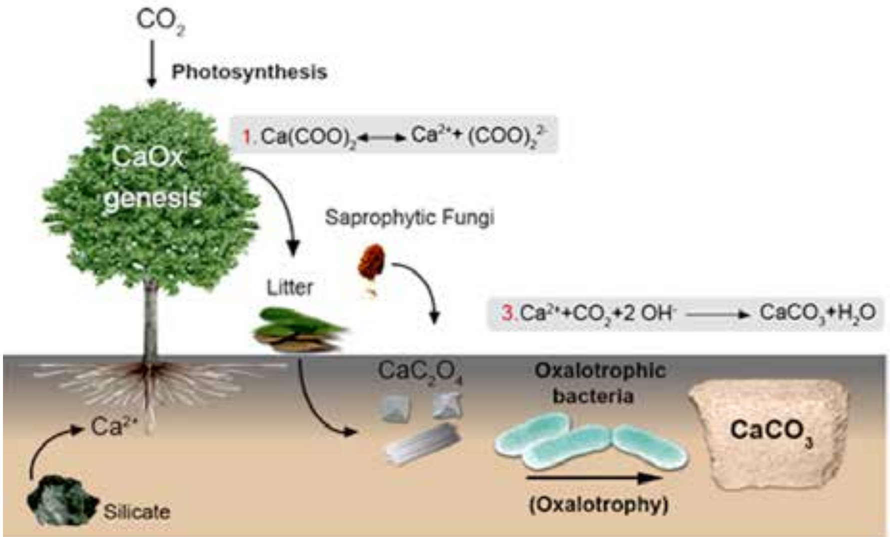
L25.P.14

The oxalate-carbonate pathway in agroforestry systems

Randevoson F.[1] (finaritraran@gmail.com), Cailleau G.[1], Razakamanarivo H.[2], Rajoelison G.[3], Verrecchia E.[1]

[1] *Institute of Earth Surface Dynamics, University of Lausanne, Lausanne, Switzerland*; [2] *RadioIsotope Laboratory, University of Antananarivo, Antananarivo, Madagascar*; [3] *Water and Forest Department, University of Antananarivo, Antananarivo, Madagascar*

The Oxalate-Carbonate Pathway (OCP) is a process by which oxalate, a photosynthetic product, is oxidized by soil oxalotrophic bacteria in interaction with Fungi (Verrecchia et al., 2006). This process results in a soil alkalinization, $CaCO_3$ precipitation, and can lead to a long-term soil carbon sequestration (Cailleau et al., 2014). In Madagascar, the OCP was investigated around 12 large-sized *Tamarindus indica* or tamarind. Three soil profiles were dug around each tree and one profile 15 m away as a reference soil. Samples from the first 15 cm of soils were taken and analyzed. The soil organic carbon (SOC) was studied thermally using Rock-Eval pyrolysis. Soil chemical properties (pH,exchangeable basic cations, CEC) and SOC under and out of influence of tamarinds were compared.Tamarinds have been shown to modify the soil chemistry, starting with an increase in pH up to 2.5 units. Soils influenced by the OCP are alkaline (pH=8) compared to distant soils which are neutral (pH = 6.5-7.5) or acidic (pH=5.8-6.5). This change in pH is accompanied by an increase in Ca^{2+}, Mg^{2+}, K^{+} and CEC. Soils under trees contained up to 11.4% of $CaCO_3$.Moreover, the accumulation of some refractory carbon in soils could be linked to changes induced by the OCP through a biogeochemical stabilization favored by the presence of a calcium pool (Ca^{2+},$CaCO_3$)(Sebag et al.,2016, Rowley et al.,2018). The OCP could thus be integrated in agroforestry systems for counteracting soil acidity and nutrient depletion.



The Oxalate-Carbonate Pathway

Keywords: Carbonate accumulations, oxalate, Tamarindus indica, Agroforestry, Madagascar.

References:

1. Verrecchia E, Braissant, O., & Cailleau, G. 2006,Cambridge University Press, 289-310
2. Braissant, O, Cailleau, G, Aragno, M, & Verrecchia, E, 2004, European Journal of Soil Science, 1-12
3. Cailleau, G., Mota, M., Bindschedler, S., Junier, P., & Verrecchia, E. P, 2014, Catena, 116, 132-141
4. Sebag, D., Verrecchia, E. , Cécillon, L., Adatte, T., Albrecht, R., Aubert, 2016, M.,Geoderma
5. Rowley, M. C., Grand, S., & Verrecchia, É. P, 2017, Biogeochemistry.doi:10.1007/s10533-017-0410-1

L25.P.15

Can't measure? Doesn't count! Why national MRV fails to capture agroforestry full contribution: the case of Peru

Suber M.[1] (m.suber@cgiar.org), Woo N.[2], Rueda C.[3], Robiglio V.[1]

[1] *World Agroforestry Centre (ICRAF), Lima, Peru*; [2] *ONU-REDD national program, Lima, Peru*;
[3] *DG de Asuntos Ambientales Agrarios, Minagri, Lima, Peru*

Of the non-Annex 1 countries, around a third incorporated Agroforestry in their NDCs pledges as a strategic climate change mitigation and adaptation measure. To prove compliance by 2030, readiness of national MRV systems in reporting it is a must. Yet countries struggle in incorporating the Agroforestry component, ultimately jeopardizing the attractiveness of these set of practices for countries to prioritize. We present the case of Peru as emblematic for Latin American countries challenged by Agroforestry incorporation in the MRV. In 2015, Peru iNDCs reported 3 Agroforestry measures with an estimated contribution up to 2.07 GgCO2e (55% of iNDCs pledge). So far, no upgrade to the MRV system was promoted to include Agroforestry. It is urgent to understand what are the gaps to support the definition of a readiness roadmap. The study first examines technical, infrastructural, legal and institutional gaps in relation to the IPCC guidelines for MRV. We consider agroforestry definitions in use, their alignment and actual capacity to include existing practices. We focus on the availability of activity data and emission factors including advancements in mapping, potential sources of quantitative information, the data format and their suitability for MRV purposes. Finally, we interview key actors from national reporting teams. As it is, the measuring/monitoring of Agroforestry in Peru presents key interconnected challenges in the classification, quantification and mapping, so Tier 2 or 3 activity data are lacking. Preliminary exploration on use of Remote Sensing Technologies and of IPCC classification-based land use change maps shows that the heterogeneity of the practices and the nature of the main crop are the main challenge in separating Agroforestry from forest or secondary vegetation, preventing activity data generation. This entails that IPCC guidelines gets applied and Agroforestry is reported as a generic perennial crop, downing its mitigation potential to the one of the associated crop. Aside technical barriers, not counting with an adopted legal definition of agroforestry prevents the construction of a consistent framework to assess and consistently integrate information from different sources. Agricultural statistics on perennial crops used as data source, if not simply outdated, present uncertain accuracy and do not refer to the tree component associated to the perennial crops. Lastly, Peru separate reporting structure (LULUCF and Agriculture) creates trans-sectorial challenges if Agroforestry contribution, generated concurrently by both sectors, has to be accounted. To address these topics and institutional challenges and to prove the attractiveness of mitigation through Agroforestry, these findings set the basis for a forthright dialogue among scientists, policy makers and governmental technical teams, supporting the definition of key building blocks of a MRV roadmap for Agroforestry inclusion where improvements are strategically prioritized

Keywords: MRV, iNDCs, readiness, Peru, gaps.

L25.P.16

Trees around fields - a substitute of agroforestry systems in homogenous European rural landscapes

Tyszko-Chmielowiec P. (tyszko@fer.org.pl)

Foundation for Sustainable Development, Wroclaw, Poland

Tree-lined roads (avenues) and hedgerows are an important part of traditional European rural landscapes. Given the barriers to introducing agroforestry systems, they serve as their substitutes. In these anthropogenic environments, they stabilize microclimate, fortify water cycle, protect from wind erosion and desiccation, filter run-off, provide fruits and wood. They also help to maintain biodiversity and ecological equilibrium as habitats and ecological corridors for numerous species, many of them protected. Avenues beautify rural landscapes and make them attractive to tourists. Importantly, trees contribute to climate change mitigation and adaptation. They make communities more resilient, reducing dependence on external energy sources.

Alas, trees are among the least appreciated elements of Green Infrastructure in rural areas. They have been decimated because of land consolidation, new technologies in agriculture, upgrades of roads, and mismanagement. Replanting is rare. After 1945 West Germany lost over 50km of avenues.

Efforts to protect trees in rural landscapes have been undertaken by NGOs in Poland, Germany, France, Czechia, Russia, and others. The task requires working with road services, local authorities, media, associations, communities. Actions include creating standards for tree management, training public officers, optimising land use planning, supporting tree advocates, and educating the general public. In Poland, 40k roadside trees were planted by an NGO.

Tree avenues in homogenous landscapes serve as substitute to agroforestry systems.
Photo Pawel Pawlaczyk

Keywords: tree avenues, hedgerows, green infrastructure, climate change adaptation.

References:

1. Oleksa A., Gawroński R. 2006. Ecological Questions 7: 29-36.
2. Brueckmann K. 2015. Avenues in Europe, pp. 71
3. Treeworks 2015. Tree-lined Routes and the Linear Forest proceedings
4. Pradines Ch. 2009. Road infrastructures: tree avenues in the landscape, Council of Europe Report

L25.P.18

Potential use of *Bixa orellana* and *Schinus terebinthifolius* in agroforestry systems for extra family farmers income gain

Fabri E. G.[1] (efabri@iac.sp.gov.br), Abdo M. T. V. N.[2], Martins M. H.[2], Salazar F. F.[2], Cordeiro Júnior P. S.[2], Martins A. L. M.[2]

[1] *IAC, APTA, Campinas, SP, Brazil*; [2] *DDD, APTA, Pindorama, SP, Brazil*

Although the main source of supply in internal Brazilian food market comes from family farming, these farmers still need appropriate production systems to support its investment capacity, farm size and type of hand labor employed. The agroforestry system (AFS) is a recommended model of production for farmers under this situation once brings economic and environmental advantages. In São Paulo state AFS is a widespread and expanding practice with native tree species, interspersed with other species of economic interests and are incentivized to reduce costs of restoration or reforestation projects, required by Brazilian laws providing commercial exploitation of area. The success of the cropping system depends on species chosen, quality of seedlings, planting conditions, spacing, shading, fertilization, irrigation and management of the species in the area. In agroforestry with high diversity we can have fruit trees, timber, ornamental and medicinal species. An area in the Polo Regional Centro Norte, Pindorama, São Paulo State, Brazil, in February 2011, an agroforestry with native species and exotic species in lines and an annual crop between the lines was planted. To evaluate the influence of management on plant development four treatments, with 32 plots randomly distributed were installed. T1: Native species and annatto planted in pits without soil disturbance and spacing 3 x 2m, with mowing mechanical control of weeds. T2: Native species and annatto planted in pits without soil disturbance and spacing 3.5 x 2m, weed control with herbicide and corn planted between tree rows of trees in no-till system. T3: Native species and annatto planted in furrows with with disc plows for weed control, spacing of 3.5 x 2m and corn cultivation in conventional system between rows. T4: Native species and annatto planted in furrows with soil tillage for weed control and spacing of 3.5 x 2m. To evaluate the production of annatto and the calculation of the stock of carbon in agroforestry (SAF) system, each plot had 10 plants of annatto.The annatto was harvested in August of 2012, 2013 and 2014 and the number of productive trees in the total of 320 trees planted started from 78 trees in 2012 and in 2014 they were 210. During this period the total stock of carbon for all annatto trees in agroforestry system in three years (2011-2014) was 1.3t C / ha and the biomass was 2.9 t /ha. The annatto productive trees had a very good development after pruning and even when shaded by native trees and in 2014 they produced 26.700 fruits in all treatments. The Schinus terebinthifolius was planted as a native tree but showed up as a very attractive tree with commercial interest its fruit and oil are commercialized as red pepper and are very well paid in specialized markets. The different managements from four treatments influenced the two species . The annatto and the red pepper fruits and oil can offer to farmers extra income when associated to other trees.

Keywords: annatto, Brazilian crops, Brazilian red pepper, red pepper oil.

References:

1. ABDO, M.T.V.N. et.al.2008. Revista Tecnologia & InovaçãoAgropecuária, p.51-59.
2. AKSHATHA, V et al. 2011. Journal of Horticultural Science & Biotchnology 319-324.
3. ARMANDO, M.S.et al.2002. Circular Técnica 16 11p.
4. DEQUIGIOVANI, G. et al. 2017.Genetic Resource Crop Evolution.1-14.

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