medPINE5 - International Conference on Mediterranean pines Solsona 2014

BOOK OF ABSTRACTS

http://medpine5.ctfc.es/

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5th International Conference on Mediterranean Pines (medpine5) Solsona, 2014

BOOK OF ABSTRACTS

Coll L, Climent J, Ximenis L, Bravo-Oviedo A & Mutke S (eds.)

CENTRE FORESTAL TECNOLÒGIC DE CATALUNYA
INIA Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria
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Keynote speakers

François LEFEVRE (INRA, Ecology of Mediterranean Forests, Avignon, France)
Annikki MÄKELÄ (University of Helsinki, Forest Ecology Departament, Finland)
Juli G. PAUSAS (CSIC, Desertification Research Centre, Valencia, Spain)
Davide PETTENELLA (Univ. of Padova, Territorial and Agroforestry Systems Department, Italy)
Rafael ZAS (CSIC, Misión Biológica de Galicia, Spain)

Instructions

Talks

The time allocated for a presentation is 15 minutes with a further 5 minutes allowed for questions. The collaboration of the speakers for respecting the time table is therefore of utmost importance. It is recommended to prepare the presentation following the guidelines (not the template) shown in http://www.iasted.org/conferences/formatting/Presentations-Tips.ppt#279,20,Conclusion. The speaker's name is underlined in the authors' list of each presentation.

Posters

Posters should be fixed by their authors at arrival on Monday afternoon or Tuesday early morning, and they will be removed on Thursday afternoon by the organization. Authors should collect them at the registration desk during the Thursday afternoon coffee break.

Each author will have one vertical board to fix his poster. Each board will be tagged with the poster code (see program). Material required to fix the poster will be provided by the organization. Authors are encouraged to design posters as simple as possible, using letters large enough to be legible. Posters need to fit a maximum size of 120 by 85 cm on the board (A0 portrait format is required).

There will be one 90 minutes Poster Sessions each day, dedicated to poster visits in which it is expected that at least one of the authors of each poster is present near their poster to attend the comments and questions of the other participants. In addition, informal visits to the posters will be encouraged especially during the coffee breaks.

In order to promote young scientist, there will be a special prize dedicated to students in recognition of the best three posters.

Programme

	MONDAY 22nd SEPT
20:00	**Registration and Welcome Icebreaker (Consell Comarcal)**
	Free dinner

TIME	TUESDAY 23rd SEPT				
08:00 – 8:45	**Registration (CTFC's Hall)**				
08:45 – 9:10	**OPENING CEREMONY (Conference Room)**				
09:10 – 09:50	**KEYNOTE #1 A. MÄKELÄ** **"Modelling stand growth for optimal management under climate change: experiences from Scots pine stands in Finland"**				
09:50 – 10:10	Abiotic interactions and Climate change	How do climate, competition and site quality affect radial growth and fruiting in young post-fire Aleppo pines? ALFARO *et al*.			
10:10 – 10:30		Attribution of growth to global-change drivers in Iberian pine species: scarce evidence of any CO2-fertilization effect CAMARERO *et al*.			
10:30 – 10:50		Resource use efficiency: Lower stand density can mitigate damages by extreme climate events in Mediterranean pine forests DEL RÍO *et al*.			
10:50 – 11:20		**COFFEE BREAK**			
11:20 – 11:40		Ecophysiological responses of Pinus uncinata, Betula pendula and Rhododendron ferrugineum to environmental factors associated with climate change FERNÁNDEZ *et al*.			
11:40 – 12:00		Comparison of the root, needle and xylem cold tolerance in four Iberian pines OLIET PALÁ *et al*.			
12:00 – 12:20		Spatial patterns and dynamics of Pinus nigra at the treeline ecotone in central Apennines (Italy) PIERMATTEI *et al*.			
12:20 – 12:40		Regional variation in tree functional traits along wide climatic and forest structural gradients VILÀ-CABRERA *et al*.			
12:40 – 13:00		Differences in seedling field performance, water use efficiency, and root structure and function explains the distribution of four Iberian pines VILLAR-SALVADOR *et al*.			
13:10 – 14:20	**LUNCH (*Can Mascaró)***				
14:20 – 15:40	**POSTER SESSION A**				
15:40 – 16:20	**KEYNOTE #2 F. LEFEVRE** **"Adaptation: where functional ecology and evolutionary biology meet"**				
16:20 – 16:40	Abiotic interactions and Climate change	Water shortage is mitigated by elevated atmospheric CO2 only in severely drought stressed P. nigra and P. Sylvestris BACHOFEN *et al*.	Evolution and adaptation	Genetic, environmental and ontogenetic effects on cone serotiny in Aleppo pine (Pinus halepensis Mill.) CLIMENT *et al*.	
16:40 – 17:00		Decline analysis of Aleppo Pine in Natural Senalba Forest (Djelfa-Algeria) CHAKALI & GUIT		Using different molecular approaches to resolve the phylogeny and taxonomic complexity of the European black pine, Pinus nigra Arnold GIOVANNELLI *et al*.	
17:00 – 17:20		Subsoil properties as the main factors in drying and mortality of Pinus halepensis at the Yatir forest, northern Negev, Israel HERR *et al*.		Species and provenances differences in the sensitivity of seed to frosts in six Iberian pines HERRERO SIERRA *et al*.	
17:20 - 17:40		The process of drought-induced tree mortality in Mediterranean Scots pine populations MARTÍNEZ-VILALTA *et al*.		Use of grafted Pinus pinea for restoration of degraded areas and early cone production in Tunisia AMMARI et al.	
17:40 – 18:00		**COFFEE BREAK**		**COFFEE BREAK**	
18:00 – 18:20		A long term history of pinewoods in central Iberia: lessons from the Holocene macrofossil record RUBIALES		Trade-offs among life history and ecophysiological traits underlying population differentiation in Aleppo pine SAMPEDRO *et al*.	
18:20 - 19:40		Pinus halepensis: a masting pine too? THANOS *et al*.		First insights into Aleppo pine population genomics VENDRAMIN *et al*.	
18:40 – 19:00		Age- related radial growth patterns of Pinus pinaster Ait. in response to climate variability in the south-central Spain RIOFRÍO *et al*.		Ecotypic differentiation in water uptake patterns of Pinus halepensis as inferred by stable isotopes of xylem water VOLTAS *et al*.	
20:00 – 20:40	**CITY TOUR**				
	Free dinner				

TIME	WEDNESDAY 24th SEPT			
08:30 - 9:10	**KEYNOTE #3 J.G. PAUSAS** **"Evolutionary fire ecology: lessons learned from pines"**			
9:10 – 9:30	Fire Sciences	Does forest bio-energy reduce fire hazard on Mediterranean Basin? A study case in Caroig range (Eastern Spain) MADRIGAL *et al.*	Biodiversity and Conservation / Biotic interactions	Degree of susceptibility of six European Pinus spp. to the pinewood nematode (Bursaphelenchus xylophilus) DÍAZ *et al*.
9:30 – 9:50		Heritability and quantitative genetic divergence of serotiny, a fire persistence plant trait HERNÁNDEZ-SERRANO *et al*.		Defensive strategies in Pinus pinaster: interprovenance variation in constitutive and induced allocation to chemical defences LÓPEZ-GOLDAR *et al*.
9:50 – 10:10		What happens to pine roots after fire and logging? Cicadas offer an answer PONS & PUIG-GIRONÈS		Contrasted functioning of fungal communities in forests of two Mediterranean pine species PÉREZ-IZQUIERDO *et al*.
10:10 – 10:30		Assessing the impact of prescribed burning on the growth of four pine species VALOR IVARS *et al*.		Tritrophic interactions: population responses of herbivores when the host pine is parasitized by mistletoe ZAMORA *et al*.
10:30 – 10:50		Post-fire salvage logging versus non-intervention: effects on dead fuel accumulation and fire behaviour in a Pinus pinaster forest GUIJARRO *et al*.		Importance of nests of pine processionary moth Thaumetopoea pityocampa Schiff (Lepidoptera: Thaumetopoeidae) in the Aleppo pine forests of semi-arid zone (Djelfa, Algeria) HEZIL & CHAKALI
10:50 – 11:20		**COFFEE BREAK**		**COFFEE BREAK**
11:20 – 11:40		Post-fire genetic structure of Pinus halepensis BEN-SHLOMO *et al*.		Brutian and Stone Pine stands in the upper Metn region (central Lebanon): a functional typology for forest conservation and management VARESE *et al*.
11:40 – 12:00		Long-term patterns of post-fire recovery in Pinus brutia forests TAVŞANOĞLU & GÜRKAN		Evolution of species richness and turnover rate of pine forests under climate change GARCÍA CALLEJAS *et al*.
12:00 – 12:20		Forest fires impacts on landslides ABDALLAH *et al*.		Functional diversity influence the balance between tree growth and mortality in Iberian pinewoods HERRERO MÉNDEZ *et al*.
12:20 – 13:20		**DYNAMIC SESSION 1**		**DYNAMIC SESSION 2**
13:20 – 14:30	**LUNCH (*Can Mascaró)***			
14:30 - 15:50	**POSTER SESSION B**			
15:30 - 19:45	**CONFERENCE FIELD-TRIP**			
20:30 =>	**SOCIAL DINER AND JAM SESSION**			

TIME	THURSDAY 25th SEPT	
08:30 - 9:10	**KEYNOTE #4 R. ZAS** **"Can we improve the health of our pine forests by managing tree investment in resistance traits?"**	
09:10 – 09:30	Stand dynamics and forest management	Optimizing Pinus sylvestris management for the provision of multiple goods and ecosystem services under fire risk in a Mediterranean context GRACIA *et al*.
09:30 – 09:50		A model-based analysis of climate change vulnerability of Pinus pinea stands under a multi-objective management in the Northern Plateau of Spain PARDOS *et al*.
09:50 - 10:10		Identifying the roles of emergence, survival and growth in a regenerating pine forest submitted to a range of disturbance intensities PRÉVOSTO *et al*.
10:10 – 10:30		Using remote sensing data for assessing mid-term post-fire regeneration trajectories in sub-Mediterranean black pine forests MARTÍN-ALCÓN *et al*.
10:30 – 10:50		Availability of maritime pine wood in Portugal in the period 2015-2105 SOARES *et al*.
10:50 – 11:20		COFFEE BREAK
11:20 – 11:40		Growth response and competition mode as modulated by climate and thinning intensity in Mediterranean pinewoods BRAVO-OVIEDO *et al*.
11:40 – 12:00		Estimation of leaf area index in a Mediterranean pine (Pinus pinea L.): from the needle to the stand level CORREIA & FREIRE
12:00 – 12:20		Impact of forest management intensity on landscape-level mushroom productivity in Mediterranean pine forests: a regional model-based scenario analysis DE MIGUEL *et al*.
12:20 – 12:40		PINEA Project: Modelling growth and pine nuts production for Pinus pinea under changing environmental conditions FONTES *et al*.
12:40 – 13:00		Effect of Aleppo pine thinning on development of introduced hardwood species: a comparison between SE France and SE Spain GAVINET *et al*.
13:10 – 14:20	**LUNCH (*Can Mascaró)***	
14:20 – 15:40	**POSTER SESSION C**	
15:40 – 16:20	**KEYNOTE #5 D. PETTENELLA** **"Markets development for pine products: actors and patterns of trade in a changing market condition"**	
16:20 – 16:40	Stand dynamics and forest management	Competition and productivity of Mediterranean Pinus species in mixed forests: basing a particularised silviculture VERICAT *et al*.
16:40 – 17:00		Height and diameter growth modeling of young Pinus pinea trees elevated on various substrates in forest nursery: Results after 15 years of growth in field trial SGHAIER *et al*.
17:00 – 17:20		Pinus nigra Arn. ssp salzmannii seedling recruitment is affected by stand basal area, shrub facilitation and climate interactions LUCAS BORJA *et al*.
17:20 – 17:45	**CONCLUDING REMARKS**	
	Free afternoon / Free dinner	

TIME	FRIDAY 26th SEPT
08:30	**DEPARTURE**
11:00 - 17:30	**Optional field visit to experimental sites (Prades Mountains)**

	Policy and social implications	
		Scenarios for payment of forest ecosystem services provision in Aleppo pine in Catalonia (Northeastern Spain) GÓRRIZ *et al*.
		Social preferences for key externalities provided by actively managed Aleppo pine forests in Catalonia: an economic valuation perspective VARELA *et al*.
		The Stone pine (Pinus pinea L.) in Southern Latin-America LOEWE *et al*.

KEYNOTE #1

Modelling stand growth for optimal management under climate change: experiences from Scots pine stands in Finland

Annikki MÄKELÄ

In forest management planning, growth models are used for predictions of forest growth under different management practices, and for the comparison of the profitability of the alternative management options from the point of view of prescribed objectives. The models therefore need to be responsive to the management options, and they need to provide information about the variables that determine the value of the product. Lately, it has become increasingly evident that the models also need to be responsive to changing climatic and site factors, in order to be applicable throughout the stand rotation in a changing environment.

Models in use in practical forest management planning systems have usually been statistically fitted to extensive data sets but without an explicit link to climatic factors. On the other hand, so-called process-based models aim for increasing our understanding of the physiological processes related to growth and yield, but often without considering the outputs central for management planning. In addition, they generally require very detailed inputs that would not be available for regional management planning systems.

This paper presents an approach to forest growth modelling that aims for combining the crucial characteristics of the empirical and ecological models, so as to make the models responsive to both management actions and the environment, and to provide outputs useful for economic assessment using inputs that are feasible at the national scale. The modelling work is based on a theoretical analysis of the forest as a complex hierarchical system, and it utilises a modular approach to represent the real system at an appropriate level of detail.

The approach has been applied to economic optimisation of thinning and rotation schedules of pine and spruce stands in Finland. This paper will focus on the pine stands both with respect to model development and results on management optimisation and environmenal impact. The opportunities and current challenges of the approach will be discussed, with special reference to the objective of developing models with a sound mechanistic basis while aiming at being robust and utilising the exisisting empirical knowledge efficiently.

Annikki MÄKELÄ, University of Helsinki, Finland

Professor of Silviculture in the Department of Forest Sciences of the University of Helsinki with long experience in development of process-based growth modelling and its management applications, and dynamic modelling in plant ecology.

How do climate, competition and site quality affect radial growth and fruiting in young post-fire Aleppo pines?

Raquel ALFARO SÁNCHEZ, J. Julio CAMARERO, Francisco R. LÓPEZ-SERRANO, Raúl SÁNCHEZ SALGUERO, Daniel MOYA, Jorge DE LAS HERAS

Mediterranean pine forests are characterised by frequent wildfires and recurrent summer droughts which condition their reproduction and growth patterns. *Pinus halepensis* is a well-adapted species to fire, showing high juvenile growth rates and reproducing precociously. Therefore, this species allocates many resources producing abundant cone crops at very early ages to reduce the risk of facing recurrent fires. Though, dry conditions could also constrain growth and induce seed release even without a fire episode. However, we still lack solid datasets to evaluate how negatively adverse climatic conditions (droughts) affect growth and how this translates into the reproductive performance of young pines in post-fire stands. In short, we need ecological and management knowledge on how to manage juvenile stages of Aleppo pine undergoing post-fire regeneration.

Our aim was to evaluate if radial growth and female cone production are positively or negatively linked at the tree level and how this coupling is affected by climate and conspecific competition in young Aleppo pine trees recruited after fires in south-eastern Spain.

We jointly analyse the effects of climate on radial growth and fruiting in Aleppo pine, considering three different tree densities (Very High − control plots, High and Moderate final tree densities − thinned plots) in two climatically contrasting sites (dry and semiarid sites) by using dendrochronology and statistical models.

Cone production and growth were positively linked. Both were enhanced by lagged wet winter-to-spring conditions up to 2 years before cone maturation or tree-ring formation. Trees with higher basal areas produced more female cones and this positive association intensified as the water balance improved. Trees under harsh site conditions produced cones earlier, i.e. they were more precocious at the semiarid site. However, long-term cone production was higher at the dry than at the semiarid site. At the semiarid site, a severe drought triggered the loss of the canopy serotinous seed bank, which hampers post-fire regeneration despite the precocity found.

Our results highlight that growth and reproduction in young post-fire Aleppo pines are positively coupled and this coupling was favoured, particularly under harsh sites, by low tree densities and a stable and positive water balance. Thus, thinning revealed as an adequate tool to enhance xeric post-fire Aleppo pine forests resilience, in growth and reproduction terms, but this positive effect can be quickly reversed by droughts.

Attribution of growth to global-change drivers in Iberian pine species: scarce evidence of any CO_2-fertilization effect

Jesús Julio CAMARERO, Antonio GAZOL, Jacques C. TARDIF, France CONCIATORI

Forests govern the carbon fluxes of terrestrial plant communities. Trees grow and uptake carbon dioxide from the atmosphere. Nowadays, atmospheric concentrations [CO_2] are rising rapidly and linked to warmer air temperatures and more frequent climatic extremes as droughts. Hotter and drier climatic conditions are becoming major climatic stressors in drought-prone areas as Mediterranean pine forests. It has been speculated that rising [CO_2] could indirectly enhance growth by decreasing stomatal conductance, reducing water loss and improving intrinsic water-use efficiency. However, field data seldom support that argument because of warming-induced water shortage may lead to carbon sink saturation.

We evaluate how [CO_2] and local climatic variables are linked to radial growth by using dendrochronological records. To perform that evaluation we sampled 33 tree populations of five Iberian pine species (*Pinus uncinata*, *Pinus sylvestris*, *Pinus nigra*, *Pinus pinaster* and *Pinus halepensis*) distributed along a climatic gradient in Teruel, NE Spain. We then determine their basal-area increment (BAi) trends for the period 1950 to 2006 and related them to [CO_2] (Mauna Loa series) and local climate data (temperature, water balance) using Generalized Additive Models. Then, we related the BAi pattern to [CO_2] and local climate data (temperature, water balance) using Generalized Additive Models.

Summer temperature and water balance were the main climatic drivers of high- (mainly *P. uncinata*) and low-elevation (mainly *P. pinaster*) species, respectively. We found scarce evidence of a BAi enhancement attributable to a CO_2-fertilization effect. This is discussed to understand future growth responses of Circum-Mediterranean pine species to a CO_2-enriched, warmer and drier environmental scenario.

Keywords: CO2 fertilization effect; dendroecology; drought stress; Mediterranean forests

Resource use efficiency: Lower stand density can mitigate damages by extreme climate events in Mediterranean pine forests

Miren DEL RÍO, Sven MUTKE, Francisco Javier GORDO, Guillermo MADRIGAL, Gregorio MONTERO, Rafael CALAMA

Predictions of climate change effects on forests focus increasingly on impacts of singular extreme weather events. Mediterranean forests are predicted to be on the rear edge due to their vulnerability to ongoing and future warming and drought in the region. Uncertainties about processes involved in extreme event impacts currently hinder predict accurately crown dieback and tree mortality in response to climate change. Mitigation requires an adaptive capacity of forests to avoid or reduce these impacts. A special case are stone pine plantations, whose area have widely increased owing to the benefit expectation for landowners, based on the high prices of their edible pine nuts.

This study answer the following questions: Do extreme climate event leave a mark in Mediterranean pine stands? Can their impact be mitigated by management balancing resource availability and demand?

Growth and reproductive effort of a young stone pine plantation were analysed after thinning and/or pruning treatments applied in 2006. The experiment follows a complete block design with 3 blocks and 2 factors, thinning and pruning. Individual height and diameter increments, crown area, crown architecture, and reproductive phase change were monitored until 2013. The repeated occurrence of summer droughts during the last decade, with less than 250 mm from autumn to summer in 2004/05, 2008/09 and 2011/12, allowed also for register the incidence of crown dieback.

Thinning changed significantly tree growth patterns, whereas the moderate-low pruning showed no effect. Mean annual diameter increment was 30% higher in thinned than in control plots, being the differences larger during the summer than in spring. Stand basal area increment was only 3% lower in thinned plots, the same as the final value per hectare (6.8 *vs.* 7.1 m^2/ha). Crown area was 64% larger in thinned plots (9.5 *vs*. 5.8 m^2), and canopy cover similar to control plots. Reproductive maturity was achieved by 6% of the trees in thinned, but only by 3% in unthinned plots. Leader shoot loss or crown diebacks had occurred in 2005 (before the thinning) in 9-11% of the trees, as well as in the control plots in 2009 (12%) and 2012 (10%), but only in 2-4% of the trees in thinned plots.

Early stand density reduction provides an increase of resources availability for individual trees, allowing larger sizes and broad crowns that even had capacity for resource allocation to reproduction. This effect is especially important in dry years to mitigate the presence of crown diebacks.

Funding: this study was funded by Spanish RTD projects AGL2010-15521, AGL2011-29701-CO2-01, AT2010-007 and AT2013-004

Ecophysiological responses of *Pinus uncinata*, *Betula pendula* and *Rhododendron ferrugineum* to environmental factors associated with climate change

Jordi FERNÁNDEZ, Lucas Silvano FERRO, Carles RIBÓ, Clàudia CANADELL, M. Alba FRANSI, Isabel FLECK

Increases in the frequency, duration, and/or severity of stressful conditions associated with climate change could alter the composition, structure, and biogeography of forests in many regions. The characterization of physiological responses in front of circumstances associated with climate change such as increased drought and elevated atmospheric [CO_2] is essential to predict likely variations in plant communities and to establish mechanisms of management.

A study was conducted analysing the responses of three typical species of subalpine forest to assess the main photosynthetic limitants under abiotic stress. Mountain pine (*Pinus uncinata*), Birch (*Betula pendula*) and Rhododendron (*Rhododendron ferrugineum*) located in the "Aigüestortes i Estany de Sant Maurici" National Park (Catalan Pyrenees) were studied. During two consecutive summer gas-exchange, assimilation response curves to increasing [CO_2] and photon flux density (PPFD) with a Li-COR 6400 gas-exchange system; chlorophyll fluorescence; ^{13}C isotope discrimination ($\Delta^{13}C$) and N content; antioxidant responses, total chlorophyll content and leaf structural attributes were determined.

At high [CO_2], Water Use Efficiency (WUE) increased due to higher assimilation rates which could help plants to overcome drought. In drought periods all studied species showed a reduction of photosynthetic parameters and stomatal conductance. At ambient [CO2], M. pine presented the highest photosynthetic rates and WUE, while Birch showed the lowest WUE as indicated by $\Delta^{13}C$ values. M. pine and Rhododendron presented high leaf mass per area attributable to their sclerophylly leading to reduced water loss.

Rhododendron was especially affected by high irradiance showing photosynthetic saturation at lower PPFD. High total chlorophyll content also evidenced the adaptation of this species to low irradiances. High irradiance did not affect negatively M. pine electron transport, while Birch experienced photoinhibition and Rhododendron presented a high dissipation of excess excitation energy as heat in order to maintain PS II functionality. High ascorbate (AscA) content under drought in M. pine increased oxidative damage protection, while AscA decrease in Rhododendron indicated lower adaptability to these conditions.

In conclusion, M. pine showed the highest photosynthetic rates and capacity; while foliar N content and Vcmax (maximum carboxylation velocity of RuBisco) were lowest suggesting that the main limitant of photosynthesis would be Rubisco availability. Birch was mostly affected by drought, showing a decrease in stomatal conductance that affected the photochemical process. Photosynthesis process in Rhododendron was limited by high irradiance.

Comparison of the root, needle and xylem cold tolerance in four Iberian pines

Juan OLIET, Andrei TOCA, Laura FERNÁNDEZ, Pedro VILLAR-SALVADOR, Jordi MARTÍNEZ-VILALTA, Robert SAVÉ, Beatriz GRAU, Felicidad HERRALDE, Jorge CASTRO, Douglass JACOBS

The distribution of natural populations of pines in the Iberian Peninsula is related to the spatial variation and intensity of low winter temperatures. *Pinus nigra* concentrates its natural populations in the highest parts of the largest Iberian mountain ranges where heavy frosts are a major limitant for plants. In contrast, *P. pinea* and especially *P. halepensis*, tend to concentrate at low altitudes, where frost are less frequent and severe. *Pinus pinaster* populations tend to thrive at mid altitude sites, with its populations frequently overlapping the populations of remainder pines. We suggest that these differences in distribution might be attributed, in part, to differences in cold tolerance among pine species.

The objective of this work is to compare the seedling cold tolerance of *Pinus nigra*, *P. pinaster*, *P. pinea* and *P. halepensis*.

Cold tolerance of seedlings was assessed as the root and needle damage, stem xylem embolism formation after a single artificial frost cycle and the root hydraulic resistance at low soil temperature. Root damage was assessed as seedling survival after frosts from -5 to -15 ºC. Shoots were isolated during root freezing. Needle damage was determined by electrolyte leakage while stem xylem embolism vulnerability was determined as the percentage of loss in hydraulic conductivity (PLC) both after a -15 ºC frost. Root hydraulic resistance (R_h) was measured with a pressure bomb at 0 and 30 ºC.

Pinus nigra had the lowest root damage after frost while *P. halepensis* and *P. pinea* had the root damage. Root damage in *P. pinaster* was intermediate between *P. nigra* and the remainder pines. Species differences in needle frost damage roughly followed the same trend than results in roots but differences among species were smaller. PLC was small and did not differ among species. Finally, R_h at 0 ºC did not greatly differ from R_h at 30 ºC. However, *P. nigra* had higher R_h than low altitude pines, which did not differ among them.

Main cold tolerance differences among the four Iberian pines occur at the root and needle level and these differences correlate with low winter temperatures conditions in their distribution range. Embolism caused by frosts seems to not constrain pine species performance in relation to low winter temperatures.

Spatial patterns and dynamics of *Pinus nigra* at the treeline ecotone in central Apennines (Italy)

Alma PIERMATTEI, Matteo GARBARINO, Carlo URBINATI

In the central Apennines most timberlines are composed by beech forests ranging from 1,500 to 1,800 m a.s.l. At some sites they are replaced by extensive black pine (*Pinus nigra* Arn.) plantations up to 1,600 m a.s.l. Black pine natural encroachment has been observed well above its altitudinal range optimum of 800-1,500 m a.s.l. This advancement is a recent complex process controlled by synergic factors such as reduced grazing pressure, climate, topography and seed dispersion.

Our research is aimed to analyze the spatial and temporal dynamics of *Pinus nigra* at the treeline ecotone, to detect possible patterns and trajectories of the new cohorts along some environmental gradient and to discriminate the effect of local factors such as altitude, exposure, microhabitat, distance from timberline and seeds source on tree growth.

We investigated and compared data at five different sites in central Italy (Marche and Abruzzo region): Mt. Vettore (VET), Mt. San Franco (SFR), Mt. Acuto (ACU), Mt. Sirente (SIR), and Mt. Ocre (OCR).

We sampled 906 individuals from the timberline to the mountaintop and for each tree, we recorded the following parameters: geographic coordinates, aspect, type of microhabitat, habitus, social status, tree vigor, basal stem diameter, total tree height, crown shape, annual height increment, and needle age. For tree-age determination and tree-ring analysis, we extracted one basal core with a Pressler borer from 641 individuals (70% of the total). For spatial distribution analysis, we used recent (2010) aerial orthoimages (0.5 m) and Digital Terrain Models (10 m). Point pattern analysis and geostatistics were adopted to detect the spatial distribution of trees within the treeline ecotone.

Preliminary results show that most of individuals are located between 1600-2000 m a.s.l. The pine recruitment started over 35 years ago and shows a Gaussian pattern at all sites and it shows no specific pattern with physical as well as other tree-structural and growing variables,).The point spatial pattern analysis revealed an aggregation of trees linked to microsite conditions (safe site)s. The natural neighbour (NN) interpolation on tree age data revealed a patchy arrangement of trees of similar age.

Our results confirm the complexity of treeline dynamics, especially where the influence of geomorphology, climate and topography is blended with that of human disturbance, making the disentangling of their individual roles very difficult.

Regional variation in tree functional traits along wide climatic and forest structural gradients

Albert VILÀ-CABRERA, Jordi MARTÍNEZ-VILALTA, Javier RETANA

Plant functional traits affect individuals' performance and, ultimately, the structure and dynamics of vegetation. Thus, characterizing the distribution of functional traits in nature and understanding their responses to environmental conditions are the first step towards linking environmental changes to changes in ecosystem function.

Here, we aim at characterizing the spatial variability of major plant functional traits along wide environmental gradients in Mediterranean and Temperate forests growing in Catalonia (NE Iberian Peninsula), and assessing to what extent this variability differs between their major tree families: *Fagaceae* and *Pinaceae*. Four functional traits were selected to incorporate information of both the leaf and the wood economics spectra: maximum tree height (Hmax), wood density (WD), leaf mass per area (LMA), and nitrogen content of leaves (Nmass). We quantified the variance distribution of each functional trait across three nested ecological scales: population, species and family. Through such scales, we assessed the coordination among functional traits, and explored their spatial variation through climatic and biotic gradients.

The largest proportion of the variance in WD, LMA and Nmass was explained at the family scale, and the proportion of variance explained at the intra-specific level was always higher than the variance explained at the species level. The distribution of variance in Hmax between the species and intra-specific scales was similar, while the family level contributed very little to the overall variation. Coordination among functional traits changed when assessed at different ecological scales, so different axes of variation emerged at the within-family scale. Climatic and biotic conditions accounted for the 42-55% of the total variance in functional traits, with mean annual temperature, thermal amplitude, and forest structure and productivity as major drivers.

Overall, our results show that functional variation of Northern Hemisphere forests is distributed differentially across different ecological scales, with important implications for the functional trait spectra, within-species phenotypic variability and vegetation responses to the global environmental change.

Differences in seedling field performance, water use efficiency, and root structure and function explains the distribution of four Iberian pines

Pedro VILLAR-SALVADOR, Robert SAVÉ, Jorge CASTRO, Andrei TOCA, Judit MAROTO, Beatriz GRAU, Paolo ZUCCARINI, Felicidad HERRALDE, Juan OLIET, Douglass JACOBS

The distribution of the natural populations of pines in the Iberian Peninsula is related to the variation in space and intensity of summer drought and low winter temperatures. *Pinus sylvestris* and *P. uncinata,* the mountain pines, concentrate in the highest parts of the largest Iberian mountain ranges under wet and cold conditions. In contrast, *P. halepensis* and *P. pinaster*, the lowland pines, tend to concentrate at low altitudes, where drought and high summer temperature are the main plant life constraints. These differences in distribution might be attributed to seedling differences in water use efficiency and the capacity to cope with drought.

We compared the field survival and growth of *Pinus sylvestris*, *P. uncinata*, *P. halepensis* and *P. pinaster* seedlings. Moreover, we assessed the root growth and hydraulic resistance, and the water use efficiency (WUE) of pine seedlings under contrasting environmental conditions.

Field survival and shoot growth of 1 year-old seedlings was compared in a common garden experiment laid in a lowland site that experiences pronounced summer drought stress. Root hydraulic was measured in seedlings at 20 and 10 ºC using a pressure bomb. Root growth and WUE were measured in seedlings cultivated under two contrasting levels of soil water availability. Root growth was measured in a rhizotron for 1 year and WUE was measured as the seedling mass increase per volume of transpired water after 2 months.

After the first summer, field survival and shoot growth of *P. uncinata* was lowest (survival 66%) while lowland pines, especially in *P. halepensis*, was the highest (survival >97%). *Pinus sylvestris* survival was 94% and its growth was significantly higher than *P. uncinata* growth but lower than the growth of lowland pines. Irrespective of soil water availability, lowland pines had higher WUE than mountain pines. Species ranking according to WUE were: *P. pinaster* ≥ *P. halepensis* >> *P. sylvestris* ≥ *P. uncinata*. Maximum depth and growth of root system was higher in *P. halepensis* and *P. pinaster* than in both mountain pines. Moreover, root hydraulic resistance was 2-4 times lower in lowland pines than in the mountain pines, irrespective of soil temperature.

We evidence that the natural distribution of four Iberian pine species can be explained by species ecophysiological differences to cope with drought at the seedling stage, with seedlings of lowland pines having greater ability to access and use more efficiently water than mountain pines seedlings.

Water shortage is mitigated by elevated atmospheric CO_2 only in severely drought stressed *P. nigra* and *P. sylvestris*

Christoph BACHOFEN, Barbara MOSER, Thomas WOHLGEMUTH, Jaboury GHAZOUL

*Pinus sylvestri*s as the dominant tree species of low elevation forest shows abnormal mortality due to climate change effects in the central European Alps. The assisted migration of more drought adapted Mediterranean provenances or species is envisaged to maintain ecosystem services of these forests on the long run.

In this context, we exposed seedlings of the three pine species *Pinus sylvestris, Pinus nigra* and *Pinus halepensis* to elevated atmospheric CO_2 (eCO_2) and artificial drought in a common garden experiment located at the bottom of central Alpine Valais valley. We sowed seeds of pines originating from dry places in Central Europe and the Mediterranean in boxes and applied a fully crossed combination of ambient (control) and eCO_2 (FACE) and wet (control), moderate and severe drought during the second growing season. We measured stomatal conductance during the course of one day in the most water-limited time of the year. We excavated the plants after two years and measured root and shoot biomass. Non-structural carbohydrate (NSC) content of the seedlings was measured before and after the second year's severe drought.

The second year's severe drought stress resulted in a significantly lower biomass (28% to 49%) of *P. sylvestris* and *P. nigra*, but not of *P. halepensis*. The latter was also able to maintain a significantly higher rate of transpiration under the severe drought treatment, compared to the other species. Elevated CO_2 partly mitigated severe effects of drought in *P. sylvestris* and *P. nigra*, with resulting higher shoot and root biomass of up to 140% compared to the control ($p < 0.01$). In contrast, *P. halepensis* did not profit from eCO2.

At moderate drought, eCO_2 had no significant effect on any of the species' biomass. By the end of the growing season, soil humidity in the boxes exposed to eCO2 had increased slightly but significantly (0.015 cm^3/cm^3) in comparison to boxes with ambient conditions, an effect that we account for a better water use efficiency under eCO2. NCS contents of the plants are in line with the findings above.

We conclude that elevated CO_2 mitigates water shortage only in severely, and not in moderately drought stressed pines. Whereas young pines need to resist moderate water shortage by means of growth reduction, eCO_2 protects from further desiccation under severe drought.

Decline analysis of Aleppo pine in semi-arid area, case of natural forest of Senalba (Djelfa-Algeria)

Gahdab CHAKALI, Brahim GUIT

This study analyzes the current status of decline in natural Aleppo pine plantations (*Pinus halepensis* Mill.) in the forests of Senalba Chergui and Gharbi (62 170 ha), both located in semi-arid area. The adopted sampling is stratified systematic, where 80 samples per plot of 800 ha were selected on the slopes in two north/south transects and East/West. Dendrometric parameters are measured (height of decayed trees; circumference at 1.30 meter, bark thickness and age) and site parameters are considered (exposure, altitude, soil depth, texture, pH and limestone rate).

Processed and analyzed, these data show that the decline is more relevant for the majority of plantations located on the southern slope for forest Senalba Chergui and those over-aged located on the northern slope of Forest Senalba Gharbi. The decline recorded in forests of Aleppo pine are closely related with the activity of populations of bark beetles species. Among the assumptions about the nature of the causal link, drought periods recorded in recent decades largely explain the transition from endemic to the epidemiological status of the pine beetle, *Tomicus destruens*. Seasonal fluctuations in temperature and rainfall amounts recorded during the last thirty years have affected the beetle populations, acting as primary and secondary stressors, thus aggravating the condition of pine stands and diminish their response capacity due to stress.

In forested areas, insects are very sensitive to variations in environmental conditions that influence their strategic distribution. The results will be presented and discussed.

Subsoil properties as the main factors in drying and mortality of *Pinus halepensis* at the Yatir forest, northern Negev, Israel

Nir HERR, Yakir PEISLER, Eyal ROTENBERG, Noam GREENBAUM

In Yatir forest - the largest forest in Israel, located at the southern edge of the dry Mediterranean region (280 mm mean annual), a patchiness mortality pattern of pines was observed after continuous droughts. The forest was planted in the 1960's-70's, with *Pinus halepensis* - a native tree, reputed as relatively drought resistant, as the main tree in the forest.

The objective of the study was to identify the environmental factors that caused the mortality of the trees exposed to ongoing dry climatic conditions at the background. The study aims at understanding the mortality phenomenon in order to implement the conclusions in establishment and management of forests in the Mediterranean Region.

An updated aerial photo and a detailed survey in the forest were used to locate plots with patches of both dead and living trees. At each patch, the trees were documented using regular forestry criteria.

In 11 plots, a trench was dug in each patch to a depth of 1.5 m into the soil and the underlying bedrock. The roots were measured, stoniness was estimated and the rock-soil-root-tree system was documented in detail. Soil and rock were sampled at depths of 20, 50, 80, 110 cm and deeper according to site-specific soil depth. Water content, mechanical composition, salinity, SAR, calcium carbonate content, and rock density, were analyzed in the lab. In addition, locations of dry trees in the forest were examined in relation to the soil and rock exposure relationships.

The main results are that the living trees are located mainly over slopes of chalky rock overlain by shallow, stony lithosol. This chalky bedrock determines the development of the shallow soil and its stony and calcareous nature. The porous chalk serves as a water reservoir. The shallow soil enables close contact between the roots and the rock. The stones help to hold moisture throughout the dry season and therefore serve as preferred zones for roots development. The soil in this environment contains tolerable levels of salinity and sodium. Their influence is minor compared to the water gain from the chalk and the importance of this habitat to the tree water system.

Our results suggest that the preferable environment for planting pines in this region is chalk overlain by shallow and stony soil. Storage of water in this rock-soil system is the key factor affecting the survival and success of the forests in this semi-arid Mediterranean Region.

The process of drought-induced tree mortality in Mediterranean Scots pine populations

Jordi MARTÍNEZ-VILALTA, Rafael POYATOS, David AGUADÉ, Mireia GÓMEZ, Jonàs OLIVA, Lucía GALIANO, Maurizio MENCUCCINI

Scots pine (*Pinus sylvestris L.*) is one of the most widely distributed trees on Earth. Despite its huge ecological plasticity, many studies show that its capacity to resist drought is being overcome in several regions, particularly at the southern (and dry) limit of its distribution. This contribution summarizes recent work on Mediterranean Scots pine populations addressing the mechanism of drought-induced mortality under field conditions, combining the approaches of ecophysiology and tree pathology.

Our results show that drought-induced defoliation and infestation by a root rot fungus (*Onnia* sp.) occur independently, but they both interact to determine the mode of physiological failure in Scots pine at the dry edge of its distribution. High levels of embolism and low carbohydrate reserves occurred in the studied trees during the dry summer. However, defoliation was more associated with reduced carbohydrate reserves (an indication of carbon starvation) than with greater hydraulic impairment at the branch level. At the tree level, defoliated Scots pines showed higher sap flow per unit leaf area during spring, but were more sensitive to summer drought, relative to nondefoliated pines. Fungal infection appeared to occur regardless of defoliation class, but only produced measurable effects on defoliated trees. In these trees infection resulted in less sapwood in the trunk and lower radial growth, possibly exacerbating both hydraulic and carbon-related constraints.

Our results highlight the intertwined nature of the processes leading to drought-induced tree mortality.

A long term history of pinewoods in central Iberia: lessons from the Holocene macrofossil record

Juan Manuel RUBIALES

Palaeoecological studies have long suggested that highland pines were dominant in extensive areas of Central Iberia during the first millennia of the Holocene. In contrast, today, their natural ranges are severely reduced and fire disturbance and human management are seen as the main drivers of this vegetation turnover.

Here, some case studies are presented, with diverse methodological approaches (macrofossils, megafossils and anthracological studies) in which palaeoecological records have help to enlighten the past vegetation history of central Iberia.

The mountains of central Iberia show a characteristic and unique vegetation history during the Holocene where highland pines (*P. sylvestris* and *P. nigra*) persisted as the dominant tree species until the late Holocene. Major vegetation changes may have occurred primarily during the past 3,000 years in this area, and although they were neither synchronous nor parallel, they seem to be mostly linked to an intensification in the human activities in the territory.

In the lowlands of the southern Duero basin, macrofossil data also point to a long-term dominance of pinewoods over extensive areas along most of the Holocene. The dominance of *P. pinaster* is greater in sandy soils (dune fields and aeolian sand sheets), but megafossil and archaeological records also evidence the presence of *P. sylvestris* and *P. nigra* at low-altitude sites on the eastern edge of the Duero Basin during both the early Holocene and the mid to late Holocene

The usefulness of these results and its impacts in the management and conservation of ecosystems are also highlighted. Insights from long term palaeobotanical data have now an increasing value in the setting of reliable management targets, including those related with forest and woodland restoration, the conservation of endangered species, reintroductions or the origin and value of cultural landscapes.

Pinus halepensis: a masting pine too?

Costas A. THANOS, Evangelia N. DASKALAKOU, Efstathia KOUNTOURI

Aleppo pine (*Pinus halepensis* Mill.), the most widespread Mediterranean pine, is generally considered as a non-masting species, perhaps due to both its prolific cone production and its considerable degree of bradychory (serotiny). Nevertheless, driven by the impetus of long-term observations and field measurements, we are posing the question "is really Aleppo pine a non-masting tree?"

Using data mainly extracted from a lengthy time-sequence monitoring study on postfire regeneration in Parnes Mt (near Athens, Greece) but also from additional short-term measurements (from various provenances), we will show results and analyses that do support the tentative conclusion that Aleppo pine is practising masting, similarly to the vast majority of its congeners. We will also try to address questions regarding several aspects of this feature, e.g. the interval between large crops, the among individuals cone production variation, the probable climatic regulators, the potential selective forces and the possible advantage gained.

Age-related radial growth patterns of *Pinus pinaster* Ait. in response to climate variability in the south-central Spain

José RIOFRÍO, Andrés BRAVO-OVIEDO, Felipe BRAVO

Mediterranean region is defined as a climatic transition zone highly sensitive to the effects of climate change. Different responses triggered in growth forests can be evidenced when considering the change in the relationship between radial growth and climate in recent years.

In order to assess whether the climate - growth relationship is age - dependent and their effect on initial growth patterns, a dendroclimatic analysis from plantations of *Pinus pinaster Ait* was performed. We considered young (18 years) and adults stands (53 years), located in south-central Spain, in the province of Ciudad Real. Cores were taken from adult stands and cross-section from young stands of 10 individuals per age-group. Chronologies were built following standard dendrochronological techniques, and correlation and response functions were analyzed to establish climate-growth relationships in each age class.

Both age groups had a differentiated response to climatic conditions and share growth variability which might be interpreted as a common response to macroclimatic factors. Further an increase of radial growth variability from 1995 was observed, where extreme growth indexes occurred Correlation and response function of seasonal climate variables on growth showed dependence of age and period analyzed, this indicates a changing climate -growth relationship throughout time. Precipitation and aridity index was the most influential climatic variables on growth with similar trends but different significance levels, while the effect of temperature was highlighted only in adult trees. Mature trees were more sensitive to climatic influence than younger. Further, response function analysis by moving time-windows allowed us to detect an increase of adult trees sensitivity to drought events prior to beginning of growing season.

KEYNOTE #2

Adaptation: where functional ecology and evolutionary biology meet

François LEFEVRE

Adaptation is a polysemous word, sometimes referring to a fixed state (adaptedness), or to a dynamic process, or to anthropic activities. It has become a major focus in ecology, and it is also a concept that bridges across disciplines. In particular, ecophysiology and genetics develop different and complementary looks at the living, focusing on the mechanisms and the variations, respectively. During the last decades, these disciplines have developed stronger interactions, going over previous competition for leadership in ecology, and the research community on Mediterranean pines was not late in this promising direction. This form of interdisciplinarity between proximate disciplines has also its own complexity (e.g. similar terms may be used for quite different concepts), and it requires good mutual understanding.

Based on examples mostly taken from the recent literature on Mediterranean pines, I will review the promising directions and future challenges for interactions between ecophysiologists and geneticists as regard adaptation issues. For example, the research on phenotypic plasticity and its role in adaptation is a good illustration of how both disciplines can collaborate after managing to harmonize their vocabulary.

In the fields of modelling and development of scenarios of the response to global change, the challenge will be to integrate processes that operate at different scales and determine their interactive effects. Tools are becoming available.

Concerning the research on the finest mechanisms, the respective graals of « key traits » and « key genes » may not necessarily coincide one with the other, and clarification is still needed on what should be the joint targets of both disciplines in this area.

François LEFEVRE, INRA Avignon, France

As a senior scientist at INRA-URFM, my research is targeted at the issues of sustainable management of forest genetic resources and adaptation of the Mediterranean forests to climate change. Having personal expertise in genetics and evolutionary biology, I also collaborate with pathologists, physiologists, statisticians and sociologists to investigate the evolutionary processes of forest genetic resources. Beyond basic research activities I am also involved in their applications regarding the two issues mentioned above, mainly at national level as chair of the national Commission on Forest Genetic Resources (CRGF), and at European level as national coordinator and member of the steering committee of the European Programme on Forest Genetic Resources (EUFORGEN). A significant part of my activity is also devoted to research management as director of URFM for eight years and member of several scientific boards.

Genetic, environmental and ontogenetic effects on cone serotiny in Aleppo pine (*Pinus halepensis Mill*.)

José CLIMENT, Ruth MARTÍN-SANZ, Luis SANTOS-DEL-BLANCO, María Regina CHAMBEL, Eduardo NOTIVOL

In the Mediterranean basin, the dramatic increase of catastrophic wildfires combined with heat waves and severe droughts has raised concern about whether the high colonizing ability of Mediterranean pines will be enough to cope with these challenges. As a fire-related trait, (the adaptive role of) serotiny has recently attracted an important scientific interest, with researches focusing on different genera and species, both conifers and angiosperms in different Mediterranean climate zones worldwide. Aleppo pine is one of the most studied species in this regard, probably because it shows a rather complex variation of cone serotiny affecting the dynamics of aerial seed banks.

The variation of cone serotiny in Aleppo pine has been postulated to derive either from ontogeny (young or small individuals tend to retain more closed cones), environment (dry and warm episodes triggers cone opening) and -still poorly known- genetic effects among and within populations. Our objective was to separate these three main causes of variation of cone serotiny in Aleppo pine. According to literature, we expected higher serotiny in small, young trees but at the same time higher serotiny under less stressful environmental conditions.

We measured serotiny at a large Aleppo pine common garden experiment replicated at three contrasted sites, with a comprehensive representation of the natural distribution range. This allowed us to separate population differentiation from phenotypic plasticity of cone serotiny, estimated through the percentage of closed cones. Also, micro-environmental variation within the sites allowed us to account for ontogenetic size effects, even when all trees were coetaneous. We also searched for correlations between serotiny and other adaptive traits, namely female fecundity (estimated through cone counts) and bark thickness.

Preliminary analysis showed that tree size has indeed a key influence on serotiny, as, as predicted, serotiny decreased with tree size, but this effect it is not easily detached from site and provenance effects affecting tree size as well. When tree size is accounted for, site effect is barely significant or not significant, but the pattern we found also fulfills predictions: higher serotiny under more favorable conditions. However, the interactions between provenance x size and site x size seemed highly significant, suggesting that an inherent allometric effect is altered by both the population of origin and the environment. These findings underline that serotiny in Aleppo pine is actually a complex trait and confirm that genotype, environment and ontogeny must be considered jointly to improve our understanding of its adaptive implications.

Using different molecular approaches to resolve the phylogeny and taxonomic complexity of the European black pine, *Pinus nigra* Arn.

Guia GIOVANNELLI, Anne ROIG, Ilaria SPANU, Giovanni Giuseppe VENDRAMIN, Bruno FADY

The European black pine (*Pinus nigra* Arn.) is a widely distributed Mediterranean conifer that covers an area of more than 3.5 million hectares, from North Africa to the northern Mediterranean and eastwards to the Black Sea. It is characterized by a large but highly fragmented distribution area and it presents a strong variability in its morphological, anatomical and physiological traits.

Although one taxonomy is now officially accepted, several others remain in use. The purpose of this work is to clarify the often conflicting classifications of black pine, to help resolve its phylogeny in the Mediterranean basin and to identify genetic markers useful for population genetic studies.

We analyzed 8 populations with 12 individuals each encompassing the maximum taxonomic diversity of the species. First, we used five DNA Barcoding genes (Cox1, MatK, Rbcl, Trnh and Nad 5-4) as identification tools to characterize the different *Pinus nigra* subspecies. These highly conserved regions are expected to provide species specific and phylogenetically deep information. Second, we used microsatellites (4 nSSRs and 5 cpSSRs) and SNP markers in potentially adaptive genes to investigate more recent gene flow and phylogenetic structure. DNA Barcoding genes could not resolve the taxonomy of black pine: all DNA sequences were identical to each other. On the contrary, results from both SSR and SNP analyses identified two groups, one eastern group including *P.n. pallasiana* and *P.n. nigra* and one western group including *P.n. mauretanica* and *P.n. salzmannii*.

P.n. laricio was highly admixed, with *P.n. laricio corsicana* related to the western group and *P.n. laricio calabrica* to the eastern group.

Although we can confirm that *Pinus nigra* is better described as a species complex with extensive gene flow rather than as a series of different species, the currently accepted taxonomy (5 subspecies) does not recognize the phylogenetic complexity of the species and the pivotal role of *Pinus nigra laricio*. We suggest that the accepted taxonomy should be revised.

Species and provenances differences in the sensitivity of seed to frosts in six Iberian pines

Nieves HERRERO SIERRA, Adrián GIL, Luis Fernando BENITO, Juan Luis PEÑUELAS, Pedro VILLAR-SALVADOR

Adaptations to extreme environmental conditions (frosts, high temperature, and drought) determine plant distribution. In many Mediterranean areas low temperature is a major limiting factor for plant life. Most studies on cold stress have focused on plant responses at the leaf, bud and stem level. However, we suggest that the capacity of the seeds that remain on the soil during winter to survive frosts is crucial for seedling recruitment and consequently for species distribution. The spatial segregation of pine species in the Iberian Peninsula is mainly related to the distribution and intensity of summer drought and low winter temperatures. *Pinus uncinata*, *P. sylvestris* and *P. nigra*, the mountain pines, concentrate their natural populations in the highest parts of the largest Iberian mountain ranges. In contrast, *P. pinaster*, *P. pinea* and *P. halepensis*, the low-land pines, tend to concentrate at low altitudes. These differences in the distribution of natural populations of pines might be attributed to differences in seed frost resistance.

This study aims to answer the following questions: Do pre-germinated seeds of mountain pines better resist frost than low land pines? Within species, do the seeds from populations of cold winter sites have greater frost resistance than population of milder winter sites?.

Pre-germinated and hydrated seeds were subjected to a single frost cycle down to -12^{o}C and their germination was compared with a non-frozen control. In each species, except for *P. uncinata*, we used two seed provenances that differed in the severity of winter conditions. Normal, abnormal and dead seedlings were counted.

Germination of low-land pines decreased after the frost. *Pinus pinea* was the less cold tolerant specie, followed by *P. pinaster* and *P. halepensis*. In contrast, germination of the mountain pines was unaffected (*P. sylvestris*) or stimulated (*P. nigra* and *P. uncinata*) by frost. The origin of the seed (cold vs. mild winter sites) had no clear effect on seed cold tolerance.

Heavy frosts damage the seeds of low-land pines seed when seeds remain on the soil in a pregermination (hydrated) state. This might affect seedling recruitment and consequently could contribute to explain the present distribution of pine species in Iberian Peninsula. In contrast, frost seems to stimulate germination of mountain pines and therefore have a positive effect in recruitment. Finally, ecotypic differences in seed frost tolerance seem to be small in the Iberian pines.

Use of grafted *Pinus pinea* for restoration of degraded areas and early cone production in Tunisia

Youssef AMMARI, Hajer OTHMANI, Tahar SGHAIER, Míriam PIQUE, Neus ALETA, David SOLANO, Salah GARCHI, David BONO, Jaime COELLO, Sven MUTKE

As an excellent Mediterranean species with multiple products and functions, Mediterranean stone pine has been introduced in Tunisia at the beginning of the last century for fixing coastal sand dunes. *Pinus pinea* offers a range of benefits in terms of revalorization and protection of degraded and marginal areas. It produces the edible Mediterranean pine nuts with very good culinary quality, highly demanded on the international market. By cone production, *Pinus pinea* has been able to generate outstanding incomes for rural forest populations.

In order to establish a systematic methodology for the production of grafted *Pinus pinea* treelets in Tunisia, two species rootstock of Tunisian origin, *Pinus pinea* (4 origins) and *Pinus halepensis* (5 origins) and scions from 16 selected clones were used. The grafting operation was conducted in the nursery of the INRGREF in the framework of the bilateral research project GRAFT PINEA, funded by AECID, and developed between CTFC and IRTA for the Spanish side and INRGREF for the Tunisian side.

The success rate of grafting varied according to the rootstock (species and provenance) and the grafted clone. The rates varied between 64% and 100% for grafting *Pinus pinea* on *Pinus pinea* and between 44% and 90% for the grafting of *Pinus pinea* on *Pinus halepensis*.

Grafted plants were subsequently used for the establishment of a network of experimental plots in different regions under different soil and climate conditions of Tunisia, covering the entire range of the two species used as rootstock. Survival, measurements and ratings after a year of growth in the field, obtained in 2014, will be presented at MEDPINE5.

Keywords: *Pinus pinea*, *Pinus halepensis*, grafting, graft success rate, survival.

Trade-offs among life history and ecophysiological traits underlying population differentiation in Aleppo pine (*Pinus halepensis* Mill.)

Luis SAMPEDRO, Jordi VOLTAS, Ruth MARTIN-SANZ, Xosé LÓPEZ-GOLDAR, Rafael ZAS, José CLIMENT

As any other living entity, forest trees must optimize resource investment to growth, reproduction and maintenance but investment in one function may occur at the expense of other functions, resulting in trade-offs that limit maximization of all processes. Global Change is imposing new challenges to Mediterranean forests, in particular combined abiotic and biotic stressors such as drought, wildfires and epidemic outbreaks of pests and pathogens. Mediterranean pine populations are expected to harbor a valuable adaptive genetic diversity for facing these challenges, already shaping the populations since long ago. Little is known, however, about how populations will respond to multiple challenges, and about the correlated responses to a single stressor in other life history traits. Common garden experiments with a wide sampling of provenances from the entire distribution range allow us to quantify population differentiation and genetic relationships between key adaptive traits.

Our objectives were to determine the intraspecific genetic variation in these key phenotypic traits and to explore the existence of tradeoffs among life history traits. Besides, we also aimed at comparing phenotypic variation with environmental distances between each population source and the trial site as a first step to detect local adaptation patterns.

We measured a wide set of traits in 19 provenances of Aleppo pine in a common garden representing average conditions for the species. Traits related to (i) growth and maintenance (height, diameter and bark thickness), (ii) reproduction (cone counts and serotiny level), (iii) constitutive and induced defenses (bio-assay based on a simulated attack) and (iv) water and carbon acquisition and storage (patterns of soil water extraction, water-use efficiency and reserves acquisition dynamics).

Results confirmed a strong differentiation among provenances for most assessed variables, and distinct trade-offs between growth and maintenance, reproduction and defense. Contrasting patterns of water and carbon acquisition and storage correlated to phenotypic divergence among populations, indicating different strategies of resource usage.

These findings confirm the evolutionary relevance of this approach. In next future, replicated assessment across contrasting sites will help understanding how climate change might modify the patterns of phenotypic integration obtained in a single site.

First insights into Aleppo pine population genomics

Giovanni Giuseppe VENDRAMIN, Rose RUIZ DANIELS, Sara PINOSIO, Zaida LORENZO, Francesca BAGNOLI, Santiago C. GONZÁLEZ-MARTÍNEZ, Delphine GRIVET

Aleppo pine (*Pinus halepensis* Mill.) is a widespread conifer of the Mediterranean Basin, highly tolerant to drought and growing in a vulnerable ecosystem in terms of climatic and land-use changes, as well as in terms of intensity and frequency of forest fires. Therefore, this conifer is an important model species for studying adaptive responses to changes in drought and fire regimes. Until now scarce molecular data were available for Aleppo pine which limited our understanding on how this species had adapted to the Mediterranean environment.

Here, we present the assembly of two Aleppo pine transcriptomes, as well as the development and application of new genomic tools derived from them. We highlight and discuss our main findings in terms of i) the characterization of two transcriptomes produced through Illumina RNA-Seq on trees phenotypically divergent for adaptive traits related to fire adaptation and drought, ii) the construction of a 384-SNP genotyping array based on available candidate gene polymorphisms and Aleppo pine transcriptomes, iii) the application of the resulting SNPs to assess the demographic and genetic consequences of long-range colonization in Aleppo pine across its full-range distribution, and finally, iv) the potential other applications these new genomic tools will provide for understanding the adaptive evolution of this keystone Mediterranean forest tree species.

Ecotypic differentiation in water uptake patterns of *Pinus halepensis* as inferred by stable isotopes of xylem water

Jordi VOLTAS, Juan Pedro FERRIO, Maria Regina CHAMBEL, Luis SERRANO, Ester SIN

The circum-Mediterranean Aleppo pine (*Pinus halepensis* Mill.) has a large distribution range that encompasses contrasting thermal and moisture conditions. We hypothesize that due to the recurrent incidence of drought stress and high temperatures occurring at varying degrees along its distribution range, populations of Aleppo pine have undergone ecotypic differentiation in soil water uptake patterns. To test this assumption, we have analyzed stable isotopic compositions ($\delta^{18}O$ and $\delta^{2}H$) of xylem water aiming at identifying genetic divergence associated to the pattern of soil water consumption of Aleppo pine populations originating from the Mediterranean region.

The results show that genetic diversity in the extraction pattern of soil water by roots is present among populations evaluated under common garden conditions. However, the ability to detect such differences depends on the period of the year examined and the particular testing conditions. In particular, data collected in mid-summer (end of July) proves to be the most adequate in revealing genetic divergence among populations, while end of summer and, specially, end of spring are less successful for this purpose. Besides, genetic differences seem to arise only under relatively favorable testing conditions for growth, as the complementary evaluation in a harsher environment (with higher temperatures and lower water availability, coupled with a very shallow soil) has proved unsuccessful for this purpose. Water uptake pattern, water-use efficiency (estimated by $^{13}C/^{12}C$ ratios) and above-ground growth are significantly related at the intraspecific level, being in turn related to some climatic and geographical variables at origin.

This suggests that the underlying variation among populations can be explained by certain characteristics at origin, hence indicating the adaptive relevance of these traits. In addition, we have used a bayesian mixing model (SIAR package for R) that incorporates isotopic signatures from xylem and soil water in order to determine the predominant soil layer of water source consumption at the aforementioned periods of the growing season, where water availably ranges from lowest (mid-summer) to highest (end of spring).

This allows gaining understanding of Aleppo pines' differential reaction to drought, at the intraspecific level, across the fluctuating conditions of the growing season by comparing the relative contribution of each water source.

KEYNOTE #3

Evolutionary fire ecology: lessons learned from pines

Juli G. PAUSAS

Pines have successfully adapted to many of the environments found in the northern hemisphere, including both fire-prone and non fire-prone ecosystems. The diversity and abundance of pines made this genus a candidate for many ecological and evolutionary studies.

Here I review what we have learned on fire ecology and evolution by looking at pines, considering both micro- and macro-evolutionary approaches. Pines account for a small proportion of the phylogenetic diversity of plants; to what extent pines may bias our view of the diversity of fire responses remain unknown.

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I am a plant ecologist and evolutionary biologist working at Centro de Investigaciones sobre Desertificación (CIDE). My research focuses on the ecology and evolution of fire-prone ecosystems, and specifically on understanding the role of fire in shaping plant species, populations, communities and landscapes.

Session *Fire Sciences*, Wednesday 24th Sept

Does forest bio-energy reduce fire hazard on Mediterranean Basin? A study case in Caroig range (Eastern Spain)

Javier MADRIGAL OLMO, Irma FERNÁNDEZ MIGUELÁÑEZ, Carmen HERNANDO LARA, Mercedes GUIJARRO GUZMÁN

Mediterranean forests with low timber growth, high slope (mechanization limitations) and scarcity of timber market generate non-profitable forests contributing to rural depopulation and increasing unmanaged forest areas. It has been emphasized by different national and international fora, that the sustainable exploitation of forest biomass for energy purposes is a profitable opportunity to promote development and employment in rural areas of Mediterranean countries, ensuring a monetary income back into the forest that can serve to finance management activities. There can be no doubt that forest management has a positive effect on wildfire prevention, but it has not been completely checked yet how intense must be silviculture treatments to reduce fire hazard as regards to prevent large fires, at least reducing the crown fire risk.

The aim of this work is to test the hypothesis that biomass management reduces fire hazard in a *Pinus halepensis* forest in Valencia province (Caroig range, Eastern Spain). Study area presents high wildfires occurrence and fire hazard. Therefore this study assumes the occurrence of large forest fires in a future climatic change scenario. FARSITE Fire Area simulator has been used to evaluate area burned and fire behaviour parameters at landscape level. Forest fire behaviour and area burned in different scenarios have been assessed: 1) Scenario A: current forest fuel models (unmanaged); 2) Scenario B: current forest fire models and assuming the conversion of agriculture lands into forest fuel models; 3) Scenario C: biomass management through thinning; 4) Scenario D: biomass management through thinning and bush clearing. Non-parametric Mann-Withney test and Partial Least Squares (PLS) models have been used to compare differences between current and simulated scenarios.

Results showed a significant increase of area burned and most of forest fire behaviour parameters in Scenario B regarding current scenario (A). Biomass management through thinning as main silvicultural treatment (scenario C) reduces canopy bulk density, but differences of the main average parameters (area burned, fire intensity) regarding current situation have not been detected. Only a slow reduction of crown fire hazard and a lesser occurrence of very intense events were detected. A strong modification of forest fuel models requires intense silvicultural treatments. Fire simulations showed that thinning and bush clearing, including the biomass reduction in large shrub fuel models areas (Scenario D), significantly reduce fire hazard beside current scenario.

The conclusion of this study is that forest bioenergy management reduces fire hazard in Mediterranean basin, only when management strategies and land uses includes an intense modification of fuel models, counting in shrub management biomass.

Heritability and quantitative genetic divergence of serotiny, a fire persistence plant trait

Ana HERNÁNDEZ-SERRANO, Miguel VERDÚ, Luís SANTOS-DEL-BLANCO, José CLIMENT, Santiago C. GONZÁLEZ-MARTÍNEZ, Juli G. PAUSAS

Although it is well known that fire acts as a selective pressure shaping plant phenotypes, there are no quantitative estimates of the heritability of any trait related to plant persistence under recurrent fires, such as serotiny. Here, we calculate heritability of serotiny in Pinus halepensis and evaluate whether fire has left a selection signature on the level of serotiny among populations by comparing the genetic divergence of serotiny with the expected divergence of neutral molecular markers (QST-FST comparison).

We used a common garden of *Pinus halepensis* located in inland Spain and composed of 145 open-pollinated families from 29 provenances covering the entire natural range of *P. halepensis* in the Iberian Peninsula and Balearic Islands. Narrow-sense heritability (h2) and quantitative genetic differentiation among populations for serotiny (QST) were estimated by means of an "animal model" fitted by Bayesian inference. To determine whether genetic differentiation for serotiny is the result of differential natural selection, we compared QST estimates for serotiny with FST estimates obtained from allozyme data. Finally, we tested whether levels of serotiny in the different provenances were related to different fire regimes, using summer rainfall as a proxy of fire regime in each provenance.

Serotiny showed significant narrow-sense heritability (h2) of 0.20 (CI: 0.09-0.40). Quantitative genetic differentiation among provenances for serotiny (QST = 0.44) was significantly higher than expected under a neutral process (FST = 0.12), suggesting adaptive differentiation. A significant negative relationship was found between serotiny level of trees in the common garden and summer rainfall of their provenance sites.

Serotiny is a heritable trait in *Pinus halepensis* and selection acts on it giving rise to contrasted serotiny levels among populations depending on the fire regime, supporting the role of fire in generating genetic divergence for adaptive traits.

What happens to pine roots after fire and logging? Cicadas offer an answer

Pere PONS, Roger PUIG

Soil and belowground biodiversity sustain trees and life aboveground. Many belowground animals, including insect larvae and adults, nematodes and gastropods depend on roots for feeding. Otherwise, severe crown fires can produce 100% tree mortality in Mediterranean non-resprouting pines. After fire the fate of root-feeding fauna depends on the degradation of the radicular system. However, there are not detailed studies describing root degradation in pines, dead from fire or from logging.

We used the cicada *Cicada orni* (*Homoptera, Auchenorhyncha*) as a model for the resistance of root feeding populations to severe disturbances. Our main hypothesis was that the abundance of cicada nymphs, strict xylem sap feeders, will fall down in parallel with the degradation of the pine roots in burned and logged Aleppo pine forests. We collected cicada exuviae attached to vegetation to estimate the abundance of nymphs that emerged from below ground. We used 12 cicada transects in a pine forest burned in summer 2010 and logged in 2010-11 and 8 transects in an unburned control forest. Transects were sampled in summers 2011 and 2012. We also collected pine roots one and two years after the fire. We used a BACI (Before-after control-impact) design approach to analyse the effect of root degradation on exuviae abundance, length and sex ratio.

Roots were turgid, in good condition and with starch one year after fire, but they appeared dry, severely cracked and without starch two years after fire. Abundance between 2011 and 2012 changed from 12.6 to 23.3 exuviae/100 m2 in the control area, but from 18.0 to 3.6 exuviae/100 m2 in the burned area (interaction time*impact: $F = 319.7$, $p < 0.001$). We did not found significant interannual trends in exuviae length neither in sex ratio.

We concluded that nymph abundance crashed in the burned and logged pine forest one year after fire. Considering that belowground development takes 2-7 years in Cicada orni (i.e. nymphs emerged in our study area came only from eggs laid before the fire) we suggest that the population crash is a consequence of root degradation taking place from a year after fire. These results illustrate a previously undescribed time lag in the response of belowground biodiversity to fire.

Assessing the impact of prescribed burning on the growth of four pine species

Teresa VALOR IVARS, Míriam PIQUÉ NICOLAU, José Ramón GONZÁLEZ-OLABARRIA

Prescribed burning can contribute to preserve pines ecosystems. However little is known about tree-growth response to prescribed burning. Characterizing the short and medium-term effects of prescribed burning on *Pinus* growth may provide valuable information for contributing to fire and forest manager's decision-making. Hence, we addressed whether prescribed burning differentially affected the mid-term growth of dominant and suppressed trees of four *Pinus* species, under different levels of fire severity, by means of dendrochronology and mixed modelling. The approach followed was based on comparing the observed post-burning growth to the expected growth of trees without burning.

Results showed, at the year of the prescribed burning, a reduction in growth in *P. halepensis* and *P. nigra ssp. nigra* trees regardless crown status and in *P. sylvestris* only in suppressed trees. Mid-term post-burning growths were favourable to dominant *P. halepensis* and *P. nigra salzmannii* trees subjected to high fire severity while *P. nigra nigra, P. sylvestris* and *P. halepensis* suppressed trees grew less than the expected growth without burning showing a delayed recovery. Although, generally prescribed burning negatively affected the mid-term growth of *P. sylvestris* and *P. nigra nigra*, trees with higher pre-burning growing rates showed a better recovery after prescribed burning. The severity of the fire influenced the growth of *P. nigra salzmannii* positively whereas the effect was negative in P*. nigra nigra* trees.

These findings showed that as time since burning increases, tree growth could be recovered, or even increased, in a relatively short period of time. Growth recovery may depend on the pine species fire tolerance, the tree-performance prior the prescribed burning, the effects of tree healing and the increased light and soil nutrient availability. Understanding and balancing those factors on *Pinus* forests should help for better planning prescribed burning operations, both in terms of desired fire intensity and required burning intervals.

Post-fire salvage logging versus non-intervention: effects on dead fuel accumulation and fire behaviour in a *Pinus pinaster* forest

Mercedes GUIJARRO, Javier MADRIGAL, Carmen HERNANDO, Carmen DÍEZ, Cristina CARRILLO, María Luisa CÁCERES

Post-fire salvage logging is a traditional practice in burnt coniferous forests, but its effects are currently controversial. One common justification for salvage logging is to reduce woody fuel load and, consequently, future fire hazard, fire behavior and severity of a subsequent wildfire. Some works suggest that post-fire logging may increase fuel loads and fire risk in the short term, as a result of accumulation of fine fuels, and reduce medium and long term fire risk, fire behavior and severity due to the removal of coarse dead fuels. Until now, there are few studies analyzing this efficacy of the removal of burnt trees, and results are equivocal and none of them have been obtained in Mediterranean pine forests.

The effects of post-fire salvage logging versus non-intervention on (a) accumulation of live and dead fuels and (b) potential fire behavior were analyzed in a *Pinus pinaster* forest (Guadalajara, central Spain), affected by a wildfire in 2005. Nineteen experimental plots were set up, distributed in nine different sites inside the burn area, from two types of stand ages: young stands (25-30 years old, 700 trees/ha average density) and mature stands (over 80 years old, 300 trees/ha average density). Two post-fire treatments were conducted: salvage logging and non-intervention. Eight years after the wildfire, inventories of live and dead surface fuel were carried out. Custom fuel models were developed and potential fire behavior was calculated selecting extreme summer conditions. Factorial ANOVA using PLS algorithm was used to evaluate the effect of the selected factors (stand age and post-fire treatment) on fuel accumulation and potential fire behavior.

Results showed a significant effect of post-fire treatment on dead fuel accumulation, which is higher on unlogged plots, mainly due to snags-fall. This effect was higher on mature than on young stands. Live fuel biomass did not show significant differences between stand ages and post-fire treatments. Simulations carried out using the custom fuel models at stand level showed that the main selected factor affecting fire behavior was stand age. Heat per Area Unit showed significant differences between control and treated plots on mature stands but no effect was detected on young stands, suggesting a potential increase of severity in unlogged plots in a subsequent wildfire.

This study highlights some strengths and weaknesses of post-fire management in a re-burn scenario. Management implications could be extracted in order to prioritize salvage logging decisions after large wildfires in the Mediterranean basin.

Post-fire genetic structure of *Pinus halepensis*

Rachel BEN-SHLOMO, Anna GERSJBERG, Gidi NE'EMAN

Pinus halepensis (Aleppo pine) produce two cone types. Regular cones open and disperse their seeds by winds in summer and serotinous cones that disperse their seeds mainly after canopy fires. Due to short seed dispersal distances and the preferred post fire regeneration microhabitat in ash beds under the burned canopies of large dead pines, each such a tree is the potential mother of the numerous seedlings under its canopy that construct the post-fire generation.

To examine this prediction and study the effects of fire on the genetics of a post fire pine population we analyzed the genetic structure of a post-fire naturally regenerating seedling population of *P. halepensis* at Lubim, Mt. Carmel, Israel. We examined if the spatial demographic structure of the post-fire seedling population is also reflected in fine scale spatial genetic structure of these seedlings. Explicitly we asked whether or not the seedling that germinated under large burned dead pine trees are their offspring.

The results revealed that Lubim post-fire seedling population is polymorphic, diverse and it exhibits a random mating system. In contrast to our prediction, we found no fine scale spatial genetic structure and no division to distinct sub populations was detected. Furthermore, seedlings growing under any large dead burned pine tree were not necessary its offspring. Long range post-fire seed dispersal can explain the results. Surprisingly, although the population as whole indicated Hardy-Weinberg equilibrium, the groups of seedling under each burnt tree demonstrated a significant excess of heterozygotes.

This high level of heterozygosity of the post fire seedling cohort might indicate an intense selection of vigorous genotypes that are well adapted to their post-fire regeneration niche, the thick ash bed under large burnt pine trees.

Long-term patterns of post-fire recovery in *Pinus brutia* forests

Çağatay TAVŞANOĞLU, Behzat GÜERKAN

Early post-fire regeneration in Mediterranean vegetation is well-known process, but less attention has been paid to the long-term post-fire dynamics in Mediterranean forests. We asked the following questions:

(1) how long-term patterns of regeneration proceed in *Pinus brutia* forests after fire?

(2) Is the regeneration mode of plants a significant determinant of post-fire succession in these forests?

To answer these questions, we investigated long-term patterns after fire in the structure of vegetation and in the diversity of plant community in a 100-year chronosequence of burned *P. brutia* forests in southwestern Turkey. A total of 222 quadrats nested in 44 study plots were sampled in nine study sites at different stages of post-fire succession. The presence of species were recorded through transects in each quadrat by using point intercept sampling method. Cover of plant species and plant functional types such as regeneration mode and life form were estimated, and the long-term trends were analyzed by linear or curvilinear regressions. Sorensen similarity, Shannon's diversity, and site heterogeneity indices were used to assess species diversity patterns in space and time. Components of diversity were further partitioned to determine the spatial scale responsible for the plant diversity of the study region.

Significant trends were found in the change of cover in many species through postfire chronosequence, and regeneration mode was the most explanatory functional grouping system for describing long-term post-fire dynamics. Obligate resprouters, facultative resprouters, obligate seeders with a soil seed bank, and obligate seeder species with a soil seed bank (*P. brutia*) followed different trends through the succession. A few life-history traits were enough to explain the observed trends. Species diversity was more heterogeneous among quadrats and among plots in early post-fire years, but was more homogenous in later periods. The diversity of the study region was mainly due to the differences among the study sites, but not the differences at plot or quadrat scales either. Moreover, the study sites at early and mid-successional stages had their own characteristics species that were not found in other sites.

We conclude that the coexistence of the study sites at different stages of post-fire succession contribute to the gamma diversity of the study region, and regeneration mode must be a major component of any vegetation or forest stand dynamics model in the Mediterranean Basin.

Forest Fires Impacts on Landslides

Chadi ABDALLAH, Rouba ZIADE, Carla KHATER

Landslides have always been one of the main natural hazards that threatened both the natural and human Environments of Lebanon and their occurrence has increased by almost 60% between 1956 and 2008. On the other hand, Forest Fire has emerged to impose as another natural hazard that has destroyed more than 25 % of Lebanon's forests in less than 40 years. The increased forest fire occurrence is one of the potential detrimental impacts of anthropogenic climate change where high temperatures and current-year drought are strongly associated with an increase in the number of fires and area burned in a variety of forest types. A simple observation shows the coincident trends between mass wasting and forest fires.

This paper investigates the potential impact of forest fires on landslide occurrence in Damour and Nahr Ibrahim watersheds of Lebanon. Preconditioning factors taken into consideration were topography, soil, geology, mean annual precipitation and land cover maps. Landslides and forest fires inventory maps were produced through Remote Sensing (RS) using aerial (1956 and 2008) and satellite images (2005 and 2011) in addition to Google Earth Timeline. Furthermore, forest fires were introduced as the inducing factor whose impact was assessed by the calculation of forest fire burn severity. This burn severity was extracted from Landsat images (1986-2011) through the Normalized Burn Ratio (NBR) index. A field study was carried out in order to substantiate the landslide inventory. Furthermore, the burn index maps were validated through the Mini-Disk Infiltrometer (MDI), a device which supplies the soil infiltration rate usually after a fire. Following the standardization of the impact factors into layers using Geographic Information System (GIS), the relative importance of these layers for causing landslides has been evaluated using modified InfoVal method and a landslide Susceptibility Map (MMSM) was generated. Hence, every factor obtained a weight that shows its impact on landslide occurrence.

Preceded only by Land Cover change, NBR obtained the highest weight making landslide burn severity the second highest impacting factor on landslide occurrence in our study areas. Testing was performed by comparing a previously extracted 30% of the landslide inventory to the MMSM. It has been observed that 84.79% of the existing landslide falls in predicted high susceptibility zone.

Degree of susceptibility of six European Pinus spp. to the Pinewood Nematode (*Bursaphelenchus xylophilus*)

Raquel DÍAZ, María MENÉNDEZ GUTIÉRREZ, Margarita ALONSO, Pedro MANSILLA, Enrique JIMÉNEZ, Andrea ABELLEIRA-SANMARTÍN, Pilar MOSQUERA, Pedro PÉREZ-GOROSTIAGA, Gabriel TOVAL, Adela ABELLEIRA

Pine Wilt Disease, which is caused by the quarantine pest *Bursaphelenchus xylophilus* commonly known as pinewood nematode, appeared in Spain in 2008. This nematode lives mainly on Pinus spp. and attacks some of these species as living trees. Since pine forests cover over 30% of the Spanish wooded land, this pest is an important threat, because it can cause an important impact, both in the economy and environment.

In present study seedlings of seven pine species, six of them typically planted in Spain - *Pinus canariensis, Pinus halepensis, Pinus pinaster, Pinus pinea, Pinus radiata and Pinus sylvestris* - and one American species - *Pinus taeda* -, were inoculated with 600 pathogenic nematodes, *Bursaphelenchus xylophilus*, to investigate the genetic variation in the susceptibility of different pine species to the pinewood nematode and to compare the symptom development among them. Leaf water potential and nematode population in stems and roots were assessed for each species at 12, 27 and 41 days after inoculation (DAI), and at the end of the assay (142 DAI).

Different species had significantly different degree of susceptibility to pinewood nematode. P. sylvestris was the most susceptible species, followed by *P. pinaster* and *P. radiata*. However, other species studied in present work seemed to be much less susceptible, since none of their seedlings died nor showed symptoms at all. The average first wilting symptoms appeared 43 days after inoculation (DAI), even though the first seedling to show them did it 26 DAI. The first seedling died 51 DAI and, in average, they lasted 71 DAI. Leaf water potential of the susceptible species decreased dramatically after 12 or 27 DAI, depending on the species. Nematode densities were very variable, but it was much greater for the susceptible species.

The results suggest that in Spain there are some pine species whose forests can be severely damaged by the nematode in the future, while others will not be so much affected.

Defensive strategies in *Pinus pinaster*: interprovenance variation in constitutive and induced allocation to chemical defences

Xosé LÓPEZ-GOLDAR, Luis SAMPEDRO, Rafael ZAS

Maritime pine can respond to antagonistic interactions with herbivores and pathogens by producing a modified phenotype with increased resistance. That involves quantitative and qualitative changes in chemical defences in target pine tissues. It is known that both genotype and environmental factors such as resource availability may modulate those induced responses. Maritime pine harbour a large intraspecific variation in life history traits, however little is still known about across population variation in constitutive and induced allocation to chemical defences.

Here we studied the constitutive allocation to chemical defences in young pine trees and the inducibility of those defensive traits in response to real herbivory and to simulated damage signalling in ten population of this model Mediterranean pine species. We performed a greenhouse experiment growing Maritime pine juveniles belonging to the CLONAPIN® clonal collection (Serida, Asturias, Spain), consisting of 25 genotypes from each of 10 provenances covering the whole range of the species distribution, with 4 clonal copies per genotype. Clones were treated either with methyl jasmonate (MeJa), a phytohormone analogue involved in the damage signalling and production of defensive responses against chewing herbivores and necrotroph pathogens, or with the large pine weevil (*Hylobius abietis*, Coleoptera: Curculionidae – a conifer specialist chewing insect) in herbivory assays. We quantified pine defences (non-volatile resin and total polyphenolics) in stem and needles and the damage by the pine weevil.

There were significant differences among populations for both non-volatile resin and total phenolics, suggesting a genetic diversity background for defence production. Both MeJa and real herbivory significantly increased the concentration of non-volatile resin in stem and needles (15.1% and 22% for both tissues for MeJa, 14.7% and 6.8% for both tissues for real herbivory). Total phenolics content decreased significantly after MeJa application in stem and needles (19.2% and 9.1% respectively) and no effect was detected for herbivory in stem but a significant increase for needles was observed (7.7%). We found a large variation in defence production and in defensive capability against the herbivore among pine populations, and also in quantitative responses to MeJa application.

This study contributes to the understanding the role of chemical defences in herbivore-pine interactions and to the understanding of the structure of co-variation of plant defensive investment with other life history traits in local adaptation in the Mediterranean range. Further analysis should address possible geographical or climatic patterns in the divergences observed in the defensive capabilities and plasticity across populations.

Contrasted functioning of fungal communities in forests of two Mediterranean pine species

Leticia PÉREZ-IZQUIERDO, Mario ZABAL-AGUIRRE, Santiago C. GONZÁLEZ-MARTÍNEZ, Miguel VERDÚ, Marc BUÉE, Ana M. RINCÓN

Fungi are a key component of forest ecosystems, involved in nutrient biogeochemical cycling and plant productivity. Symbiotic ectomycorrhizal fungal communities can be particularly relevant under harsh environmental conditions, such as those imposed by the Mediterranean climate.

We examined the influence of the soil properties and the host tree on the functioning of fungal communities in forests of two representative Mediterranean pine species: *Pinus pinaster* Ait. (Ppi) and *Pinus halepensis* Mill. (Pha). Soil analyses were performed, and eight fungal enzymatic activities determined in two different edaphic compartments: the ectomycorrhizosphere and the bulk soil.

As expected, forests of both pine species showed highly contrasted soil properties, with lower pH, organic matter and general nutrient contents in Ppi compared with Pha. In each pine forest, the ectomycorrhizosphere and the bulk soil were similarly active compartments. However, a strong influence of the edaphic properties was observed in the functioning of their respective soil fungal communities, with higher activity of enzymes related with the carbon cycle (i.e. glucosidase, cellobiohydrolase, xylosidase) and lignin degradation (lacasse) in Ppi compared with Pha, whereas enzymes of nitrogen (chitinase) and phosphorous (phosphatase) cycles were more active in Pha. By contrast, the functioning of fungal communities forming ectomycorrhizas was similar in both pines, particularly for most of the carbon cycle enzymes, probably indicating a greater independence of the soil properties by relying on host carbon supply. The exception was phosphatase that, contrarily to soil and being more dependent on pH variations, was higher in the rhizosphere of Ppi than Pha.

Our results revealed the compartmentalized and contrasted activity of fungal communities in forest soils, pointing out to edaphic properties and tree host as main environmental drivers of their functioning, probably by determining their specific composition selecting fungi adapted for optimal exploitation of resources in each pine forest. Gaining knowledge on forest fungal communities will contribute to better understanding the feedbacks among the complex tree-fungal-soil interactions, which are crucial for the functioning of Mediterranean forest ecosystems.

Tritrophic interactions: population responses of herbivores when the host pine is parasitized by mistletoe

Regino ZAMORA, Alba LÁZARO, José Antonio HÓDAR

Mistletoes (*Viscum album* subsp. *austriacum*) cause changes in the chemical composition of pine trees. These changes modify needle quality as a food, thus affecting herbivorous insects. However, even the most rigorous chemical analysis of plant tissues cannot adequately predict population responses of herbivores. In this work we analyse the response of herbivore populations to mistletoe parasitized pines by using bioassays. Three common pine herbivores belonging to two different guilds were selected: two folivorous, the pine processionary moth (*Thaumetopoea pityocampa*) a curculionid beetle (*Brachyderes suturalis*), and a sap-sucker aphid (Cinara sp.).

The study was set in Sierra de Baza (southern Spain), where V. album is widely distributed. We chose 40 *Pinus nigra* divided into four groups according to mistletoe infestation degree, categorized as Control (no infestation), Low, Medium and High infestation level. We use four different bioassays: 1) field experiment with Cinara sp. by bagging a parthenogenetic female in previously defaunated branches, and counting the ulterior progeny, 2) field experiment with the pine processionary moth, by fixing experimental egg batches in pines and estimating the survival success of new-born larvae until second instar, 3) laboratory experiment with the pine processionary moth, by estimating the survival success of new-born larvae until second instar fed with needles from the four experimental pine groups previously described and 4) cafeteria test in laboratory with the curculionid beetle, by recording the consume of needles from the four experimental pine groups.

All species of herbivores have similar responses to the infestation of mistletoe, reducing 1) the number of progeny; 2 and 3) the survival of larvae surviving until second instar; and 4) preferring needles from control pines or low infestation level versus needles from high and medium infestation level, which were rejected.

We can conclude that mistletoe infestation gradually decreases the quality of pines as food for the arthropod herbivores, although the sharp contrast between Control+Low versus Medium+High suggests the existence of a threshold of infestation, from which herbivores are more affected by the presence of mistletoe.

Importance of nests of pine processionary moth *Thaumetopoea pityocampa* Schiff (Lepidoptera: Thaumetopoeidae) in the Aleppo pine forests of semi-arid zone (Djelfa, Algeria)

Sara HEZIL, Gahdab CHAKALI

Aleppo pine forests of the semi-arid area are very sensible and fragile to the pine processionary moth, *Thaumetopoea pityocampa*. The examination of 400 trees of Aleppo pine, *Pinus halpensis* in natural and plantation forests infer that the rate of defoliation showed a variable significance of the defoliation provoked by the processionary in the plantations prospected, Moudjebara and Torerssane, which vary from 25 to 50% for the plantation of Moudjebara and from 10 to 25% for the plantation of Tokerssan. In the natural forests, it doesn't exceed 10%.The defoliations by pine processionary are variable in the aegis of environmental conditions and in the dynamics of these populations. Frequency analysis of the number of nests counted per tree shows a very highly significant difference between the four stations prospected. On the cases observed, the high concentration of winter nests of pine processionary is noted in trees that their height between 4 to 6 m with a number of 3 to 5 nests per tree in the plantation of Tokerssan situated in the northern position. In the south-west, the plantation of Moudjebara, trees which height between 3 to 4 m have a significant number of nests 2 to 5 nests per tree. The distribution of nests in natural pine forest of Senalba Chergui showed that the most important nests are in the height of trees varies from 3.5 to 5 m. In natural forest of El-Charef, 1 to 3 nests per tree are recorded in the trees which their height ranging from 3 to 5m.

This study highlighted the presence of natural forests near the plantation ones facilitated the migration of adults from their origin sites where there are repeated treatments periodically in to the monoculture plantations which offered a favorable conditions. The change of directions of the insect indicates that the age, the exposure and the situation of forest enter in the choice of construction of winter nests of pine processionary moth and in their occupation and distribution strategy.

Keywords: processionary pine, Aleppo pine, nest, strategy of occupation

Brutian and Stone Pine stands in the upper Metn region (central Lebanon): a functional typology for forest conservation and management

Paolo VARESE, Carla KHATER, Rita EL HAJJ, Julien VIGLIONE

Arising from a 2 years participatory process, a sustainable development plan was developed in 2013 by the federation of municipalities of the upper Metn (mountain catchment delineating the valley of the Beirut River) with the support of a French decentralized cooperation (Région Ile de France). Consequently, a territory charter covering a set of varied priorities, operational objectives and projects was conceived, approved and endorsed by both municipalities and local communities. The elaboration of the plan was founded on several baseline surveys including a forest and biodiversity assessment that was performed based on a functional typology revolving around a multi-criteria approach.

Brutian (*Pinus brutia*) and Stone (Pinus pinea) Pines cover an important area in Central Lebanon, especially on the western side of the Mount Lebanon range (Mediterranean side slopes), from the Thermo-Mediterranean to the Montane-Mediterranean vegetation levels. Aleppo Pine (*Pinus halepensis*) is on its turn locally present at the Meso and Thermo-Mediterranean levels on the southern parts of Mount Lebanon. In western central Lebanon, forest stands variability is very important: pine species extend over a great altitudinal range (from sea level to 1600 m) on varied morpho-topographical, geological (limestones, sands, marl, basalt rocks) and pedological conditions. Forest eco-complexes exhibit various structures along with high rates of habitats and species diversity (Abi Saleh & Safi, 1988; Khater & El Haji, 2012). However, basic management practices are still adopted in these forests (Regato & Asmar, 2011, FAO, 2010). Only a traditional pine nuts culture is developed in stone pine stands which are always artificially regenerated. Wood production is not managed, but firewood picking is frequent and widespread. Forest fires, overgrazing and chaotic urban development have increased forests' fragmentation and fragility. In open spaces and regular forests' understories, a dynamic succession of broadleaved species (including mainly Palestinian and Gall oaks: *Quercus calliprinos* and *Quercus infectoria*) is today noticed. This fact is actually perceived as an issue of concern in traditional pine-nuts stands' management.

An ecological and dynamic forest typology aims at optimizing and reconciling economic development with biodiversity conservation priorities. Any forest type or sub-type has its specific features and patterns of potential growth, natural regeneration and structural variability as well as different types of biodiversity markers and other particular ecosystemic services. Based on the French typological method (Rameau, 1991) later modified in Italy for regional forest typologies, this paper suggests a synthesis of site, vegetation and stand data, report characteristics and potentialities of acidophilous and calcic Stone Pine and calcic Brutian forest types. Identification keys with differential characteristics are presented for 3 sub-types. Vegetation classification (Paleartic, Eunis and phyto-sociological systems) is escorted with general description, spreading, stand variability, ecological data, indicative species, and functional evaluation. All along, conservation and management measures are suggested.

Despite the unstable socio-economic and political situation in Lebanon, a multifunctional forest management is possible with a simplified forest type approach. Traditional practices must be integrated with new knowledge in joint part.

Evolution of species richness and turnover rate of pine forests under climate change

David GARCÍA CALLEJAS, Roberto MOLOWNY HORAS, Javier RETANA ALUMBREROS

The Mediterranean basin is expected to be severely affected by climate change in the next decades, and the need to forecast the potential consequences of this climate variability on Mediterranean forests is pressing. We set to study the specific influence of climate change in population dynamics of tree species in mainland Spain, evaluating the effect of climate variability and biotic interactions in tree survival, growth, colonization potential, sapling recruitment and transition from sapling to adult stages. For doing so, we have designed and implemented an Integral Projection Model parameterized with individual tree data from the Spanish Forest Inventories. Integral Projection Models are based on matrix population models but avoid the need of artificially dividing the studied population in discrete categories of age or size. The treatment of species size as a continuous variable is especially interesting for taxa of slow and continuous growth, such as trees.

Preliminary analyses show that our model effectively reproduces the succession stages of multi-species forest stands, and allows an evaluation of the potential tree species distribution and abundance under climate change. We present here novel results on the evolution of species richness, relative abundance and turnover rate of tree species within pine forests of the province of Barcelona, for the next 100 years. Mean species richness in pine forests will increase in the next decades, triggered by species tracking of climate change: mortality episodes, through decreases in mean basal area and subsequent release of space and light, will increase the potential of current forested areas to incorporate new species, and tree species will tend to migrate towards climatically favorable conditions. Climatic variability, therefore, will be a main driver behind the establishment of novel, transient communities.

The increase in species richness will vary significantly between forest masses, being highest in forests currently dominated by *Pinus pinea* (from 2.8 ± 1.6 species in 2000 to 7.2 ± 1.7 in 2090), and lowest in pine forests of *Pinus uncinata* (from 2.2 +- 1.3 species in 2000 to 4.7 +- 1.8 in 2090). Species turnover will also increase significantly, especially under the scenario of strongest climate variability and in forests dominated by *Pinus uncinata, Pinus sylvestris* or *Pinus nigra*.

These results suggest that, in order to apply management and conservation strategies to Mediterranean pine forests, the effects of climate change on specific demographic processes and the migration potential of the species must be taken into account.

Functional diversity influence the balance between tree growth and mortality in Iberian pinewoods

Asier HERRERO MÉNDEZ, Jaime MADRIGAL, Paloma RUIZ-BENITO, Sophia RATCLIFFE, Miguel Ángel ZAVALA

Climate change threats Mediterranean pinewoods through growth reduction and increased mortality caused by warmer and drier conditions. However, species diversity could modulate population responses, increasing productivity via complementarity and selection effects. In addition, diversity could raise mortality due to stronger inter-specific competition or decrease due to facilitation and niche partitioning. Recent studies have shown the importance of functional diversity in clarifying the underlying mechanisms of the effects of biodiversity on ecosystem functioning.

In the present study, we analyze the effect of functional diversity in tree net biomass increment, accounting for tree growth and mortality, for the most widespread pine species in Spain: *Pinus sylvestris, P. nigra, P. pinaster, P. halepensis*. We used data from the Spanish Forest Inventory applying maximum likelihood techniques to quantify how climate, stand structure and diversity shape tree net biomass increment (calculated using basal area increment of live trees and basal area of dead ones). Phylogenetic diversity was used as a proxy of functional diversity.

Our results showed that functional diversity increase tree net biomass increment after controlling for climate and stand structure, although the positive effect varied for the considered pine species and neighboring ones. However, the largest changes in net biomass increment were recorded at low levels of functional diversity.

These results showed the importance of maintaining functionally diverse forests and functionally important species to adequately preserve Iberian pinewoods.

KEYNOTE #4

Can we improve the health of our pine forests by managing tree investment in resistance traits?

Rafael ZAS

The human interference in forest ecosystems has recently broken the equilibrium between trees and their enemies, increasing the frequency and intensity of sanitary problems. Factors such as global warming, the increases of movements of forest genetic materials throughout different countries and even continents, the reduction of the genetic diversity in breeding programs, or the decrease in resistance associated with the increase of productivity through breeding or silvicultural practices, predict an increase of the frequency and intensity of epidemic episodes in forest ecosystems. Range expansions of non-native pests and pathogens to new host plant species is also an extremely problematic consequence of global change. Given the difficulties of applying intensive management practices in forestry, searching for new environmentally-friendly and cost-effective alternatives for pest and pathogen management becomes essential.

Management of pine forest health has been traditionally focused on the control of pests and pathogens populations, mainly by means of phytosanitary chemicals and pheromones. Pine trees, however, have evolved extremely efficient defensive mechanisms that have allowed them to persist in earth for many millions of years despite the enormous pressure imposed by their multiple natural enemies. Recent investigations indicate that the expression of these defensive mechanisms is extremely variable both genetically and phenotypically. This huge variability opens the door for searching for new management alternatives focused on optimizing the resistance of our pine stands accordingly to the biotic risk to which they are exposed. In this communication, I present recent results about the sources of variation of resistance to pests and pathogens in Mediterranean pines, and discuss about the viability of exploiting this variability for enhancing pine forest health.

Rafael ZAS, MBG-CSIC Pontevedra, Spain

PhD in Forest Science in 2001 and Tenured Scientist in MBG-CSIC since 2008, where I lead the Forest Genetics and Ecology research group (www.genecolpines.weebly.com). Our general aim is to improve our understanding of the genetic and ecological basis of plant responses to biotic threats in long-lived woody species, and specifically in Iberian pines. We aim to understand how trees are able to resist and/or tolerate the multiple and variable biotic aggressors with which they have to coexist during their long-live span. This knowledge will help to build new sustainable and environmentally-friendly strategies to manage forest pests and forest diseases. Besides, we are also interested in other life history traits and in their interaction with the resistance to biotic threats. During the last years we have been involved in several National research projects aimed to understand at what extent the trade-offs between resistance and other life history traits are driving the evolution of Iberian pine populations. As a result of these projects, two students have defended their PhD thesis, and we have published more than 40 articles in scientific journals.

Optimizing *Pinus sylvestris* management for the provision of multiple goods and ecosystem services under fire risk in a Mediterranean context

Carlos GRACIA, Sergio DE MIGUEL, Santiago SABATÉ, Juan MARTÍNEZ DE ARAGÓN, José Antonio BONET

Mediterranean *Pinus sylvestris* forests are fire-prone ecosystems that provide not only timber, but also valuable non-wood forest products (e.g., edible mushrooms) and ecosystem services (e.g., water and carbon cycle regulation). Since the ecological and socio-economic importance of *P. sylvestris* extends far beyond the traditional timber-oriented forestry practice, forest planning should reflect this multifunctionality by integrating a wide range of management objectives. Indeed, previous research has focused on integrating, separately, either fire risk, or the joint production of wood and non-wood products, or some ecosystem services into forest management simulation and optimization of Mediterranean ecosystems. However, no studies have been devoted so far to further considering the ecological complexity and multifunctionality of Mediterranean *P. sylvestris* forests in a broader sense.

In this study, we analysed the effect of including ecological and economic criteria such as timber production, mushroom yield, water use efficiency, carbon stock and fire risk in the optimal management of *P. sylvestris* stands based on a hybrid modelling approach (i.e., using both process-based and empirical growth and yield models). The analysis was conducted in a systematic way by maximizing the soil expectation value and the provision of ecosystem services using simulation-optimization techniques (i.e., particle swarm algorithm) with Gotilwa+ software.

The results suggest that some trade-offs may appear in the provision of different goods and services between different forest management alternatives. However, certain stand structures and management schedules may provide fairly acceptable levels of a number of wood and non-wood values, which contributes to increasing the overall multifunctionality of *P. sylvestris* ecosystems through forest management. For instance, optimal forest management schedules for mushroom production may also lead to reasonably fire-resistant stands with fairly high water use efficiency and timber yield that, in turn, may result in more resilient forest ecosystems in terms of adaptation to climate change and carbon balance.

A model-based analysis of climate change vulnerability of *Pinus pinea* stands under a multi-objective management in the Northern Plateau of Spain

Marta PARDOS, Rafael CALAMA, Michael MAROSCHEK, Werner RAMMER, Manfred J. LEXER

The Mediterranean Basin is likely to experience the most adverse effects of climate change in Europe. In this context, it is important to understand the adaptive capacity and vulnerability to climate change in Mediterranean forests where multifunctionality is the key characteristic of their management. Among the Mediterranean tree species, Mediterranean stone pine (*Pinus pinea* L.) is one of the most characteristic tree species. Currently, the sandy flatlands of inner central Spain are the genuine habitats for stone pine; however this is one of the most limiting regions in terms of precipitation. Thus, planned adaptation measures in the management of Mediterranean stone pine forests need to address especially the main climate change threat in the region, which is severe summer drought.

In this study we assess the climate-related vulnerability of stone pine by using an extended version of the hybrid forest patch model PICUS v.1.41 that includes a cone and nut production submodule for stone pine. In this study we analyze through a simulation study (time horizon 100 years), the vulnerability of stone pine stands to climate (baseline climate and four climate change scenarios, C1 to C5) according to the region (sandy lands and limestone high plateaus), site index (9m, 13m, 17m and 21m in sandy plains; 13 m and 17 m in limestone high plateaus), and three different management alternatives (timber, nut and timber + nut production), looking at timber assortments and cone production, expressed as monetary revenues (NPV). The model was accurately calibrated for the species, and the species parameters validated by comparing model runs to long term inventory data of even-aged pure stone pine stands.

Results from the simulations showed that under the current climate the monetary revenues obtained from the main ES (nut, timber and nut+timber) were slightly different according to the alternative management, while they were clearly affected by the site type. The most profitable site was site type 1 (sandy lands, site index 21m), followed by site type 5 (high limestone plateaus, site index 17m). In the sandy lands, nut production showed the higher monetary revenues, while a mixed nut+timber production was the most profitable in the high limestone plateaus. Under future climate scenarios, a decrease of 30% in the mean rainfall affected to a greater extent than a temperature increase of 4^{o}C. For the worst climate scenario (-30% precipitation/+4^{o}C), NPV values decreased to 0.15 - 0.27 the current NPV values.

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Identifying the roles of emergence, survival and growth in a regenerating pine forest submitted to a range of disturbance intensities

Bernard PRÉVOSTO, Jordane GAVINET, Christian RIPERT, Catherine FERNANDEZ

The regeneration phase is often a critical step in population dynamics but it is still incompletely understood due to the intricacy and complexity of the factors concerned. We investigated the role played by emergence, survival and growth in the recruitment process of a mature Aleppo pine forest (Age: 90, basal area =12 m^2/ha) located in SE France and submitted to disturbances of various intensities. Disturbances were produced by site treatments replicated 4 times and including mechanical chopping, mechanical chopping followed by soil scarification in one or two directions, controlled fire of low or high intensity, and control. Seedling emergence, survival, dimensions were monitored over 6 years (2005-2010) on 580 one-square-meter plots in which the individual fate of each seedling was surveyed. Covers in bare soil, grass and shrub were also recorded.

Seedlings did not emerge continuously and regularly with time but mostly during peaks particularly marked in the rainy autumnal seasons of the two first years. This specific pattern defined a 'window' of emergence characterised by the duration during which seedlings emerged, the number of emerged seedlings and the shape of the seedlings distribution with time. Survival and growth decreased from the earliest cohort to the latest cohort as soil conditions became less favourable mainly due to grass development. Emergence, survival and growth did not respond in the same way to treatments and soil surface conditions. The most intense treatments (scarification, high-intensity fire) were also the most efficient for creating sites free of ground vegetation favourable to seedling emergence. In contrast, less intense treatments (chopping, low-intensity fire) with lower impacts on soil and ground vegetation were also less efficient in promoting emergence. The high-intensity controlled fire treatment was the most beneficial to survival whereas the highest growth was recorded in the scarification treatments. From these results, it appeared that environmental factors controlling survival, emergence and growth processes differed and that their importance was likely to fluctuate with time. A clear illustration was given by the contrasting role played by shrubs that exerted a negative influence on emergence but a positive one on survival and growth.

We concluded that environmental factors controlling survival, emergence and growth processes could differ and their importance could fluctuate with time. Adapting silvicultural treatments to foster regeneration could thus benefit from a more detailed understanding of the processes involved in seedling recruitment.

Using remote sensing data for assessing mid-term post-fire regeneration trajectories in sub-Mediterranean black pine forests

Santiago MARTÍN-ALCÓN, Lluís COLL, Miquel DE CÁCERES, José Ramón GONZÁLEZ-OLABARRÍA

Wildfires play a major role driving vegetation changes and causing environmental and economic losses in Mediterranean pine forests. This role is especially important in areas where the dominant species lacks efficient regeneration mechanisms after burning. This is assumed to be the case of the forests dominated by black pine (Pinus nigra Arn ssp. salzmannii). In these stands, several post-fire successional trajectories (i.e. from shrublands to pure oak and mixed pine-oak forests) can occur depending on multiple factors, such as the composition of the understory before fire and the survival of pine trees in the neighborhood.

In this study, a simple and cost-effective methodology is presented for assessing post-fire regeneration types of a black pine forest burned in 1998 on a spatially continuous way. Our method allows the regeneration type of each stand to be determined by the use of a combination of airborne LiDAR data (for characterizing the three-dimensional distribution of plant canopies) and multi-spectral high-resolution data from aerial images (for species differentiation). Six post-fire regeneration types were obtained by applying a K-means partitioning on remote sensing data corresponding to a subset of stands where a field-based inventory had been carried out. Data from the field inventory allowed the interpretation of the typologies obtained.

Two of the types showed a clear dominance of broadleaves, other two types showed dominance of pines, and the two remaining types matched with areas mainly covered by shrubs, non-woody vegetation or bare soil. Centroids obtained by K-means were used to extrapolate the classification to the whole burned area, resulting in a spatially continuous assessment. Finally, a field-based validation was carried out in a number of additional locations scattered all over the study area.

The information provided in this study may be of great utility to advance in the understanding of the factors driving post-fire vegetation responses and could be directly used by the forest services to define post-fire management strategies.

Availability of maritime pine wood in Portugal in the period 2015-2105

Paula SOARES, João Pedro PINA, Margarida TOMÉ

The area occupied by maritime pine (*Pinus pinaster* Ait.) in Portugal has declined over the past decades (according to Portuguese NFI reduction of 17,500 ha/year between 1995 and 2010). The maritime pine stands are mostly in the north and centre (90.8%) and 63% of the stands are smaller than 10 ha. There are several phenomena, namely hazards, which may result in a land use change. For instance, the inland desertification, forest fires and the presence of the nematode (*Bursaphelenchus xylophilus*). The availability of wood from maritime pine in the coming decades is crucial for defining development strategies for industries linked to this resource.

In this work, we evaluated, using the forest regional simulator SIMPLOT, the availability of wood for the period 2015-2105 for alternative scenarios that consider annual values of burned area, abandoned area, new areas, the use of genetically improved material and market demand.

The results show that the supply tends to be lower than the demand. This difference increases during the period considered and can only be reduced through increased area and/or increased productivity of already existing area. However, contribution of new areas (obtained by planting or seeding) and of the use of a certain percentage of genetically improved material, only contribute significantly to the increase of supply after 40-45 years, which is the rotation age, although the contribution begins to have some effect after the first thinning.

The impact of the different scenarios tested is discussed as a basis for the definition of forest policy measures.

Growth response and competition mode as modulated by climate and thinning intensity in Mediterranean pinewoods

Andrés BRAVO-OVIEDO, Gonzalo Andrés GUERRA, Felipe BRAVO, Ricardo RUIZ-PEINADO, Gregorio MONTERO, Miren DEL RÍO

Thinning has been found to buffer the climate effect on tree growth, but responses vary among sites and species. This thinning effect plays a key role in Mediterranean pinewoods, where extreme drought events are expected to increase in the face of climate change. In this work we study tree growth response to climate under three management regimes in a *Pinus pinaster* afforestation. The main objectives were: i) to identify the main climatic variables influencing radial growth in non-managed stands; ii) to analyse whether climate-growth relationships are modified by thinning treatments; and iii) to explore whether climatic conditions and thinning determine the mode of competition.

Data were gathered from Fuencaliente Experimental Site (SW Spain) where a thinning intensity experiment was established in 1984. A randomized complete block design was set with three blocks and three treatments (control, moderate and heavy thinning). The total number of plots is nine and thinnings were from below and performed every 8 years. The climate-growth relationship was analyzed by means of growth series. Two cores in fifteen dominant and codominant trees in each plot were sampled. Cores were treating using standard methods of dendrochronology, including computation of the correlation between series, first order autocorrelation and mean sensitivity. Three nested diameter increment models were tested in order to accomplish the objectives. The first model was considered as reference and included only diameter as independent variable, the second model took into account the thinning effect and the time elapsed since thinning. The third model included those climatic variables that were found significant in the dendrochronological analysis. Finally, a model with interactions was also tested.

Climate-growth relationship studied in control plots indicated that *Pinus pinaster* growth in this area is mainly influenced by previous autumn-winter precipitation and May precipitation. Temperature has an opposite effect on tree growth. High temperatures in May are related to lower growth rates, while temperatures of February and September have a positive effect, the last one probably associated to a second growth period during the last summer or early autumn typical of some Mediterranean pines.

Results found in thinned plots showed that a reduction in tree density can decrease the tree growth dependence on precipitation, highlighting the importance of thinning as an adaptative silvicultural measure. These results are discussed exploring the variability of tree growth-size relationships among years and thinning treatments in order to explain how thinning modify growth partitioning among trees depending on climatic conditions.

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Estimation of leaf area index in a Mediterranean pine (*Pinus pinea* L.): from the needle to the stand level

Alexandra CORREIA, João FREIRE

Leaf area index (LAI) represents the amount of green leaf material in an ecosystem and is defined as the total one-sided area of photosynthetic tissue per unit ground surface area. It is a key parameter in ecosystem processes understanding because it controls photosynthesis, respiration, transpiration and rain interception. Any changes in LAI are accompanied by modifications in stand productivity.

Crown variables are closely linked with cone production in *Pinus pinea*. In fact, management requires successive thinnings during stand lifetime in order to allow crown development free from neighbourhood tress competition. This highlights the importance of crown conformation and leaf area development in pine cone production cycle. Nonetheless there is a research gap regarding methodologies to estimate leaf area in *Pinus pinea*.

This study is organized in three level of analysis. At the needle scale, we provide an accurate description of its geometry and the variation of specific needle area (surface area/ dry weight) within the crown and with needle age. At the tree level, and using needle biomass data collected throughout tree harvesting, we developed models that describe tree leaf area as a function of dendrometric variables and also with the sapwood (xylem water conducting) area. Finally, at the stand level, we correlate cone production with LAI for different ecological regions.

We conclude that: 1) an error of up to 20% on needle area estimates can be expected by assuming a semi-cylinder shape of the needle, 2) Specific leaf area vary significantly between sun and shade needles and with needles age, 3) Sapwood area measured at the base of the crown explained almost 80% of the variability in tree needle leaf area, 4) Preliminary results suggests a maximum LAI threshold beyond which cone production decreases.

Accurate estimates of leaf area within tree and between stands can be linked with remote sensing indexes and integrated in process-based ecosystem models allowing a more comprehensive understanding of ecological processes affecting cone production.

Impact of forest management intensity on landscape-level mushroom productivity in Mediterranean pine forests: a regional model-based scenario analysis

Sergio DE MIGUEL, José Antonio BONET, Timo PUKKALA, Juan MARTÍNEZ-DE-ARAGÓN

Edible wild mushrooms are among the most valuable and popular non-wood forest products in many parts of the world. Since many mushrooms are symbionts of forest trees, understanding the effect of forest management on mushroom productivity at multiple scales is crucial to ensure the provision of this non-wood forest product.

In this study, mushroom yield models were developed for most Mediterranean pine forest ecosystems of north-eastern Iberian Peninsula. Since local site characteristics, forest stand structure and weather conditions may affect sporocarp emergence, variables representing all those factors were considered in model fitting. In combination with individual-tree growth models, the obtained mushroom yield models were used in continuous cover forestry simulation and optimization in order to assess the impact of alternative regional forest management intensity scenarios on landscape-level mushroom productivity. The baseline scenario was defined as the current forest harvesting intensity or felling rate in north-eastern Iberian Peninsula (25% of annual forest growth). The time frame considered in the scenario analysis was 30 years.

The results suggest that the current average productivity of commercially important edible mushrooms is 14 kg ha^{-1} yr^{-1} (4,600 tonnes yr^{-1}). Under the current forest management intensity, a loss of 220 tonnes yr^{-1} (5%) in mushroom production at the regional level can be expected. In the absence of forest management, the loss in productivity can attain almost 500 tonnes yr^{-1} (11%). If forest harvesting intensity was 65% of annual forest growth (i.e., the average felling rate in Europe) an increase of 100 tonnes yr^{-1} (2%) in mushroom production could be expected. If forest harvesting was equal to 100% of annual forest growth (i.e., sustained yield forestry) an increase of 262 tonnes yr^{-1} (6%) could be expected.

PINEA Project: Modelling growth and pine nuts production for Pinus pinea under changing environmental conditions

Luis FONTES, Abel RODRIGUES, Alexandra CORREIA, Carlos PACHECO, Carolina VARELA, Edmundo SOUSA, Encarnação MARCELO, Francesco MINUNNO, Isabel CARRASQUINHO, João FREIRE, João SILVA, Joe LANDSBERG, Juan GUERRA, Manuela BRANCO, Margarida TOMÉ, Marta Baptista COELHO, Paula SOARES, Pedro JORDAO, Peter SAVILL, Rafael CALAMA, Sven MUTKE, Teresa VALDIVIESSO

It is intended to provide an overview from the PINEA Project which has being carried out with the following main objectives:

(i) the calibration and validation of a process-based model for *Pinus pinea* in Portugal. This will allow estimation of the productivity of existing stone pine plantations in the context of climate change, considering different climatic scenarios, and will provide a tool to support decision-making regarding new planting;

(ii) evaluation of the effects of irrigation and nutrient availability on *Pinus pinea* growth and nut yields;

(iii) to improve existing empirical modelling equations relating to growth and nut yield of *Pinus pinea*.

The PINEA Project is organised in nine Tasks. It uses existing Pinus pinea data, including data from permanent sample plots, previous biomass trials, and an established fertilization trial. A new irrigation and fertilization trial is being established. New data is being collected from it and from existing permanent sample plots and a fertilization trial. All these data will be validated and organized in databases. Following database development the data will be analysed in different ways, bearing in mind that one of the major objectives is to develop a process-based model calibrated for *Pinus pinea*.

Effect of Aleppo pine thinning on development of introduced hardwood species: a comparison between SE France and SE Spain

Jordane GAVINET, Alberto VILAGROSA, Esteban CHIRINO, Maria GRANADOS, Ramon VALLEJO, Bernard PRÉVOSTO

Developing silvicultural methods to adapt pine forests to climate change has become a priority. Recommended management include in particular stand thinning in order to reduce competition for water and re-introduction of resprouting hardwood species to promote diversity and resilience through a faster vegetation recovery and soil protection after new wildfires.

In this study, we examined the effect of Aleppo pine thinning on early establishment of a set of introduced hardwood seedlings with different shade and drought tolerance, in relation to environmental factors under different canopy covers. Stands were selected in 2 sites -South-East France and South-East Spain, corresponding to wetter and dryer conditions, respectively- and thinned at three levels (control=30 m^2/ha, moderate=13-20m^2/ha or heavy thinning= 7-10m^2/ha).

Hardwood species performances were higher under thinned treatments in France, whereas in Spain thinning was detrimental for the survival and height growth of most species, but positive for basal diameter growth. Best performing species were shade-tolerant in France and drought-tolerant in Spain.

Thinning increased light transmittance (control=10-15%, moderate=20-30%, heavy thinning=40-60%) and accentuated the daily extremes (maximum and minimum) of air temperature and vapor pressure deficit in both sites. Thinning effect on soil water content was different between the two sites: no or slight effect in France but an increase of soil humidity in the most intense thinning treatment in Spain. In France, thinned plots were rapidly colonized by an abundant layer of tall understorey shrubs but not in Spain. This shrub layer may explain the difference of thinning effect on soil water content.

Surprisingly, species survival was lower in the thinned treatments in the dry conditions of Spain in spite of higher soil water content. This suggests that reduction of air vapor pressure deficit, temperature and light irradiation may be more critical than soil water content for species survival in Spain whereas in France light availability is the most crucial parameter.

This study highlights the major importance of shading for species survival in the Mediterranean. Pine thinning can be a tool for accelerating the transition towards mixed stands but with contrasted impacts according to site conditions. In wetter sites, intense thinning is adapted to enhance growth and survival whereas in drier sites moderate thinning producing enough shade to ensure saplings survival can be recommended. However, further investigation is needed to fully understand the role of understorey shrubs in modifying this pine density - sapling interaction.

Competition and productivity of Mediterranean Pinus species in mixed forests: basing a particularised silviculture

Pau VERICAT GRAU, Mario BELTRÁN BARBA, Míriam PIQUÉ NICOLAU

In NE Iberian Peninsula a third of pine forests are mixed stands, and this ratio is increasing. However, current management of mixed stands including pines is essentially the same than the one applied to pure stands.

Our aim is to analyse the different performance of *Pinus halepensis*, *P. nigra* and *P. sylvestris* in pure vs. mixed conifer-conifer or conifer-broadleaved stands. The question is to determine whether there is a relation between the proportion of each Pinus species within the different mixed stands and their competitive capacity and growth.

Data for the study came from Spanish Forest Inventory plots, and we considered 5 types of mixed stands: *P. halepensis* - Quercus sp., *P. nigra* - Quercus sp., *P. nigra* - P. halepensis, *P. sylvestris* - Quercus sp. and *P. sylvestris* - *P. nigra*. For each pine species, we calculated its specific Stand Density Index (SDI) parameters based on pure stand plots. Then, SDI and Growing Stock Increment (GSI) were calculated for both dominant and secondary species, and for the total stand. SDI was computed by the summation method. GSI was obtained by comparison of inventory data. Finally, plots were classified according to the basal area proportion of the dominant species and, for each class, SDImax and GSI were calculated.

SDI analyses showed that *Pinus nigra* performs different to *P. halepensis* and *P. sylvestris* in competitive capacity. In pure stands, *P. nigra* showed a higher SDImax and a lower β parameter than the other two pines. In mixed stands, *P. halepensis* and *P. sylvestris* showed a decline of SDImax when the proportion of other species increased, especially when the secondary species is broadleaved. However, *P. nigra* showed a softer decline in SDImax when the proportion of other species increased. Total GSI resulted somewhat similar for the entire stand along the whole range of basal area proportions.

Competition and productivity indexes provide useful information to improve the silviculture of Pinus-dominated mixed stands. The detected interspecific competence effects suggest the need for explicit silvicultural schemes for mixed stands. Stands mixed by patches may be preferable than those mixed by single-tree for *P. halepensis* and *P. sylvestris*. However, for *P. nigra* both options can be considered.

Increased productivity of mixed stands vs. pure stands documented for several forest types was not observed in our study, suggesting that Mediterranean climate could impose abiotic restrictions different to those existing in temperate forests.

Height and diameter growth modeling of young *Pinus pinea* trees elevated on various substrates in forest nursery: Results after 15 years of growth in field trial

Tahar SGHAIER, Yves BROSTAUX, Youssef AMMARI, Jean-Jacques CLAUSTRIAUX, Hajer OTHMANI

The purpose of the present study is to compare in reforestation site, through a statistical evaluation of dendrometric data collected from field trial, the behavior of *Pinus pinea* trees coming from plants produced in various substrates in forest nursery. The experiment was installed in the framework of the modernization program of Tunisian forest nurseries which aims to substitute the forest or diverse textured agricultural soil-based substrates by compost produced from locally available forest biomass in the objective to improve the quality of forest plants produced for reforestation programs. Five compost-based growing media (S1, S2, S3, S4 and S5) mixed with different support and aeration materials and a control substrate (ST) made of peat generally used in Tunisian forest nurseries were used to produce *Pinus pinea* plants used for this experiment.

The experimental trial was installed in 1997 in the north-west of the country according to a randomized complete blocks design with four replicates. Each treatment (substrate) was represented by 45 trees in each block. Three measurements were taken at 6, 9 and 15 years after plantation. The measurements have concerned the height and diameter of trunk at 0.30 and 1.30 m. During 2013 (16 years after plantation), three trees per treatment and replicate were selected systematically for stem analyses. The selected trees were cut down to 0,10 m and total heights were measured. Each tree was then cut at 0.5 m intervals until the diameter 7 cm. The number of rings was counted at each cross sectioned point and then converted to stump age. To measure the annual diameter increment, the discs obtained at the cross section 0.10 m for the 72 cut trees were used. Annual radial growth was measured from the discs with the LINTAB table and TSAP software.

Data obtained from stem analyses (cut trees) were used to establish two growth models by treatment (substrate): one for height growth and one for diameter under-bark growth. To select the adequate model for each growth parameter, three algebraic difference equations (ADA) derived from the base models of log-logistic; Bertalanffy-Richards and Lundqvist-Korf were adjusted and compared. For the height parameter, as cross-section lengths did not coincide with periodic height growth, we adjusted the height/age data from stem analysis to account for this bias using Carmean's method. To correct the inherent autocorrelation of the longitudinal data for the two measured parameters, a second-order continuous-time autoregressive error structure was used, which allows the models to be applied to irregularly spaces, unbalanced data. Both qualitative analysis based on the biological realism of the models, as well as numerical and graphical analyses based on the accuracy of the models were used to evaluate the performance of candidate models.

For the statistical evaluation of this test we proceeded in two steps:
- An evaluation based on the analyses of the data resulting from the three measurements taken directly on all trees of the field experiment.
- An evaluation based on the analyses of the simulated data for all trees of the experiment using the obtained models by treatment and studied parameter. Height and diameter measured after 15 years for each tree of the field experiment were used as exogenous parameters for the simulation. With this second method of evaluation, studied treatments could be compared for various ages from 1 to 100 years.

Pinus nigra Arn. ssp salzmannii seedling recruitment is affected by stand basal area, shrub facilitation and climate interactions

Manuel Esteban LUCAS BORJA, David CANDEL-PÉREZ, Francisco A. GARCIA MOROTE, Philippe BALANDIER, Eva María RUBIO CABALLERO, Marta I. PICAZO CÓRDOBA, Julián MOLERO CARRASCO, Eduardo MARTÍNEZ GARCÍA, Tarek DADI, Manuela ANDRÉS ABELLÁN, Francisco R. LÓPEZ-SERRANO

Spanish Black pine (*Pinus nigra* Arn. ssp *salzmannii*) forests in the Cuenca Mountains (Spain, 40º 00' 36, 77'' N; 1º 57' 36,45'' W) have traditionally been managed using the shelterwood method, with a shelter-phase of 20–25 years and a rotation period of 100–125 years. However the lack of natural regeneration has been one of the most important problems since the end of the 19th century, sometimes jeopardizing stand persistence. Some authors cited the following as the main problems for Spanish black pine natural regeneration success: the masting condition of Spanish black pine, dry summers over a period of at least three years, excessive grazing and uncontrolled ploughing activities. On this context, nurse shrubs and an adequate overstorey density may have facilitative effects by increasing seed emergence and seedling survival in harsh environments.

The main objective of this work was to evaluate the influence of stand basal area (15-20; 25-30 and 35-40 m2 ha-1) × with/without shrub protection on seedling recruitment of Spanish black pine. In spring 2012 and 2013, 72 plots 30 × 30 cm were established in “Los Palancares y Agregados” forest (12 replications × 3 stand basal area × 2 shrub conditions, under and away). Each plot comprised 20 seeds previously collected at the forest’s experimental site. Seedling emergence and then early survival were monitored every month in both 2012 and 2013. Light was measured above each plot and a meteorological station (METEODATA 1270C) was installed in the forest’s experimental site.

Roughly 2012 was drier and warmer than 2013. The year greatly influenced seedling recruitment. In 2012, seedling emergence was higher under the 25-30 m2 ha-1 stand basal area and favoured by the shrub protection, whereas in 2013, both basal area and shrub protection were not significant factor affecting emergence. Seedling survival was the lowest under the 15-20 m² ha-1 basal area in 2012 but the highest in 2013. Finally, higher seedling survival was found under shrubs protection in 2012, whereas higher away from shrub protection in 2013.

Thus we can conclude that the success of Spanish black pine recruitment results from complex interactions between stand basal area and shrub protection, indeed modulated by the climatic conditions of the given year. Shrub facilitation is only obvious the drier years under moderate light, whereas seedling survival is favoured by higher light availability the wet years.

KEYNOTE #5

Markets development for pine products: actors and patterns of trade in a changing market condition

Davide PETTENELLA

The market conditions for pine forests are undergoing a process of structural change that is affecting also pine forest plantations and semi-natural forests in Europe. The wood market is affected by a structural decrease in the pulpwood demand, traditionally the main final market for pine plantations. Other market segments, like packaging and reconstructed wood panels, have been seriously affected by the economic crises. On the contrary the development of markets for pine Non Wood Forest Products, namely pine nuts and resin, are, for different reasons, characterized by positive trends in terms of demand and prices.

The paper, relaying on COMTRADE and EUROSTAT data on trade flows for the three products (pine wood, nuts and resin), will highlight the main patterns of trade, the emerging players in the market and the price trends, with a focus on the European market conditions. The results of the market analysis should be taken into consideration in order to adapt the management policies and the investments in the sector.

Davide PETTENELLA, University of Padova, Italy

I am full professor at the University of Padova where I teach forest economics. I am also the director of the LERH PhD program. I have worked extensively in forest products and services marketing, with a special focus on Corporate Social Responsibility and the ethical aspects connected with public institutions role in regulating the forestry sector (illegal logging and FLEGT, ENA-FLEG, flexible mechanisms, PES, REDD+, ethical finance). J have published more than 400 papers in the field of forest economics and marketing as a result of research activities and field works carried out within programs financed by the European Commission, FAO, European Forestry Institute, World Bank, CIFOR and by Italian institutions.

Scenarios for payment of forest ecosystem services provision in Aleppo pine in Catalonia (Northeastern Spain)

Elena GÓRRIZ, Elsa VARELA, Míriam PIQUÉ, Irina PROKOFIEVA

The management decisions of private forest owners entail different levels of ecosystem services' (ES) supply; however they often do not receive market signals to fit their provision with societal demands. When the policy objective is to provide economic incentives to engage landowners in new forest management practices, a preliminary step is to assess the instrument feasibility, chiefly contrasting key economic indicators e.g. the costs with the Willingness To Pay (WTP).

In this work we identify key ES produced in Aleppo pine forests in Catalonia, and establish hypothetical stand scenarios with the silvicultural requirements that modify the ES levels, as follows: (i) status quo, i.e. timber-oriented traditional management with occasional selective cutting, (ii) timber-oriented planned management, with intensive silvicultural interventions, (iii) same than previous but with existing subsidies, (iv) biodiversity improvement scenario, and (v) wildfire prevention management. Forest stand development is calculated from growth models and empirical tables. We compute the financial indicators of each scenario and the opportunity costs of changing them depending on the site quality. Findings show that changing from the status quo situation to the improvement of biodiversity or fire prevention scenarios has negative consequences for the landowner. However those owners already managing for timber purposes face almost no additional costs for moving towards fire prevention or even have positive balances when increasing biodiversity.

In parallel, an economic valuation survey was conducted in Catalonia in 2011 to evaluate the social preferences for key ES provided by Aleppo pine forests, which are expected to be enhanced with active management, e.g. biodiversity improvement and fire risk reduction. The WTP for changes in these ES was elicited from the respondents through the choice experiment methodology. The results showed a higher individual WTP for biodiversity improvements than for fire prevention.

Upscaling the results for the entire Catalonian population, we found that the value of social demand covers the owner's expected losses of changing management. We argue that these numbers show the feasibility and likely acceptance of the introduction of a specific earmarked tax, whose amount would fit within both values. There is a prominent relative mismatch between the costs of provision and social demand for both ES, given that costs for improving fire prevention are much higher than those for biodiversity. This work represents an initial step for the policy instrument design, which needs to be complemented with additional analyses of social preferences and forest owner behaviour.

Social preferences for key externalities provided by actively managed Aleppo pine forests in Catalonia: an economic valuation perspective

Elsa VARELA, Robert MAVSAR, Jette Bredah JACOBSEN

Aleppo pine stands occupy almost 20% of the Catalan forest area. Frequently, these are highly homogeneous stands with a high density of trees/ha. Most of these stands belong to private forest owners and due to their low profitability, are abandoned and lack active forest management. This results in a low resilience of these stands towards perturbations, also decreasing the potential flow of goods and services of these stands to society.

This study applies a choice experiment an economic valuation technique that allows estimating the social preferences for four key externalities provided by these forests that are expected to be enhanced under active management scenarios: biodiversity (increase in the number of tree species), CO2 sequestration, recreational access and reduction in the annual burnt area. Those externalities are produced jointly by these forests, but the nature of their value varies through private personal use (recreation), economic loss for society and some individuals (fire risk), pollution mitigation (carbon sequestration) and almost pure passive use values (biodiversity).

The economic valuation questionnaire was conducted interviewing a representative sample of 410 Catalan citizens. The inclusion of a monetary attribute in the valuation questionnaire allows estimation of the social preferences for the aforementioned externalities in monetary units. A discrete mixture model was estimated, which identified significant differences in the population in terms of their sensitivity to the cost of the proposed scenarios. We find that people's preferences for these various ecosystem services do indeed differ, with biodiversity being the highest valued. Consumer surplus estimates were calculated for different scenarios relevant for the forest management Scenarios where the focus was placed on biodiversity improvements were achieving a higher social welfare gain. Lessons learnt from this study could be relevant for the development of management policies and specific measures to promote active management of these stands among private forest owners.

The Stone pine (*Pinus pinea* L.) in Southern Latin-America

Verónica LOEWE, Claudia DELARD, Marlene GONZÁLEZ, Angela ZULETA, Mónica BALZARINI, Aldo SALINAS, Andrea ÁLVAREZ, Mariane LUTZ

In southern Latin-American stone pine was introduced more than a century ago by European colonists, especially Italians and Spaniards, who brought it for its cultural and gastronomic importance, since the pine nut, dried fruit highly appreciated worldwide, forms part of their diet. Since then, the species has been planted mainly for stabilizing dunes, cattle shading and ornamental purposes, reaching an area near to 100 hectares in Chile, very fragmented along an extension longer than 1,300 km of latitude, and 400 hectares in Argentina, concentrated in approximately 500 km in the coastal area of the Buenos Aires province.

In both countries numerous groups of trees and plantations with comparable management practices were evaluated. For the analysis in Chile there were considered 56 sites and 2,995 individuals, and in Argentina 21 sites and 179 individuals. Likewise, pine nuts were collected in both countries, and their chemical and nutritional characterization was performed.

The work presents the growth (dasometric) and pine nut nutritional quality results, characterizing in this way the Stone pine formations in both countries.

Results show the great potentiality of cultivating *P. pinea* in these zones, oriented to pine nut production for exports, given the worldwide increasing demand and diminishing offer that represents an important opportunity for our countries. It concludes that in zones of Chile and Argentina where unproductive soils exist, the cultivation of stone pine represents an interesting alternative, for being a multi-purpose species, whose annual fruit production is economically relevant, with a potentially relevant socioeconomic impact, as happens in other countries.

The development of a productive innovative chain based on the culture of this species, using intensive or semi intensive management techniques, would contribute to the economic activity of our countries by generating currency income flow; to the sustainable development, with environmental positive externalities; and to the social development by increasing revenue and generating employment, especially in zones of low income.

POSTER SESSIONS

POSTER SESSION A – Tuesday 23th September 14:20 – 15:40 h

Abiotic interactions and climate change

Evolution and adaptation

POSTER SESSION B – Wednesday 24th September 14:30 – 15:50 h

Fire sciences

Biotic interactions

Biodiversity and Conservation

POSTER SESSION C – Thursday 25th September 14:20 – 15:40 h

Stand dynamics and forest management

Policy and social implications

Implications of drought-induced forest dieback for the water balance of a Mediterranean mountain ecosystem

David AGUADÉ VIDAL, Rafael POYATOS LÓPEZ, Mathew WILLIAMS, Dani NADAL I SALA, Jordi MARTÍNEZ-VIALALTA

Episodes of drought-induced tree mortality have been reported worldwide and may potentially change the composition and functioning of ecosystems under a warmer and drier climate. The Mediterranean basin could be particularly vulnerable due to its intrinsically dry summer conditions. However, studies evaluating the effect of drought-induced forest decline on ecosystem fluxes in Mediterranean forests are still scarce. Here, we study the implications of drought-induced substitution of the currently dominant Scots pine (*Pinus sylvestris* L.) by Holm oak (*Quercus ilex* L.) on ecosystem water fluxes at the level of a watershed from the Tillar valley in the Prades Mountains (NE Spain), where drought-induced Scots pine mortality accompanied by abundant Holm oak recruitment has been reported since the 1990's. We sampled three areas within the same valley: a pure Holm oak coppice, a mixed Scots pine-Holm oak stand with clear signs of Scots pine decline, and a pure Scots pine stand in a moister site with no symptoms of tree die-off. Environmental variables and sap flow (Granier probes) were monitored over two consecutive years (2010 and 2011), which included the driest May-October period on record (2011). Water flows were scaled to the watershed level by using forest inventory data and the Soil-Plant-Atmosphere (SPA), process-based, ecosystem model. Our results showed that during spring, sap flow per unit of sapwood area was similar in pines and oaks, whereas the flows per unit of leaf area were much smaller in oaks, due to their higher leaf-to-sapwood area ratio. In the summer both species reduced their sap flow, but the reduction was more pronounced in the pines, with up to more than 5 months of near-zero sap flow rates in summer 2011. Up-scaled sap flow values indicate that the seasonal distribution of transpiration would change towards higher water use in the summer if Scots pines are substituted by Holm oaks due to ongoing climate change. Yearly transpiration may increase > 10% at the catchment level, likely resulting in a noticeable reduction in stream flow.

Linking climate, competition and growth: modelling annual tree diameter increment in even-aged forests of *Pinus pinea* L.

Rafael CALAMA, Rubén MANSO, Javier DE DIOS, Guillermo MADRIGAL, Mar CONDE, Miren DEL RÍO, Marta PARDOS

Within the classical framework of single tree level modelling empirical functions that predict accurately tree diameter or basal area increment are highly required, since they are the main core of the general models defining stand growth and dynamics. These functions work in fixed-period intervals (five-ten years) whose length matches with the demanded forest management outputs. When developing these functions it is necessary to assume that (i) site factors (soil, climate) remain constant through the whole cycle (covering several simulation periods); (ii) inherent stand (stocking, composition) and tree (size-age, competition) factors affecting average tree growth remain constant during the simulation period; and (iii) the simulation interval is long enough to average the effect of climatic factors controlling interannual variability in growth.

However, previous assumptions are not easily sustained due to the uncertainty associated with climate change scenarios, at least in Mediterranean forest systems. Recent climate trends in the region show a clear pattern of increase in temperatures, larger rainfall interannual variability, and higher frequency of severe droughts, effects which are expected to be aggravated during the next decades. Besides, under the context of flexible sustainable forest management there is information that should be evaluated and decisions that should be carried out at a yearly scale; for example, the possibility of loss of vigor due to extreme climate events and the response to thinning during that year. Based on the previous assessments, we postulate that new tree increment functions working at annual scale should be developed and integrated within general growth and yield models. These new functions should incorporate climate variables explaining annual and periodical growth, and should be sensitive to within-period changes of stocking density or composition due to management.

As an example we present a preliminary modification of the existing tree diameter increment function available in PINEA2, an integrated model for the management of even-aged stands of *Pinus pinea*. The new function allows for annual increment predictions by incorporating an annual climate index that modifies average growth, assuring compatibility between period and annual increment estimates, as well as annual changes in competition patterns. The function has been developed matching periodical growth data from trees within permanent plots with annual increment data from extracted cores. The developed function is easily coupled with the annual model for cone production for the species in order to carry out long term simulations of the provision of ecosystem service under different climate change scenarios.

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Poster Session A. *Abiotic interactions and Climate change*

Xylogenesis of Pinus pinaster in the Atlantic Coast of Portugal: looking for intra-annual density fluctuations

Ana CARVALHO, Filipe CAMPELO, Joana VIEIRA, Cristina NABAIS

Cambial activity is regulated by both internal (e.g. auxin levels) and external conditions (e.g. temperature, precipitation, radiation). The constant adjustment of cambial activity to environmental conditions is recorded in tree rings. Such adjustment can be in the width of earlywood, latewood or both or in a narrower time scale, the anatomy of tracheids. Mediterranean pines often present intra-annual density fluctuation (IADFs), which are characterized by latewood-like cells within earlywood or earlywood-like cells within latewood. IADFs are induced by environmental conditions during the growing season that modify cambial activity, and therefore can give climatic information with intra-annual resolution. Although IADFS are common in Mediterranean pines, their formation has not yet been monitored. In order to determine what triggers IADFs formation and their climatic signal, the cambial activity, wood formation and stem radial increment of *Pinus pinaster* (maritime pine) was monitored weekly in eleven trees from February 2013 to February 2014 in a plantation located in the Atlantic coast of Portugal. The band dendrometers showed two periods of stem radial increment, one in spring and another in autumn. The wood anatomical observations also showed two periods of enlargement, one in April and another in October, followed by two periods of cell wall thickening, one in June, and another in November. The second period of enlargement corresponded to the formation of a latewood IADFs probably triggered by the precipitation events observed in September and October, which lead to the resumption of cambial activity after the summer drought. It was the first time that the formation of latewood IADFs was monitored in maritime pine. IADFs seem to function as a fine anatomical adjustment to changing environmental conditions within the growing season. However, more studies are necessary to quantify the adaptive value of IADFs, namely their impact on the hydraulic adjustment of trees to the availability of water.

"Blue rings" formation in *Pinus nigra*: the influence of air temperature on xylogenesis at the Apennines treeline

Alan CRIVELLARO, Alma PIERMATTEI, Marco CARRER, Carlo URBINATI

Changing growing conditions determines adaptation in stem anatomical structure during a plant lifetime. Many different factors can influence the xylem formation, slowing down the process or changing the relative proportion of xylem tissues. The structural adaptation results in intra- and inter-annual xylem anatomical variability that can be used as environmental and climatic proxies.

Wood anatomy analytical methods have been improved to make the slide preparation process more accessible, enhancing the possibility to easily detect the cell walls lignification process. Here we show an unusual phenomenon that we observed in cross sections prepared for anatomical studies of young pine trees (*Pinus nigra* Arnold) with maximum age of 40 years. The study site is a transect located between 1750 and 2200 m a.s.l on Mount Sirente in the central Apennines (Italy). We collected 140 basal cores of encroached pine trees and we selected the ones without compression wood, mechanical damages and with more than 15 growth rings. We obtained microsections from 41 trees sampled along the entire altitudinal gradient. Using a double staining procedure we detected some layers of not completely lignified cells that appear blue in safranin-astra blue stained sections. The tree rings showing the blue cells were named "blue rings".

Blue rings occurred in trees located randomly along the entire elevation gradient and their presence seems more related to microsite variables. Since lignification is a temperature controlled process, we compared trends of average daily temperature from 1980 to 2012 with the occurrence of "blue rings" finding negative anomalies of 10 degrees in mid-late October of peak years. The cambium reactivation produces earlywood-like cells in the latewood but the following colder temperature in October stops the lignification process that does not continue in the following spring, as if the tree had "forgotten" the not lignified cells.

Our results are in agreement with literature works but we are planning to transfer the analysis also at lower elevation and on further sites to confirm the influence of climatic variables on wood formation. The identification of "blue rings" within tree-ring series could enhance the information provided by dendroecological analysis especially about the sensitivity of trees to environmental and climatic factors.

Tools for molecular genetic studies in *Pinus halepensis* Miller

Rakefet DAVID-SCHWARTZ, Leonid KOROL, Galina SHKLAR, Adi FAIGENBOIM

Aleppo pine (*Pinus halepensis* Miller) is the most widely spread pine in the Mediterranean region and is well known for its eco-physiological capabilities for drought tolerance. Various provenances of Aleppo pine were introduced to Israel by massive plantation between the 50's and the 70's of the previous century and two of the biggest forests were planted in the semi-arid region of Israel, where annual precipitation is below 300 mm. The multiple origins of Aleppo pine generated a unique opportunity to study genetic adaptation of Allepo pine to semi-arid climate. The use of genetic tools in this type of study is frequently hampered by high costs and complex technologies.

In this study, we performed partial Illumina paired-end sequencing of four provenances of Aleppo pine originated in Greece, Italy, France and Algeria. We first analyzed their chloroplast DNA for single nucleotide polymorphism (SNP) and identified 91 polymorphic sites with 9 parsimony informative sites. Polymorphic sites between provenance pairs ranged from 32 - 58. We converted polymorphic sites into cleaved amplified polymorphic sequences (CAPS) markers that were used to analyze drought resistant stand.

We found that individual trees exhibiting overall better growth performance were *P. brutia* x *P. halepensis* hybrids. In addition, we used the Illumina sequencing results to identify nuclear simple sequence repeats (SSRs). The large number of nuclear SSR markers that have been identified should facilitate future population genomics and association genetics in this species.

This study demonstrates that development of easy to use and low cost DNA markers can be applied to robust genetic research in conifers.

Poster Session A. *Abiotic interactions and Climate change*

Polycyclic and growth related traits in provenances of *Pinus pinaster* from contrasting environments in relation to drought

Carolina DELATORRE, Víctor GRANDA, Angelo Kidelman DANTAS, Mónica MEIJÓN, Juan Pedro MAJADA, Isabel FEITO, Ana RODRÍGUEZ

Pinus pinaster is one of the most important forestry species in Spain often used in reforestation programs due to its facility to adapt to different ecological conditions. Implementation of genetic programs aimed at selecting clones with improved production rates and abiotic and biotic resistances are desirable, given P. pinaster economic importance.

Polycyclic growth -more than one period of growth per year- is a process related with yield and quality of wood occurring in some species of conifers, but it is believe to be controlled by water stress as it only occurs under favorable climatic conditions. Thus, making insight into the physiological, molecular and genetic bases of this process is important for developing rational breeding strategies in forestry species.

In this work, water stress ecophysiological parameters, as well as ontogenic and phenologic ones, have been characterized in 15 clones of P. pinaster showing different degrees of polycyclic growth, in their third and fourth growing season, from three contrasting provenances. Data of the last traits were collected weekly, while the ecophysiological parameters were measured three times a year: in spring, summer and autumn.

Current available results indicate that the differences between provenances in relation to polycyclic traits are less relevant than expected considering the different shapes of the clones in the field. Nevertheless, growth parameters, varied significantly between populations and clones, provenances from aridity environments showed lower total height. In relation to water stress related traits, differences were observed depending on the provenance of the clone, not being so relevant between seasons.

The results obtained so far indicate that all plants were able to adapt to water availability but to different degrees according to origin. Thus, although a relation between this adaptation and polycyclic growth has not been established to date, the fact that polycyclism-water stress tolerance appears to be related to growth suggests that it may well exist.

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Drought-induced mortality in *Pinus sylvestris*

Núria GARCIA FORNER, Carme BIEL LOSCOS, Robert SAVÉ MONTSERRAT, Jordi MARTÍNEZ-VILALTA

Recent drought-induced tree mortality processes have been described in forests worldwide. Plant responses to water scarcity are varied between species and even within the same species. For better understanding of drought-induced mortality a greater knowledge of the physiological process involved and their interactions is needed. Our objectives were to identify the functional attributes underlying different plant responses to drought leading to mortality vs. survival within a species.

We carried out a manipulative experiment under semi controlled conditions where young trees (~1.5 m tall) of *P. sylvestris* growing on natural soil were submitted to extreme drought. Non-structural carbohydrates dynamics (NSC) and xylem hydraulic properties were measured and gas exchange and water potentials were monitored during the study.

Mortality of *P. sylvestris* was 20 % after two months without watering, and this percentage achieved 80% after three months. Plants ability to keep positive carbon balances during stress and high values of xylem hydraulic conductivity measured at stress peak were good predictors of *P. sylvestris* survival to drought. Initial NSC levels (pre-drought) were not associated to plant survival or to the elapsed time between drought beginning and tree death. However, dead *P. sylvestris* showed lower and very close to 0 NSC values at the end of the study, consistently with some level of carbon starvation.

Our results confirm that both hydraulic failure and carbon starvation are likely to have a role in trees'ability to cope with drought.

Constraints in the allocation to growth, defences and tolerance to frost stress in Maritime pine

Francisco José LARIO, Rafael ZAS, Luis SAMPEDRO, María REGINA CHAMBEL

Phenotypic characterization of forest reproductive material (FRM) is a key step for establishing recommendations of use. Traditionally, the suitability of FRMs to a given deployment area has been determined upon the assessment of survival and growth traits in common garden tests. However, others vital functions such reproduction and resistance/tolerance to biotic and abiotic stresses may be also highly relevant for survival and regeneration, especially under the predicted increases of biotic and abiotic threats associated to global change. Because resources are limited, theory predicts that all these functions can not be maximized at a time, and thus selecting the best growers could be translated to reduced allocation of resources to defensive mechanisms against biological threats and reduced frost tolerance.

In the present work we studied the relationships between growth parameters, constitutive allocation to chemical defenses and needle frost sensitivity in a collection of 25 Maritime pine (*Pinus pinaster* Ait.) FRMs established in several common garden tests. This series of genetic trials was established for searching for alternative FRMs to be use in the Interior area of Northwestern Spain, a transitional region between Atlantic and Mediterranean climates.

Growth in terms of height and diameter at the root-collar was assessed at the age of 6 years old in 8 field trials established within this interior area. Non-volatile resin and polyphenolics were determined at age 7 in both stems and needles in a subsample of trees and FRMs in two field trials with contrasting environments. Previously, at age 4 years, FRMs were tested for their needle sensitivity to frost damage through artificial freezing at -16^{o}C.

A negative strong relationship at the FRM level was found between non-volatile resin in needles and needle frost resistance ($r = -0.78$, $p = 0.02$), and marginal relationships were observed between diameter growth and non-volatile resin in needles ($r = -0.56$, $p = 0.15$) and needle frost resistance ($r = 0.65$, $p = 0.08$). Results showed up that FRMs originating from the coastal areas allocated more resources to defense against foliar pathogens and herbivores but showed less frost tolerance and reduced diameter growth. On the other hand, Mediterranean and Continental FRMs, originating from Central Spain were more tolerant to frost but showed low concentrations of chemical defences in the needles that may led them more susceptible to biotic damage.

Poster Session A. *Abiotic interactions and Climate change*

Physiological changes in *Pinus canariensis* after a volcanic eruption based on carbon and oxygen stable isotope measurements

José Carlos MIRANDA GARCÍA-ROVÉS, Giovanna BATTIPAGLIA, Luis GIL SANCHEZ

Pinus canariensis, endemic to the Canary Islands, has been growing in the archipelago for at least 13.5 My, and its colonization pattern coincides with the time of new islands emersion. Hence, *Pinus canariensis* has suffered millions of years of volcanic activity. A volcanic eruption is one of the most extreme events that a tree can be exposed to and it is expected to result in serious physiological changes in the tree. However, Canary Island pine has been shown to survive through the perturbation imposed by volcanic eruptions primarily due to its resprouting capability, among other traits.

In our study we aimed to use carbon an oxygen stable isotopes to quantify changes in the physiological condition of trees in response to a volcanic eruption. Stable isotopes are useful markers of physiological responses, as the variations in their ratio (13C/12C and 18O/16O) throughout the tree rings can be interpreted as variations in photosynthetic capacity and stomatal conductance.

In 1949 the Hoyo Negro's crater was originated in a freatomagmatic eruption on La Palma Island. This eruption damaged the nearby pine stand, causing complete defoliation, burying the base of the trunks and causing open wounds and broken branches due to pyroclast impacts. Four damaged trees in this area were felled down, and cut into slices. After a dendrochronological analysis, C and O stable isotope analyses were performed on the wood slices. We sampled tree rings from 1940 to 1969 on one slice of each tree. As there were missing rings after the eruption, samples were pooled in 5-ring groups. Cellulose was extracted for those wood samples, and $\delta^{13}C$ and $\delta^{18}O$ were measured.

Results showed that $\delta^{13}C$ was not significantly different before and after the eruption, and $\delta^{18}O$ was significantly lower in the first growing rings after the damage as compared to rings grown before the eruption. The constant $\delta^{13}C$ values indicate that once the pine has restarted its radial growth, it does not show any sign of stress after the eruption. Furthermore, the slightly decrease of $\delta^{18}O$ observed right after the eruption suggest that the newer and smaller crowns increase their photosynthetic capacity and stomatal conductance as compared to the previous bigger ones.

Our results highlight the well-known plasticity of this pine. This species seem to be able to deal with strong perturbations by staying "latent", holding its growth while it recovers its lost crown and restores the nutrient reserves.

Land surface phenology (LSP) changes in relation to climatic variables under different climate change scenarios in the Mediterranean coniferous forests, Southeastern Spain

Hassane MOUTAHIR, Grant CASADY, Barron ORR, Issam TOUHAMI, Francisco RODRIGUEZ MATEO, Juan BELLOT

The Mediterranean is one of the most sensitive regions to global change, particularly climate change. Advances in synoptic monitoring and evaluation can help decision makers project trends and prevent or reduce negative effects on regional ecosystem. In particular, vegetation phenology derived from remotely sensed multi-temporal satellite imagery can be used as a bio-indicator for climate change. Land surface phenology (LSP) is described as the seasonal pattern of variation in vegetated land surfaces observed from remote sensing. The ready availability of time-series satellite imagery and associated analytical tools makes possible the monitoring of LSP over extended periods of time. In this work we used the MODIS 16-day composite NDVI time series to derive several phenological metrics in order to assess LSP changes in relation to climatic variables in the Mediterranean coniferous forests in the province of Alicante (southeastern Spain) over the period of 2000 to 2012. The best-fit regression results when comparing phenological metrics and climatic variables were then used to predict the future changes in LSP under different climate change scenarios for the period of 2011 through 2099. The results show that fall and spring precipitation and maximum temperature are the climatic variables that best explain the changes in LSP. A decrease in the precipitation and an increase in the maximum temperature may result in a shorter growing season (LOS), delayed start of season (SOS) and earlier end of season (EOS).

Key words: MODIS, phenology, climate change, climate scenarios, coniferous forests, Alicante, Spain.

Climate change-controlled dendroecological signal in *Pinus pinea* in Southern Spain

Fabio NATALINI, Reyes ALEJANO, Javier VÁZQUEZ-PIQUÉ

Researching the dynamic response to climatic variability of Mediterranean pine forests is a basic issue when evaluating the vulnerability of these ecosystems to climate change-induced abiotic stress. Tree-rings can provide valuable information to approach this purpose.

We established five *Pinus pinea* ring-width chronologies in SW Spain. Tree-growth variability was analyzed using principal component analysis (PCA) for the period 1935-2011. A common climatic signal expressed by the first principal component (PC1) was found. Considering the PC1 scores as a regional chronology, significant correlations with meteorological data were found: correlation was positive for winter-spring precipitation and winter minimum temperatures, and negative for spring maximum temperatures. The PCA, the PC1-climate correlations and the inter-annual ring-width variability (sensitivity) were computed for successive intervals to check whether the variance explained by the PC1, the climate-growth relationships and the intensity of growth response to climate varied over time. Both sensitivity and shared variance increased over the last decades. The correlation with winter precipitation and temperatures became stronger, spring precipitations lost significance and negative correlation with spring temperatures was enhanced. This indicates that climate became more limiting and a major force controlling growth in the recent decades. In agreement with our findings, meteorological series showed an increase of maximum temperatures in the warmer months, a decrease of minimum temperatures in winter and a marked increase of precipitation variability. Finally, running-interval correlations were performed between PC1 and three *P. pinea* reference chronologies from Central Spain: correlation increased significantly since the 1970s, indicating an enhanced common macro-climatic signal.

Our study highlights the sensitivity of *P. pinea* to more restrictive climatic conditions and the synchronizing effect of climate change on *P. pinea* forest growth patterns at regional scale.

Soil gypsum effects on root density and site index of *Pinus halepensis*

José Ramón OLARIETA, Rafael RODRÍGUEZ-OCHOA, Manuel GARRIDO, Elena TOMÁS

Pinus halepensis is generally considered a species adapted to soils with gypsum but there is hardly any quantitative data available to support such assertion. We studied fifty five 200 m2-plots in a 48 year-old *P. halepensis* plantation in NE Spain including both plots on soils with gypsum and plots on soils without gypsum. In each plot the number of trees with a diameter at breast height (dbh) greater than 5 cm was counted, and their height and dbh measured. From these data, basal area, dominant height and site index at age 40 years (SI40) were estimated. A soil pit was described in each plot to a depth of 1 m or to underlying rock, samples of the various soil horizons were obtained and analysed for pH, organic carbon, total nitrogen, Olsen phosphorus, exchangeable potassium, calcium carbonate-equivalent and gypsum content, and texture. In 15 of these plots, the number of roots was counted at depths of 0-25 cm, 25-50 cm, and 50-80 cm in three 100 cm2-squares per depth; five measurements of soil penetration resistance were at each soil depth with a hand penetrometer; and soil bulk density was obtained from three undisturbed samples at each depth.

Soils with gypsum were frequently very shallow, less than 25 cm deep, and had negligible concentrations of Olsen phosphorus. Values of SI40, with a maximum of 15.5 m, were primarily determined by soil rootable depth, with a positive effect, and to a lesser extent by gypsum concentration within the rootable depth and rock fragment content in the upper 30 cm of soil, both with a negative effect on SI40. Soils with a gypsum concentration higher than 200 $g.kg^{-1}$ in the rootable depth had SI40 values smaller than 10 m, and those with a concentration over 800 $g.kg^{-1}$ had values smaller than 5 m. Density of fine and very fine roots decreased in deeper soil horizons from a maximum value of 97 $roots.dm^{-2}$, but also as gypsum concentration and penetration resistance increased. Horizons with a gypsum concentration above 600 $g.kg^{-1}$ had fine-and-very-fine-root densities below 20 $roots.dm^{-2}$, and those with a penetration resistance of more than 6.6 MPa had densities below 30 $roots.dm^{-2}$.

Gypsum concentration in soils is a significant factor for root development and *P. halepensis* growth in semarid areas, but this variable must be interpreted in the context of the whole soil profile.

Poster Session A. *Abiotic interactions and Climate change*

Expression of dehydrin proteins from stone pine during water stress

Pedro PERDIGUERO, Víctor CHANO, Álvaro SOTO, Carmen COLLADA

Dehydrins are thought to play an essential role in the response, acclimation and tolerance to different abiotic stresses, such as cold and drought. Due to their putative functions in the response to stress, dehydrins have been often used as candidate genes in studies on population variability and local adaptation to environmental conditions, especially in *Pinus pinaster* or *Pinus halepensis*. However, little is still known regarding dehydrin gene family from the genetically depauperate *Pinus pinea*, a well-adapted conifer to the high temperatures and drought characteristic of Mediterranean climates.

Based on the sequences corresponding to dehydrins described in previous work with pines we have isolated eight different dehydrins from stone pine. We have obtained their genomic and mRNA sequences and identified their intron/exon structure. We have also classified them according to their conserved segments in the deduced amino acid sequences, and predicted their secondary structure and disordered regions.

Quantitative RT-PCR analysis of their expression pattern in needles, stems and roots during a severe and prolonged drought stress showed a severe increase of transcripts levels in six of them, especially when the water potential reach values around of -3MPa at 40 day without irrigation. Comparison between the expression patterns obtained in *Pinus pinaster* and *Pinus pinea* shows notable differences in levels of transcripts, especially in aerial parts where *Pinus pinea* shows remarkable higher inductions.

Ecological factors affecting growth of four main conifer species in Catalonia (NE Spain)

Pau VERICAT-GRAU, Míriam PIQUÉ-NICOLAU, Antoni TRASOBARES

The study of climatic factors together with other ecological variables on the performance of Pinus species in South Europe is of great interest regarding likely effects of climate change on the growth, distribution area and vitality of forests in this region.

We studied the effect of ecological variables on the diametric growth of the four major conifer species in Catalonia (*Pinus halepensis, Pinus nigra* subsp. salzmannii, *Pinus sylvestris* and *Pinus uncinata*). Forest National Inventory (IFN) plots and several climatic, physiographic and litho-edaphic variables were used. For each species, we selected the IFN plots with AB> 80% and, as a growth indicator, we used the random plot factor of a tree-level mixed model of diameter increment. The random plot factor indicates the growth variance at a plot level not explained by the tree and stand factors, used as fixed factors in the model. The relationship between this growth indicator and ecological variables was studied by means of simple/multiple regression, ANOVA, and CHAID (Chi-square automatic interaction detection) decision tree algorithm.

The results indicate that *Pinus sylvestris* and *Pinus halepensis* display a more plastic behaviour than *Pinus nigra* subsp. salzmannii and *Pinus uncinata*. The four species respond differently depending on the variables studied, but availability of soil appears to be a key variable in the growth of all. Rainfall is the main climatic factor that positively influences growth of *Pinus halepensis* and *Pinus sylvestris*, while high temperatures have a negative effect. For *Pinus nigra* subsp. salzmannii the climatic variables are important to determine the distribution area of the species but its effect on growth is reduced. Meanwhile, soil availability and exposition (related to water reserve in the soil) appear be the most important determinants of growth. Finally, the growth of *Pinus uncinata* is limited mainly by the low temperatures.

In the context of global change, these results suggest that the altitudinal displacement of these species is likely and will imply important adjustments in the current areas of distribution, in which in *Pinus nigr*a subsp. salzmannii may be the species more adversely affected. The results provide useful information for policy decisions on forest management and forest adaptation to global change.

Root growth patterns in different pines species

Paolo ZUCCARINI, Beatriz GRAU SAAVEDRA, Felicidad DE HERRALDE TRAVERIA, Robert SAVÉ MONTSERRAT

The Iberian Peninsula hosts six native pine species (*Pinus uncinata*, *P. nigra, P. sylvestris, P. pinaster, P. halepensis and P. pinea*), which are distributed according to an altitudinal gradient from coastal to mountain areas, between 0 to close to 1000 m.a.s.l. Root growth and functional response to factors such as seasonal temperature and water availability conditions will be a determinant of future population and species spatial dynamics in a changing climate scenario.

The present work is focused on root growth dynamics and root systems respiration. In June 2012 replicates of above mentioned species (n=3) were planted in Torre Marimon facilities (Caldes de Montbui, Barcelona) in sandy individual rizotrons ($0.3m^2$ of surface x 1.1m of depth = $0.36m^3$ each), under tunnel conditions in order to avoid rainfall. Plants received 2 water treatments.

Cumulative dose ($l \cdot m^{-2}$)

	Tmt 1	Tmt 2
2012	427	325
2013	1110	489

Soil water content was measured every two weeks through an accession tube using a FDR Diviner 2000 (Sentek Technologies)Root length and vertical distribution was measured every two weeks (digital photos were evaluated with the program WinRHIZO 2009, Regent Instruments Canada INC.), and root respiration was monthly measured with a LCi-SD portable Infrared gas analyser (ADC BioScientific, UK).

Coastal pines (*P. halepensis, P. pinaster and P. pinea*) show higher root length growth and soil deep distribution than montane pines (*P. uncinata, P. nigra, and P. sylvestris*), similarly to what happens in root respiration, which is clearly affected by water availability. The observed results support this classification on the basis of root and growth respiration:

P. halepensis > P. pinaster >= P. pinea >> P. nigra >= P. sylvestris = P. uncinata

These growth patterns can help to describe the potential distribution of these species in Spain under the future climatic change conditions.

Poster Session A. *Evolution and adaptation*

Gene expression analysis in *Pinus canariensis* Chr. Sm. ex D.C. in response to mechanical injury

Víctor CHANO, Carmen COLLADA, Álvaro SOTO

Wounds stimulate diverse responses in plants, including mainly modifications in the differentiation fate of the injured and surrounding tissues, leading to the development of barriers against the attack of opportunistic pathogens and pests, healing or, in certain cases, regeneration of damaged organs or de novo generation of organs. The healing capacity is usually higher in angiosperms than gymnosperms. Specifically, re-sprouting is a relatively common feature in angiosperms, very important in post-fire recovery, after predation by herbivores, or even after logging. In conifers, resin from constitutive and traumatic channels covers the surface of the wound, preventing the entrance and development of fungi and other pathogens, but also impeding the eventual proliferation of immature xylem cells and the formation of a callus, as occurs in angiosperms. Thus, wounds in conifer stems must be sealed exclusively from the borders, presumably from vascular cambium, being a much slower process, which very often remains unconcluded. *Pinus canariensis* Chr. Sm. ex D.C. shows an effective wound-healing process and being the only Pinaceae in the Old World able to re-sprout.

We have developed the first transcriptome resource of the Canary Island pine related to cambium activity, and identified approximately 20K unigenes. A microarray containing these unigenes of *Pinus canariensis* was used to study both processes, in three different stages of wound-healing and re-sprouting (immediate response, early response, and late response). Genes involved in phenylpropanoid biosynthesis, flavonoids biosynthesis, cell-wall formation, sugar transport and metabolism, genes encoding different transcription factors, such EXORDIUM, HD-Zip domain, WRKY, MYB, NAC, KNOT, hormones like brassinosteoids, or genes encoding protein kinases like LRR-RLKs, were identified in re-sprouting samples as differentially expression genes (DEGs). Genes related with biotic or abiotic stress, defense-related genes encoding dirigent-like proteins, peroxidases, chitinases, thaumatin-like proteins or hevein-like proteins, genes encoding transcription factors involved in callus formation, or genes involved in phenylpropanoid biosynthesis, sugar transport and metabolism as well, were identified in wound-healing tissues as DEGs.

This work describes for first time the re-sprout and wound-healing processes at the transcriptome level in conifers, allowing new functional annotation and comparative analysis of genes involved in processes not well known in gymnosperms.

Understanding genetic diversity in a relict population of Scots pine in Scotland

Patricia GONZÁLEZ-DÍAZ, Alistair JUMP

Scots pine (*Pinus sylvestris* L.) in Scotland is a keystone species of the remnant Caledonian pine forests. This species reached its maximum extent in Scotland 4400 years ago, covering 1.5 million ha. Nowadays, 84 fragments of the ancient native pinewoods remain in this area, reaching a total area of 18.000 ha and distributed across sites with different environmental conditions. Human impact, browsing, burning, habitat fragmentation and afforestation with non-native provenances are considered the most important threats. Contrary to expectations due to the low geographical distance between many remaining fragments, strong genetic differentiation has been found among remnant populations through the use of markers as monoterpenes, isozymes, mtDNA, cpDNA, nucleotide polymorphism and nuclear DNA. Genetic differentiation is not strongly related to geographical distance between remnants and it is uncertain how isolated and small populations maintain genetic diversity and local adaptation.

The aim of this work was to assess the level and distribution of genetic variation at fine scales in an ancient forest remnant in the North West of Scotland, in order to analyse the genetic substructure of the population and understand how genetic diversity is maintained. This heavily anthropogenically impacted stand was contrasted with one without human interference. To test the hypothesis that spatial genetic structure is of greater magnitude and extends over longer distances in un-impacted stands and that these show more localised seed paternity, we genotyped adult trees, saplings and seeds from these two stands. I will present the results of analyses assessing age-dependent genetic structure and the implications for gene flow and paternity in the investigated populations.

Poster Session A. *Evolution and adaptation*

The infestation by mistletoe changes the chemical defense against herbivores in Black Pine

Alba LÁZARO-GONZÁLEZ, José Antonio HÓDAR, Regino ZAMORA

Pine trees may show considerable variability in chemical composition in response to environmental conditions. Pine consumers, particularly herbivores and parasitic plants, can also promote pine chemical changes. For several pine species, the mistletoe (*Viscum album* subsp. *austriacum*) acts as a keystone species, taking a leading role on the modification of the host chemical composition. These chemical changes have implications for herbivores, resulting in a decrease in the quality of food of the pine tissues, and subsequently reducing the populations of herbivores.

In this study we want to tease out which of these factors affect more strongly the chemical changes of pines. We used two data sets: in the first one, we used needles belonging to different cohorts of Black pine *Pinus nigra* at three sites within an altitudinal gradient (1300-1900 m a.s.l. in Sierra de Baza, SE Spain), from parasitized and unparasitized pines. The second set of needles was collected at another site (1500 m a.s.l.), following the same protocol, but here pines were chosen according to their degree of mistletoe infestation, categorized as Control (unaffected), Low, Medium and High mistletoe infestation. The analysed compounds were terpenes (secondary metabolites acting as defensive compounds), phenols and tannins (digestibility reducers for herbivores) and C/N ratio (as an index of food palatability).

The results show there are differences in palatability between needle cohorts, food palatability diminishing from current- to past-year needles. The infestation by mistletoe increases the pine defensive compounds, especially at Medium-High levels of infestation. Therefore we can conclude than mistletoe parasitized pines represent a worse food for herbivores: the higher the infestation level, the worse are pine needles as a food for herbivores. On the other hand, current-year needles are a better food for herbivores than old ones.

Transpiration patterns of Aleppo pine trees reflect spatial surface heterogeneity and seasonal drought avoidance

Fyodor TATARINOV, Yakir PREISLER, Shani ROHATYN, Dan YAKIR

Aleppo pine (*Pinus halepensis* mill.) is a dominant forest tree species in the Mediterranean semi-arid region that show drought resistance. This characteristic is associated with adjustments in the timing and rate of transpiration during the long dry season. The aim of this study was to investigate the water flow dynamics of Aleppo pine trees in a semi-arid stand at the edge of the northern Negev desert (the Yatir FLUXNET site in Israel). In addition to continuous eddy flux and meteorological measurements, we measured tree sap flow (SF) and variation in stem diameter between 2010 and 2013, complemented by short term campaigns of leaf-scale transpiration and leaf water potential measurements.

During the rainy season (December-April) sap flow (SF) was well synchronized with evapotranspiration (ET), with both SF and ET reaching maximum rates at midday, between 12:00 to 15:00. However, during the dry season (May-November), the SF of different trees had different characteristics. Three groups of trees were identified: One with mid-day SF maximum; a second showing a shift to an early morning peak in SF; and a third with a shift to an evening peak in SF. Correlation analysis indicated that the timing of maximum SF in summer was related to tree size (DBH) and to a competition index. The larger and low competition index trees tended to have a later SF maximum. The diurnal maximum in tree diameter was always observed in the morning, shifting from about 9:00 in winter, to about 6:00 in summer, indicating that nighttime stem refilling is typical throughout the year. Soil moisture (SWC) at 5 cm and 30 cm depth during most of the year reached maximums around 15:00 and between 3:00 and 6:00 at the two depths, respectively. In the intermediate depth of 15 cm (main rooting depth), SWC showed peak values both during pre-dawn in winter and in the afternoon during the summer.

The results demonstrated that it was possible to quantify the stand hydraulic budget using measurements of ET, SWC, tree water potential and SF. This capability, in turn, provides insights to the role of the hydraulic behavior underling the Aleppo pine trees survival in this dry environment. This included the shifts in the daily patterns of SF; and the large variations in rates and timing of SF between adjacent trees. The specific factors influencing these variations are not yet fully understood.

Ex-situ genetic conservation of *Pinus nigra salzmannii* endangered populations from the Spanish Central Range

Javier TRANQUE PASCUAL, Santiago C. GONZÁLEZ-MARTÍNEZ, Manuel Estaban LUCAS-BORJA, Ángel IGLESIAS-RANZ, Jesús FERNÁNDEZ, Enrique HERNÁNDEZ-TECLES, Eduardo NOTIVOL, Oussama AHRAZEM, José CLIMENT

Despite being an abundant species as a whole, some subspecies and populations of the European black pine (*Pinus nigra* Arnold) are particularly threatened due to climate change and alterations of fire regimes across the Mediterranean basin. This is the case of westernmost populations of *P. nigra salzmannii* in the Spanish Central Range (mostly in Sierra de Gredos mountains). Scattered and aged stands thrive in acidic soils, frequently surrounded by Maritime pine and oaks in mid and lower altitudes. The main challenges for the conservation of stands are wildfires –to which Maritime pine is much better adapted– and general lack of regeneration due to low seed viability, putatively deriving from a combination of ageing and inbreeding. In addition, planted stands of allochtonous subspecies can be hybridizing with some neighbouring natural stands.

All factors considered, the regional forest administration (pertaining to *Junta de Castilla y León*) leaded an initiative aimed both at conserving these genetic resources and ensuring the supply of genetically diverse reproductive material. A highly cooperative work among institutions (JCyL, CIFOR-INIA, UCLM and CITA) culminated with the plantation of a clonal seed orchard devoted to the ex-situ genetic conservation of these *P. nigra salzmanii* populations.

Scions of 98 ortets (donor trees) were collected in 9 natural stands of *P. nigra salzmannii* in Gredos mountains. Scions were tip-grafted in two-years-old rootstocks of the same species. Simultaneously, ISSR molecular markers were analyzed in needles of the donor trees. Using SoftSog software and relying on molecular relationships, the optimum design fitted to the plantation size and shape was determined. This design maximized the genetic distance among neighbour plants by minimising the global coancestry between trees weighted by the distance between them; therefore, ensuring minimum inbreeding for future seed orchard crops even with open pollination. The plantation was carried out successfully in a former farmland, far enough from any undesired pollen source.

We further compared the levels of inbreeding and genetic diversity of the natural stands with those expected from seeds originated in the conservation seed orchard to evaluate the utility of the latter for increasing the fitness of these endangered black pine populations.

Fire effects on seed germination of the maritime pine - does seed provenance affect this?

Leonor CALVO, Verónica HERNÁNDEZ, Mª Luz VALBUENA

The principal aim of this study is to analyse the implications of seed provenances and seed size on germination and seedling survival of *Pinus pinaster* after fires. A laboratory experiment was designed in which seeds from three Spanish provenances were subjected to thermal shocks. We investigated the relationship between seed weight, seed germination and seedling growth after heat treatments. The results obtained indicate that there were significant differences in the seed weight between the three *Pinus pinaster* provenances. Mean seed weight was positively correlated with the proportion of germinated seeds but only within heat treatments not in the control. So the heavier seeds, associated with one of the three provenances showed the highest resistance to heating damage. Larger seed size improved the success of germination after heat treatments, mainly after severe situations (200Cº - 5 min), because large seeds insulate the embryo better. In *Pinus pinaster* we detected a positive relationship between seed size and seedling growth after fire.

Poster Session B. *Fire Sciences*

The contribution of fabaceae and cistaceae to post-fire recolonisation of *Pinus halepensis* forest in North-Eastern Algeria

Farid BEKDOUCHE, Mokrane DJAOUIDA

Legumes and Cistaceae due to their roles after fire are widely studied in ecosystems of the Mediterranean basin. In the southern part of this area (North Africa), no data on this topic are available, except the analysis of Bekdouche *et al*. (2011) on the dynamics of legumes in forest communities without addressing the effect of topography.

The dynamics of the soil seed bank of legumes and *Cistus* species on two different topographic situations is followed during the first two years after a wildfire in a *Pinus halepensis* forest. The analyzed aspects are seedling demography, species richness, floristic diversity and species abundance distribution. To test the effect of topography; for each station, legumes and *Cistus* seedlings were counted each month on five plots of 1m2, uniformly distributed over a 100 m transect. To highlight the dominant species that could play a large role in the early stages after fire, particularly against water erosion; floristic surveys were conducted during the spring of the first year.

Legume seedlings demography showed a unimodal pattern for each year of observation, with a maximum in December for the first year and another in November of the second year. The *Cistaceae* appear the same demographic model for the first year of observation with a lag of one month. During the second year, no substantial recovery of Cistus species was observed. The floristic richness and diversity of the two stations are statistically equivalent. Species abundances distributions at both stations follow the same general pattern, with the dominance of a few species and sharing the rest of the territory for the others species (Motomura model). So, topography does not generate a large difference in the floristic composition of the pine forest studied. However, qualitatively the species that dominate in flat or slope are different.

This result is explained by the ability of species to colonize the two area situations. *Ononis natrix*, *Ononis reclinata* and *Lotus corniculatus* dominate on flat, *Cistus monspeliensis* and *Anagalis arvensis* on slope. Therefore, the proposition of species for ecosystem restoration programs should consider their ability to maintain themselves in various topographic situations.

Poster Session B. *Fire Sciences*

Are community flammability traits driven by climate? Evidences from Alpine mountain forests

Thibaut FRÉJAVILLE, Thomas CURT, Christopher CARCAILLET

Climate is the main driver of wildfires. Indeed climate controls both the biomass available for burning (fuel build-up) and the conditions conducive to fire (fire weather). However, how climate controls community flammability syndrome is not yet understood. We define it as the result - at given vegetation moisture contents - of a set of flammability traits carried by live and dead plant biomass (i.e., fire conducive vegetation properties). This study aims to determine the relationships between climate and community flammability syndrome across the mountain forest ecosystems types (FET) of the western Alps.

Four FET were defined from a co-inertia analysis between composition, biophysical and local climatic properties of 2609 mountain forest plots. The main flammability traits describing fine understory fuels were measured in litter, grass and shrub layers among FET. We quantified their flammability syndrome by simulating the potential intensity of surface fires, using the fire behaviour simulator "Flammap" and three standard fuel moisture and wind speed scenarios. Finally, Boosted Regression Trees (BRT) were performed to test if and how community flammability syndrome is driven by local climate.

In the western Alps, the more flammable forests exhibit low tree cover and high load of litter, grass and small shrubs, namely the open subalpine *Larix decidua, Pinus uncinata* and P*. cembra* forests in the inner continental area. At lower elevation, *P. sylvestris* and *P. nigra* forests in the Mediterranean range are less susceptible to intense surface fires for similar vegetation moistures due to lower litter or grass load. Poor-understory dense forests dominated by *Picea abies, Abies alba* and *Fagus sylvatica* in the moister areas of the northern part seem the less flammable. BRT revealed that climate gradients across Alpine woodlands explain the main part of variance of simulated surface fire intensity. Indeed, load and depth of both litter and fine understory fuels increase along an autumn drought gradient and tend to peak at intermediate rainfall levels during the driest months.

These results emphasize the climate control on fuel properties through high litter deposition and low decomposition rates in the drier autumn areas against limitation of surface fuel productivity for too relatively moist or dry annual climate. Redundancy analyses show that climate drives also fuel properties through the interaction with community structure and composition. Our findings point out that ongoing climate changes and may likely alter Alpine community flammability by promoting both fuel build-up and changes in community composition.

Poster Session B. *Fire Sciences*

Effects of fire regime changes on the extent and seral stage structure of Mediterranean pines: a landscape dynamics modelling approach

Asunción GIL-TENA, Núria AQUILUÉ, Miquel DE CÁCERES, Lluís BROTONS

Forests of the Mediterranean Basin are hotspots of predicted global change impacts with likely broad-scale effects on forest species composition and ultimately ecosystem functioning. Changes in fire regimes have been identified as a major global change driver in these regions. In fact, the occurrence of large fires and increased fire recurrence in the last three decades has commonly caused a decrease of *Pinus* spp. dominance in many areas, coupled with an increase of *Quercus* spp. forests and shrublands. Even though these current trends are known, we lack a comprehensive and quantitative understanding on how further changes in fire regimes may affect the future relative dominance of dominant tree species in Mediterranean forests. In this work, we aim at projecting how Mediterranean *Pinus* spp. forests may be affected by more severe fire regimes, due to drier conditions, while considering the impacts of firefighting capacity to offset climate change effects on fire regime.

We used the MEDFIRE landscape dynamics model developed for the Mediterranean context and parameterized for Catalonia (NE Spain). MEDFIRE allows a yearly prediction of forest landscape composition (at 100 m) as a function of fire regime and includes ecological processes driving post-fire regeneration and natural succession responses. We considered two climatic treatments, differing in the percentage of climatically adverse years, and two fire suppression strategies: no firefighting and active firefighting. Model simulations were run for 50 years. The temporal evolution of *Pinus* spp. forest cover was assessed at the regional and the county level according to a representative latitudinal gradient in climate and landscape composition. Forest seral stages were based on the time required for canopy closure after fire disturbance.

Our results showed strong changes in the future distribution of pines and oaks in the study area under different future fire regimes. While the general signal of past land abandonment translated in an overall increase in forest cover, a severe fire regime accelerated a shift towards landscapes progressively dominated by oaks and shrubby vegetation. Our results indicate that an active fire suppression strategy may offset the effects of climate change on fire impact but also reverse trends in tree forest dominance changes favouring the persistence of pines at the landscape scale.

Poster Session B. *Fire Sciences*

Thinning treatments in overstocking Aleppo pine forest to reduce vulnerability and improve resilience after fire

Mónica JIMÉNEZ-MANRIQUE, M. Jaime BAEZA, Karim SAAD, V. Ramón VALLEJO

Wildfires occurring during 1994 in the east of Spain affected large area of mature Pinus *halepensis* forests. In many cases the pine regeneration was altered and post-fire pine density was extremely high producing overstocking. In fact, the regeneration could reach around 160,000 pines/ha. Because of high intra-specific competition, the overstocking produced low tree growth and seed production, generating fuel accumulation and increasing fire risk. This problem is relatively common in many Mediterranean regions, so these Aleppo pine overstocked stands should be managed to decrease the fire risk and forest vulnerability.

The purposes of this study are to (i) Testing silvicultural treatment in the burned areas by reducing the mass of fuel and risk of forest fire, (ii) Change the species composition of the forest ecosystem to a more diversified and less flammable, (iii) Monitoring post-fire resilience of the vegetation in the forest fire.

We changed the initial conditions by mechanical thinning from densities about 150,000 pines/ha to 1200 pines/ha and 600 pines/ha in three experimental sites in Valencia region (east of Spain) and analyzed descriptive Aleppo variables during 3 years, like growth rates (basal diameter and high), live and death fuel and vegetation cover.

Due to lower intra-specific competition of Aleppo pines, basal diameter growth rates increased after thinning treatment, especially in the second year (1.970 cm ± 0.12 cm). In contrast control zones presented low basal diameter growth (0.411 cm ± 0.047 cm). Related to high growth rates, control (27.94 cm ± 2.51 cm) and treated (28.08 cm ± 2.13 cm) sites differences were not significant. Regarding biomass, the quantity of live and dead fuel was reduced by silvicultural treatments. Moreover horizontal and vertical fuel continuity was lost.

According to our preliminary results, thinning treatments improved *Pinus halepensis* forests structure and decrease vulnerability to new fires.

Secondary metabolites of three Mediterranean pine species before and after prescribed burning: assessment of preliminary ecological consequences

Elena ORMEÑO LAFUENTE, Teresa VALOR IVARS, Pere CASALS TORTRAS

Prescribed burnings are low intensity fires used mainly for fuel management purposes but fire can also be used as a thinning tool to enhance forest productivity. There is an extensive knowledge about the burning severity thresholds determining short-term post-burning survival of pine species. By contrast, there is a poor understanding on the mechanisms involved in the delayed tree-mortality and the consequences of thermal stress on the physiology of the remaining standing trees. Specifically less attention has been paid to the effect of fire on secondary metabolites such as terpenes produced by pine species, despite the protection they confer against biotic and abiotic stressors.

Hence, we addressed the impact of prescribed burning on terpenes produced in needles of three Mediterranean pines: *Pinus halepensis*, *P. nigra ssp. salzmannii and P. sylvestris*. Four stands, 2 pure-stands of *P. halepensis* and 2 mixed-stands of *P. sylvestris* and *P. nigra*, were subjected to prescribed burning in spring 2013. Terpenes were analysed 24h-before and 24h-after fire, in 10 trees per pine species. For each tree, fire intensity was measured at the base of the trunk and at 1.30 m height using two thermocouples and fire severity was estimated as the percentage of crown scorch.

Preliminary results suggest a reduction in terpene concentration immediately after the prescribed burning respect to pre-burning concentration. Further analysis will be conducted to understand how fire intensity and severity affects terpene concentration in the pine species studied as well as its effects as time-since-burning expands.

Assessing the effects of prescribed burning on pine secondary metabolism may provide valuable information regarding their vulnerability to insect plagues, pathogens and severe abiotic stress conditions throughout time. This data may be used in management decision-making before and after prescribed burnings.

Poster Session B. *Fire Sciences*

Seed removal by rodents in burned and logged pine forests

Roger PUIG-GIRONÈS, Pere PONS

Wildfires are major ecological disturbances in Mediterranean ecosystems. Post-fire recovery of understory cover, consequence of resprouting and germination of grasses, shrubs and trees, is relatively fast in pine forests. However, plant-animal interactions can hamper vegetation regrowth due to seed predation and can assist it thanks to seed dispersal. Rodents are known to act as seed removers (both seed predators and dispersers), especially in the short-term after fire.

Here, we studied the role of rodents as seed removers in three burned pine forests in Catalonia. Our aims were to evaluate rodent populations and seed removal by rodents for the first two years after fire in unburned (UN), burned-unmanaged (BU) and burned-logged forests (BL). Study sites were located in and around severely burned pine forests, one in lowland (dominated by *Pinus halepensis*) and two in the Pyrenees (with *P. sylvestris* and *P. uncinata*). The number of sites was 59 in unburned and 171 in burned habitat (74% of these sites logged at the end of the study). At each site rodents were captured and marked and acorns were offered in trays protected from the removal by other vertebrates.

The wood mouse (*Apodemus sylvaticus*) was captured at the three areas in both burned and unburned sites (256 captures) whereas the Algerian mouse (*Mus spretus*) was only captured at the lowland sites (22 captures). Acorn removal showed a seasonal pattern in UN sites, with lowest rates in winter, especially in mountain areas. In burned sites acorn removal was higher in the second than in the first year after fire. Although BU sites showed, in general, higher removal than BL sites, in areas where wood debris had been piled rodents occurred since the first weeks after fire and seed removal increased.

Our results support the idea that the management of burned pine forests affects seed predation and dispersal.

Comparing *Pinus halepensis* and *Pinus pinea* post fire mortality

Eric RIGOLOT, Jean-Luc DUPUY, Joël MARECHAL, François PIMONT

Mediterranean pines have developed different strategies to cope with fire. In that respect, *Pinus halepensis* and *Pinus pinea* have been classified as fire embracer and fire tolerater species respectively by Keeley. Preventive silviculture needs to take into account the most recent knowledge on fire ecology of trees to implement successful guidelines. Self protection objective, the global post-wildfire survival of trees at the stand level, is certainly the most demanding option of preventive silviculture. This study aims at answer the following question**:** Does differences in fire ecology of pines, justify developing specific preventive silviculture guidelines?

An experimental fire has been carried out in early July 2011 in a mixed *P. halepensis* - *P. pinea* plantation of 16 years old. Five years before burning trees were pruned at 2 m high and stand density was reduced to 1500 t/ha with even proportion of each species. Mean diameter at breath height for *Pinus halepensis* and *P. pinea* were 13.9 cm and 13.0 cm respectively. Undergrowth fuel was replaced by straw uniformly spread with a 10 t/ha load. Fire weather conditions were severe (IFM >100) with dry and hot (27°C) conditions and gusty wind (55 km/h). Fire was characterized by measuring fire rate of spread, and flame geometry. Fire temperatures were recorded using both thermocouples and thermometer strips distributed along vertical gradients in pine crowns. Immediate fire effects on pines were measured using both crown and bole damage indicators. Post fire pine mortality was monitored until stabilization in early 2013.

Fire rate of spread was 0,18 m/s, and mean flame heights were 1-1,2 m and 1,5-2 m for flank fire and head fire respectively. Immediately after fire, crown volume scorched was higher on *P. halepensis* (81%) compared to *P. pinea* (56%). Eighteen months after fire, *P. halepensis* mortality rate was 78% whereas no mortality was recorded for *P. pinea*. Pine mortality was compared to prediction of published post fire survival models using tree size and fire damages as explanatory variables. Morphological traits explaining species differences in fire resistance are discussed.

Results are in agreement with previous studies by Rigolot showing that *P. halepensis* is more fire sensitive than *P. pinea*.

High post fire survival of *P. pinea* under severe fire conditions suggests this species is a good candidate for preventive silviculture including implementation of self-protection objective in relatively young stands. Preventive silviculture has to adapt to the fire ecology of pines.

Keywords: *Pinus halepensis*, *Pinus pinea*, experimental fire, post-fire mortality, preventive silviculture

Poster Session B. *Fire Sciences*

Silvicultural treatments in the natural regeneration of pine forests to reduce fire risk and its handling for mature, stable and diverse forests

Karim SAAD, M. Jaime BAEZA, V. Ramón VALLEJO

At the last decades, in the Mediterranean basin, the climate change causes an increase in all that relates to the number and the severity of forest fires as in its repetition, by decreasing time between two fires in the same area. In general, after fire occurs an increase in the regenerated forest areas of conifer like *Pinus halepensis* Mill., which is dominant in the Mediterranean basin, mainly in lowlands and dry climate.

In some areas, regeneration after fire was practically is absent, due to lack of seed (lower availability and consumption by fire...). In other areas, we came to measure up to 160,000 trees/ha in the area of Valencia. The accumulated amount of death fine fuel may occur up to 17 Mg/ha in the mixed forest of pine and other species. With little or without silvicultural treatment, these areas presuppose a high risk of fire and need control of the fuel considering the high regeneration.

This study examines the effects of several silvicultural treatments on *Pinus halepensis* Mill. Therefore, we used five different silvicultural treatments by different intensities of thinning and planting of *Quercus faginea*. These treatments were examined in three areas on parcels of 0.5 ha each one characterized by a high regeneration of *Pinus halepensis* to 15 years after fire event (Fire 1994). The treatments were applied in winter to have a large collection of applied management.

We employed two thinning intensities (1,200 and 600 trees/ha) and we combined between mechanical and manual treatment to increase yields and at the same time we have selected noble species (*Juniperus*, *Quercus ilex* ...). We have introduced some *Quercus faginea* dealing with the pine forest to increase the stability of the young masses of pine density, biomass, height, diameter and basal diameter (5-10 cm) at 1.30 m were recorded, and dendrochronological analysis were conducted to address the situation of pine after treatment.

Key words: Aleppo pine*, b*iomass, density, thinning, forestry treatment.

The role of herbivores in seedling performance in Pyrenean pine stands: influence of micro- and macro-habitat factors on browsing pressure

Aitor AMEZTEGUI, Lluís COLL

Performance of seedlings during the first years is one of the key processes in the dynamics of forest communities. Successful recruitment depends on many factors, but the damage caused by herbivores (mainly by browsing) is among the most determinant ones, often leading to massive mortalities that can reduce or even completely prevent the regeneration of some species.

To assess the impact of current grazing conditions in forest regeneration in mountain Mediterranean pine stands, we performed an experimental plantation in the NE Pyrenees, in an area with a relatively high presence of domestic livestock (cattle and horses) and wild ungulates (mainly roe deer and chamois). We analyzed for 4 years the role of seedling size, macrohabitat (elevation and type of forest cover) and microhabitat (herbaceous cover, distance to shrub, light availability) on the browsing-induced mortality of more than 500 seedlings of *Pinus sylvestris* and *Pinus uncinata* (the dominant tree species in the study area) and of an equivalent number of plants of *Betula pendula* and *Abies alba* (the most common accompanying species).

We found that both macrohabitat and microhabitat exerted a significant effect on browsing patterns, with some remarkable interactions among factors acting at the two spatial scales. Despite their lower stocking density, wild ungulates caused a similar mortality as livestock. Mortality for the three conifer species (*Pinus uncinata*, *P. sylvestris, Abies alba*), was much lower (< 20%) than the one observed for birch (> 60%) and depended on microhabitat, mainly on the distance to protective elements such as shrubs; and also on macrohabitat, with an interaction between the elevational belt (site) and the type of forest cover (gaps *vs* understory). During summer, browsing on *A. alba* and *P. uncinata* was higher at plots located in the understory of the subalpine belt (response index = 0.32, $P < 0.05$), whereas, during winter, it was higher at plots located in gaps ($P < 0.05$).

The study suggests that both macrohabitat and microhabitat can exert an effect on the patterns of plant damage by herbivores, providing useful information to adapt forest management in areas particularly exposed to them.

Poster Session B. *Biotic interactions*

Allelopathic effect of aqueous extracts of *Pinus brutia* needles on the germination and seedling growth of 25 Mediterranean plants

Sücrü Serter ÇATAV, Cagatay TAVSANOGLU, Köksal KÜÇÜKAKYÜZ, Kenan AKBAŞ

Allelopathy is the chemical interaction between plants, including inhibitory effects of secondary metabolites on plant germination and growth, and on plant defense against herbivores. *Pinus brutia* Ten. (Turkish Red Pine) is the predominant pine species in the forests of Mediterranean Turkey, which are frequently subjected to fires. There are relatively less plant species in old-aged *P. brutia* stands, but more are observed in younger or more open stands. Although the patterns of species diversity in *P. brutia* forests through post-fire age gradients give some insight about the dynamics of the relationship between *P. brutia* and co-occuring plant species, the possible allelopathic effect of *P. brutia* on the other plants has not received any attention to date.

The aim of our study was to determine the effects of water extracts of *P.brutia* needles on the germination and seedling growth of 25 Mediterranean plants co-occurring with *P. brutia* in many young stands in the region. To prepare a water extract gradient, 2.5, 5 and 10 g of *P. brutia* needles were placed in glass flasks containing 100 ml of ddH_2O. These flasks then were incubated at 25°C in a shaking incubator for 24 h. The supernatant of these solutions were used in germination and seedling growth tests. Additional solution of distilled water was also used as control. For the germination experiment, seeds were placed in 9 cm Petri dishes on two layers of filter paper moistened with 10 ml of corresponding solution, and with distilled water for the control. After 14 days of growth, the final germination percentage, seedling length and seedling mass of each species were determined. Data on germination and seedling growth were analyzed with the analysis of deviance (GLM) and the analysis of variance (ANOVA), respectively.

Seed germination and seedling growth of most of the study species were negatively affected from the aqueous extracts of *P. brutia* needles, and this effect strengthened with increasing concentration. However, seedling growth in three species was enhanced by low extract concentrations. In conclusion, our results suggest that *P. brutia* has allelopathic effects on the germination and seedling growth of many plants growing in the region.

This finding contributes to our understanding on the drivers of vegetation dynamics and the factors shaping plant community assembly in Mediterranean Basin pine forests.

Poster Session B. *Biotic interactions*

Constitutive vs. induced defences in three pine species against an expanding pest, the pine processionary moth

José A. HÓDAR, Lucía TORRES-MUROS, Regino ZAMORA, Karim SENHADJI

Trees react against defoliation by producing new tissues having morphological and nutritive changes, in order to prevent future attacks. These changes may result in lower food quality for herbivores, reducing their populations.

In this work, we analyse the capacity of three pine species, namely cluster (*Pinus pinaster*), black (*P. nigra*) and Scots (*P. sylvestris*) pines, naturally set along an altitudinal gradient (1350-2000 m.a.s.l. in SE Spain), to produce an induced defence against defoliation by an expanding pest, the pine processionary moth *Thaumetopoea pityocampa*. Pines were subjected to experimental defoliation, and the tree response was analysed by means of chemical analysis and bioassays with first-instar larvae of *T. pityocampa*.

None of the pine species showed a notable change in chemistry after experimental defoliation, suggesting that chemical defences in pines represent constitutive rather than inducible defences. However, constitutive defences no not deter T. pityocampa, and larval survival did not vary depending of the previous damage suffered by trees. These results indicate that the three pine species analysed have a low capacity of response after the pest attack, and thus a limited induced response against the herbivory caused by an specialist insect like *T. pityocampa*.

Susceptibility evaluation of *Pinus pinaster* families to Pinewood nematode (*Bursaphelenchus xylophilus*)

María MENÉNDEZ GUTIÉRREZ, Adela ABELLEIRA, Pedro MANSILLA, Pilar MOSQUERA, Andrea ABELLEIRA-SANMARTÍN, Margarita ALONSO, Gabriel TOVAL, Raquel DÍAZ

Pine Wilt Disease, caused by pinewood nematode *Bursaphelenchus xylophilus*, appeared in 2010 in Galicia (NW Spain), where the pine forest cover about 400.000 hectares dominated by maritime pine (*Pinus pinaster*), a highly susceptible species to pinewood nematode. This disease has become an important threat due to the clear risk of spread all over the territory causing serious economic and environmental damages.

One of the alternatives to face this disease is to find resistant trees through genetic breeding. There is evidence of *P. pinaster* surviving trees in widely damage forest in Portugal.

Two-year-old seedlings from fifty open-pollinated *P. pinaster* families were inoculated with 600 pathogenic nematodes, *B. xylophilus*, in an inoculation assay to investigate the genetic variation in the susceptibility of *P. pinaster* families from the Galician Tree Breeding Program to Pine Wilt Disease. The external wilting symptoms of the disease were assessed for each seedling two days a week and the nematode population were determined at the end of the study.

The first wilting symptoms appeared 21 days after inoculation (DAI) and the first seedling died 48 DAI. The average duration of the symptoms until death was 49 days. Pine families were clustered into 9 groups according to their tolerance to pinewood nematode, being the differences between groups significant. One hundred and thirty five DAI the survival percentage oscillated between 25 and 92%, depending on the group. No correlation was found between the number of *B. xylophilus* per gram of dried weight and the beginning of the symptoms or the duration of them.

Even though these are preliminary results they suggest that genetic breeding could be a way to fight against this disease.

Poster Session B. *Biotic interactions*

Generalist frugivore birds govern the seed dispersal of a parasitic plant with strong recruitment constraints that inhabits Mediterranean pinelands

Ana MELLADO, Regino ZAMORA

The mistletoe *Viscum album* subsp. *austriacum* is a common parasitic epiphyte of European pinelands and an interesting study case to address the role of generalist consumers in the study of plant-animal interactions. Numerous mistletoe species inhabit forest canopies around the world, offering abundant fleshy-fruits as food resources for frugivore animals. They show among the most restricted range of safe sites for recruitment of any plant; for this reason, frugivores specializing in mistletoe have been considered almost indispensable for the seed dispersal of these parasitic plants. However, the absence of such specialists in the Northern Hemisphere, on many ocean islands, and in several regions of the Southern Hemisphere inhabited by many mistletoe species, raises a question concerning how unspecialized vectors successfully disperse mistletoe seeds in tightly defined safe sites.

In a Mediterranean pineland of Southeastern Spain we recorded a broad range of 11 bird species that disperse mistletoe seeds. For these species, we studied the mistletoe-visitation rate and feeding behavior to estimate the quantity component of dispersal effectiveness, and the post-foraging microhabitat use, seed handling, and recruitment probabilities of different microhabitats as a measure of the quality component of effectiveness. Both endozoochory and ectozoochory are valid dispersal mechanisms, as seeds do not need to be ingested to germinate, increasing seed-dispersal versatility.

Thrushes were the most effective dispersers, although rather inefficient; whereas small birds (both, frugivores and non-frugivores) offered low-quantity but high-quality services for depositing seeds directly upon safe sites.

As birds behave similarly on parasitized and non-parasitized hosts, and vectors have broad home ranges, reinfection within patches and the colonization of new patches would be ensured by an ample assemblage of generalist birds. In doing so, a parasitic plant requiring precision in seed dispersal can rely on unspecialized dispersers, which permits the existence of *Viscum* a. *austriacum* in the canopy of pine forests.

Poster Session B. *Biotic interactions*

Severe seed yield loss in Mediterranean stone pine cones

Sven MUTKE, Javier MARTÍNEZ, Javier GORDO, Juan Luis NICOLAS, Nieves HERRERO SIERRA, Amelia PASTOR, Rafael CALAMA

The main marketed product obtained from stone pine *Pinus pinea* L. forests or plantations are the pine cones and their seeds, the Mediterranean pine nuts, a gourmet food. In the last decades, the planted area of stone pine has widely increased throughout the Mediterranean (+25%), as well as a starting cultivation in Chile, Argentina, Australia or New Zealand. But in the last three years, a severe loss of seed yield has been reported by processing industries for stone pine cones collected in the main producing countries, namely Portugal, Spain, Italy, and Turkey. Opening apparently sane cones, up to half of the seeds are found to be empty. Additionally, cone pickers report an unusual high percentage of dried first- or second-year conelets on tree (stone pine cone ripen only in their third winter), reducing drastically the amount of the final cone crop. Both phenomena has been called the Dry Cone Syndrome. As consequence of shortage, the wholsale price of shelled Mediterranean pine nuts has risen from around 25 to 45 €/kg in the last two years.

The main suspect is the Western conifer seed bug, *Leptoglossus occidentalis*, an invasive alien from North America that feed on conifer seeds and can provoke seed and cone abortion. WCSB's first citations in different European countries coincide in time with local appearance of the Dry Cone Syndrome.

Is certain the generalised seed yield loss in Mediterranean pine cones and the elevated abortion rate of unripen conelets reported by the industry? Are there any evidences about the causes of this Dry Cone Syndrome? Might WCSB be implied?

Time series of cone processing data from several processors in Spain were compared with published data or verbal information gathered from colleagues of the FAO/CIHEAM Research Network on Nuts and the StarTree project. The results were contrasted with the damaged caused by cone pests, especially by *Leptoglossus occidentalis*.

Since 2011, the seed output of stone pine cones, that had been around 17 (16-20) % of cone weight before, has dropped in all studied series to 5-12% within shell, from formerly 3.5-4% to 2-2.5% or less shelled pine nuts. The generalised appearance of dry conelets in pinewoods and grafted plantations has been confirmed *in situ*. The phenomenon is plainly compatible with the damages described forthe introduced recently seed bug.

The Dry Cone Syndrome is a serious threat for commercial pine nut crops. The causality of *Leptoglossus* as main biotic agent and possible implication of increasing draughts or phenological shifts due to climatic change will be elucidated by ongoing work of various research groups. Possible implication of *Diplodia pinea* blight propagated by the bug as vector can not be ruled out.

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Poster Session B. *Biotic interactions*

Oviposition behaviour and host selection of the pine processionary moth

Lucía TORRES MUROS, Jose Antonio HÓDAR, Regino ZAMORA, Karim SENHADJI

Host selection for oviposition is a main step in the life cycle of the insect pests, Lepidoptera among them. The hatching larvae are relatively immobile, and for this reason the choice of host by females is essential for the survival of the next generation. In this work we analyse the pattern of egg deposition by the pine processionary moth (*Thaumetopoeapityocampa*), an important forest pest with great ecological and economic impact for Mediterranean pine woodlands. Visual stimuli can determine the decision of the moth when selecting the tree for oviposition. We study these processes with three pine species, namely cluster (*Pinus pinaster*), black (*P. nigra*) and Scots (*P. sylvestris*) pines, naturally set in SE Spain along an altitudinal gradient (1350-2000 m.a.s.l.). We fixed three sites, with one pine species each. We searched for infested pines, and take morphological measurements (number of egg batches, height, diameter, distance to neighbours), both at the infested one as well as the three proximate pine neighbours. A total of 60 infested pines and 180 neighbours (20 and 60 per site/species) were measured. At the lower site (1300 m, only *P. pinaster*) we studied more in detail the egg batch distribution within the pine, recording for every egg batch found the position within the pine canopy, the height and the aspect. A total of 441 trees were measured.

The results showed that host selection process is linked to pine morphology and isolation degree: the higher and the more isolated is the pine, the higher is the probability of being oviposited by pine processionary moth ($P<0.001$). However, at the lower site, this relationship vanishes, and in fact there is a negative (but unsignificant) relationship between pine height and number of egg batches received ($r_s=-0.013$, $p=0.853$, $n=154$ pines). The position of the egg batches within the pine also shows a clear pattern: egg batches are preferentially fixed at the lower part of the canopy(more than 60% of egg batches), thus at low height (average 107±2 cm, n=361 egg batches) and predominantly to East aspect (more than 90% between 15 and 195º).

These results suggest than the visual stimuli play an important role determining the host selection process for this pest species.

Implementing dynamic conservation units in forest tree conservation: maritime pine as a case study

Isabel RODRIGUEZ-QUILON, Luis SANTOS DEL BLANCO, Santiago C. GONZALEZ-MARTINEZ, Juan MAJADA, Ricardo ALIA

Human-driven environmental change is a well recognized threat to Mediterranean forests, a biodiversity hotspot. In such scenario, conservation of keystone Mediterranean forest trees is an urgent task. Recommended conservation guidelines, termed dynamic conservation, stress the importance of maintaining genetic diversity for keeping evolutionary processes and adaptive potential of populations, thus ensuring long-term sustainability. However, its implementation is often hindered because the relevant evolutionary processes are yet to be well understood. A combination of quantitative genetic, neutral molecular and environmental information can provide an accurate picture of past and present evolutionary history of a species, shedding light on how to implement conservation plans.

We present a comprehensive study of neutral and adaptive genetic variation in maritime pine (*Pinus pinaster* Aiton), an outcrossing Mediterranean forest tree with typically fragmented distribution, and its application to development of conservation plans in the species. Quantitative genetic data was obtained from four maritime pine clonal common gardens (34 provenances, total of 16,544 trees), located in contrasting environments. We estimated standing genetic variation and population differentiation, and disentangled environmental effects from genetic control of two fitness traits (survival and total height). We additionally used two types of molecular markers (12 nuSSRs and 266 SNPs) to estimate neutral genetic variation and differentiation.

At the species level, broad sense heritability was negligible for survival, and ranged from 0.15 ±0.01 to 0.28 ±0.07 for total height, suggesting higher evolvability for this trait. Quantitative genetic differentiation (QST) was higher (range 0.31-0.45 for total height) than neutral molecular differentiation (FST) in the four locations, for both nuSSRs (0.10, CI: 0.09-0.12) and SNPs (0.13, CI: 0.12-0.14), suggesting local adaptation and divergent selection within the species. Neutral genetic differentiation revealed six gene pools with distinct evolutionary histories. We suggest considering those pools derived from neutral variation as the minimum number of conservation units. Then, within those units, we tested whether further adaptive genetic differentiation was present, attending to survival and height density functions. This allowed us to expand the conservation unit network to 13 candidate (and differentiated) gene pools, within which population viability was assessed through the computation of standing genetic variance, phenotypic plasticity, genetic diversity and effective population size.

In this case study, we provide general criteria to account for genetic variability in tree conservation, using both molecular marker and quantitative genetics information. These need nonetheless to be further complemented with field-based demographic data in order to provide robust and achievable dynamic conservation goals.

Effect of regeneration cutting on biodiversity in Mountain Pine (Pinus uncinata) forests in the Pyrenees, using birds as bioindicators

Jordi CAMPRODON, Jordi FAUS, Míriam PIQUÉ

The effect of regeneration system by Shelterwood system on birds in Mountain Pine (*Pinus uncinata*) forests of Catalan Pyrenees was analyzed. Birds were used as bio-indicators, in association with forest and ecological variables. Birds are sensitive to changes in forest structure and extreme climatic conditions in subalpine forests (1,900-2,150 m in the study area). The bird census was performed by quantitative point counts. Habitat sampling was performed by inventories of dasometric variables, vegetation cover and availability of dead wood and tree cavities.

Five scenarios was analyzed: 1) Old Stands, without intervention in at least the last 50 years; 2) High Forest with thinning; 3) Seed Cutting; 4) Final Felling with reserve of some seed trees; 5) regeneration in Small Groups (15 to 20 meters radius).

High Forest was the forest structure with more richness and abundance of forest specialist species of birds, followed by Seed Cutting stands. This latter are also the most diverse in species of the 5 structures analyzed, to join him some presence of species of open areas. The Final Felling with seed trees retains some numbers of forest birds, but species of open areas became dominant in the community. The Old Stands get very limited results in richness and abundance of forest specialists, despite its developed structure. The Small Groups had similar values in richness and abundance of birds than High Forest.

The availability of large trees with cavities and snags and understory cover (deciduous tree species and bushes) was the key factor explaining the abundance of forest birds in regeneration cutting, especially those with largest home range (eg. woodpeckers). However, the decrease in density of crowns decreases habitat suitability for passerine species with small home ranges (eg. tits). Weather conditions that prevail at higher altitudes may explain the low diversity of birds in Mature Stands.

The management of reclaimed pine as even-aged stands by shelterwood system supports bird conservation. To get the key structural variables and the alternation in the space of Old Stands, High Forests and stands in regeneration must be respected. Regeneration by Groups-shelterwood cutting occupying small continuous surfaces is recommended. In the study area is important to locate new Old Stands at lower altitudes, where abiotic conditions are not extreme.

Poster Session B. *Biodiversity and conservation*

Seed germination ecophysiology in native *Pinus heldreichii* H. Christ populations of Greece

Evangelia DASKALAKOU, Costas THANOS

Pinus heldreichii H. Christ is a Tertiary relict, endemic in the western Balkan Peninsula and southern Italy and belongs to the high-elevation pines of the Mediterranean Basin. In Greece, *P. heldreichii* is naturally distributed in the northern part of the country at high elevations (1300-2600 m), often replacing *P. nigra* at the highest zones and forming woodlands on serpentine, limestone or granite soils.

Mature and closed cones were collected in autumn (Oct) for three consecutive years (2011-2013) from Pindos and Olympus Mts (1400 and 2300 m a.s.l., respectively). Cones were dried in a sunny place at room conditions in the lab and opened, without additional treatments, after 1-2 weeks. Cone and seed morphological characteristics were recorded along with the young seedling cotyledon number. Seeds were tested for germination at constant (10-30 °C) temperatures under light (12:12 h L/D) and continuous darkness respectively, in addition to alternative (20/10 °C) conditions.

Cone mass varied from 11.80 ±0.56 to 15.89 ±0.72 g and the number of seeds per cone from 60 to 80 ones, depending on collection year and provenance. Seed mass was estimated from 22.62 ±0.85 to 31.13 ±1.34 mg respectively; the overall mean of cotyledon number was 7.33 ±0.01 (n=202) and 7.20 ±0.01 (n=353) for Pindos and Olympus seedlings. Seed germination was enhanced under light conditions (15-25 °C), favourable temperature was 20 °C (12:12 h L/D); however a medium final germination (≤50%) was recorded for both seed lots. Null germination was mentioned at low or high temperatures tested (10 and 30 °C). Although cold stratification was not an absolute requirement for seed germination, different chilling period treatments (15, 30 and 45 days at 5 °C) promoted both final percentage and rate of germination.

Under natural conditions, *P. heldreichii* seed germination and seedling emergence is probably timed late in spring, thus avoiding the adverse winter temperatures.

Why are Aleppo pine and umbrella pine so difficult to distinguish on the basis of their wood anatomy in calcareous Provence area (Southern France)?

Cécile FOUQUEMBERG, Brigitte TALON

Aleppo pine (*Pinus halepensis* Mill.) and umbrella pine (*Pinus pinea* L.) are two abundant trees within the Mediterranean region. These two species may coexist in their distribution areas when soils are deep and sandy. Nevertheless these two types of pinewood can induce different ecosystem processes and services. Umbrella pine has been favorised by roman populations for seed production whereas fires largely contributed to the extension of Aleppo pine. Therefore it would be interesting to differentiate this two type of tree in holocene environmental reconstruction. The main studies of wood anatomy distinguish these two species on the basis of qualitative characteristics: the aspect of ray tracheids and positioning of axial resin canal. However, the acquisition of our own wood reference allowed us to highlight large interspecific variations in both species.

The aim of our study was to observed charcoal anatomy at microscopic scale (x 500) to characterize the wood anatomy of these two pines. We tested 10 quantitative and qualitative criteria on different samples from Southern France with different geographical origin and growth conditions.

The results demonstrate the difficulties to distinguish these two pines only on the basis of their anatomy. On the other hand, this study reconsiders determinations on the species-level of small pieces of wood or charcoal within calcareous Provence area of Southern France.

Poster Session B. *Biodiversity and conservation*

Variation in biomass production and relation to genetic diversity in three Pinus species

Enrique HERNÁNDEZ-TECLES, Eduardo NOTIVOL, Jorge DE LAS HERAS, Ricardo ALIA

Vast reforestation programmes in Spain during the early 20th century hardly considered seed origin. We evaluated the provenance effect on biomass production of the three main Pinus species used in plantations: *P. halepensis, P. pinaster* and *P. sylvestris*.

Dendrometric data was measured in provenance common garden experiments, covering the natural distribution range of these species in Spain, in order to estimate the individual tree biomass. Neutral genetic diversity through CpSSR (genotype) was also measured in a subset of populations in order to prove their possible correlation.

The three pine species showed significant intraspecific differences regarding provenance biomass production, without a clear geographic variation pattern. No significant correlation was detected between phenotype vs. genotype for any of the three pines. Allometric equations are required taking into account geographical distribution of natural populations in order to obtain accurate measurements of carbon stocks through forest inventories.

Poster Session B. *Biodiversity and conservation*

Impact of the processionary moth in projects plantations of Aleppo pine in El Hamel area (Boussaada-Algeria)

Nora KHELLAF, Gahdab CHAKALI, Ilham AOUARI y Amel GHERBI

In semi-arid area, the projects plantations of Aleppo pine (3 millions hectares) are conducted for more than thirty years. During their development trees in monoculture are highly sought after by the pine processionary moth, *Thaumetopoea pytiocampa*, defoliators took a large extension in the Mediterranean countries. This monovoltin pest evolves in two phases of the ecosystem; ovo-larval development occurs in aerial phase during the summer-winter period and pupal development in the soil from the spring season.

In stands surveyed between Djelfa and Boussaada areas at an altitude of 900 meters, defoliation are periodic and often spectacular phase dimming. Counts performed using a systematic, showed variability in the distribution in relation to age and geographical location of the stations visited. A number of winter nests is varied (0 at 10) per tree were recorded with an average of 3 nests/tree with signification between the enumerated population. Counting winter nests made according to their location and their exposure on the shaft indicated that the nests South exposure of the middle part of the crown of the tree more hosts the most significant number.

Despite various interventions conducted with bio-pesticides, a strategy of occupation is carried out according transect North/ South in relation to various environmental variables.

Complementarity from the viewpoint of two contrasted Iberian pine species

Jaime MADRIGAL-GONZÁLEZ, Paloma RUIZ-BENITO, Sophia RATCLIFFE, Joaquín CALATAYUD, Miguel Ángel ZAVALA GIRONES

Observational evidence supports a positive relationship between tree diversity and stand productivity in a number of forest-types in temperate latitudes, including Mediterranean pinelands. Hence biodiversity loss due to land use changes and management intensification may hinder on forest productivity. The mechanisms underlying positive diversity-productivity relationships in forests, however, are poorly understood even though they are crucial for a proper evaluation of the functional consequences of biodiversity losses. In particular, the relative roles of climate and population structure factors such as tree size in modulating tree diversity effects on productivity have been seldom explored.

Here, we study how all these factors affect the probability of complementarity effects on growth of two contrasted pine species, *Pinus halepensis* (Mediterranean pine) and *Pinus sylvestris* (Eurosiberian pine) in the Iberian Peninsula. We conducted a random selection of trees from a data base of more than 45,000 plots and 279,000 trees recorded in the Spanish Forest Inventory database. We followed a similarity criteria regarding tree size, stand structure and climatic conditions, but allowing different diversity values. For each pair of trees we noted whether the tree in a higher diverse plot is the one with higher growth rate (complementarity effects including facilitation). With this information we created a binomial variable composed of 1 and 0 where 1 is indicative of complementarity (positive diversity-growth relationship) and 0 is assigned to the other possibilities (i.e. negative or null relationships). We fitted generalized linear models (GLM) using maximum likelihood and a logit link function. Our results show that positive diversity effects are chiefly modulated by the proportion of the stand basal area occupied by other functional types than the target tree. Also complementarity effects in both pine species are more likely in xeric areas.

Besides diversity and water availability, our results suggest a significant role of size on the probability of complementarity for *Pinus halepensis*, i.e. particularly under more mesic conditions in the distribution range of this species, complementarity is less likely in large trees (dbh ≈ 50cm).

These results support the idea that increasing diversity could lead to higher productivity in both pine species although climatic/structural conditions, as well as tree size, modulate these diversity-productivity relationships. However, slight differences in diversity-productivity relationships along climatic/structural gradients can occur in contrasted pine species.

Grafted stone pine stand installation optimization

João FREIRE, Margarida TOMÉ, Miguel CONSTANTINO

The importance of stone pine has grown in Portugal in recent years with an increase in area of 54 % between 2005 and 2010. Therefore the area of young plantations is large. The main distribution area of this species occurs in the Southern of Tagus River, along the Atlantic coast. Grafting has been used for more than 20 years, in order to anticipate cone production by several years. There are records of grafted umbrella pines producing more than 200 cones at 16 years of age. This can cause problems in dry years in which grafted stone pines can yield small, lightweight, low quality pinion cones. To overcome this situation forest owners are deciding for the installation of irrigation with fertilization in grafted stands. There are also records that the irrigation with fertilization in grafted stone pine stands is responsible for the increase of female flower production and the decrease of first year cone death. In many cases there are cattle grazing in the plantation area which requires the use of metal protectors to protect the young plants from the cattle.

In this work we compare the net present value of grafted stone pine stands considering alternative treatments at installation such as various spacings between rows and within the row, the use of individual plant protectors versus fencing the area and the use or not of the technique of irrigation with fertilization. Operational research techniques were used to select the combination of techniques that maximize the net present value.

Cone production of Stone pine grafted onto Aleppo pine

Neus ALETÀ, Antoni VILANOVA

The stone pine (*Pinus pinea L.*) is a common species of the Mediterranean countryside. It grows in sandy and poor soils and in coastal or continental climate. The high value of its edible nut has traditionally conferred an economic importance to this species in large rural areas mainly in Portugal and Spain. Currently, this species shows interest in some other areas of the Mediterranean basin but also outside its original area, like Chile.

However, cone production is still coming from very high and old trees which grow naturally as forest. To get small trees precocious in bearing would be an important aim to favour this production. Since some years ago, grafted trees of *Pinus pinea* onto Aleppo pine (*P. halepensis* Mill.) show they can produce cones much earlier than seedlings of *P. pinea*. On the base of this result a trial of 96 trees, grafted in nursery onto 3 years old Aleppo pine seedlings, was planted in 2008 in Torre Marimon (IRTA) to study the productive behaviour of this material and its performance (E1: planting distance 6m x 6m). In addition, another trial was planted in 2009 to compare the productive behaviour of *P. pinea* grafted onto *P. halepensis* vs *P. pinea* grafted onto *P. pinea* (E2; planting distance 6m x 3m). Both E1 and E2 trials were planted under a planned experimental design of randomized complete blocks in an area where *P. pinea* exists naturally.

The response of the pine trees was evaluated from planting until now by shoot growth, phenology of female and male flowering, cone cohort evolution and production (cone and seed yield). E1: after two years of planting, up to 2000 strobolii per ha were formed and the male flowers appeared two years later. In average, the production of the period 2011-2013 was 7 cones per tree (weight >400g/u). E2: the comparison between rootstocks shows that bearing age starts before in trees grafted onto Aleppo than onto Stone pine. On the fourth vegetative period the productive ratio was 3/2, result which supports again the same tendency: grafts onto Aleppo produce more cones than those onto Stone pine.

Even-aged vs. multi-aged management of Pinus nigra Arn. forests in north-eastern Iberian peninsula: silvicultural guidelines and economic implications

Mario BELTRÁN, Míriam PIQUÉ

Pinus nigra forests are dominant in the pre-Pyrenean area in north-eastern Iberian Peninsula. They are mainly private-owned and managed traditionally through selective cuttings, mostly based in diametric criteria, which has helped to bring about complex structures, with uneven-aged distributions and high vulnerability to forest fires.Forest managers carry out multi-aged management due to assumed economic benefit versus even-aged. Nevertheless, this type of management creates a wide multi-aged structural diversity that difficult the definition of adequate management schemes and it may lead to a progressive degradation of forests and an increase of forest fires risk.New silvicultural guidelines regarding wood production and fire prevention are needed in order to improve *P. nigra* management, especially multi-aged one. In this line, economic implications and strengths of even- and multi-aged management should be clarified, in order to improve the decision-making process in forest planning.

We established a set of scenarios combining site index, fire risk, stand structure and productive objectives. Then, silvicultural guidelines were developed for each scenario in an iterative elaboration process that started with a design of the different stand stages. Stand parameters were calculated at each stage with the support of site index and mortality models, allometric relationships and competition indexes. Inside the iterative process, an economic evaluation of each proposed guideline was done. Treatments and wooden products obtained were valuated and behaviour of the whole management cycle was assessed using a common framework. Strength tests were carried out varying wood price increase rate and wood production obtained. Finally, we established forest management guidelines for 10 management scenarios considering 3 site classes, 2 fire risk categories, even- and multi-aged structures and some different productive objectives.

P. nigra management would be improved by following the set of guidelines developed, which offer an accurate silviculture scheme to each scenario. Economic behaviour shown differences between site class and stand structure as well as different strength, although results were positive in most of the scenarios. Even-aged management was more profitable than multi-aged, but only within the best site class, since the inverse was observed in medium-quality site class. Furthermore, even-aged management had less resistance than multi-aged when rate or actual wood production changes. Nevertheless, pros and cons in ecologic and economic terms should be considered carefully, as well as other factors like stand vulnerability to wildfires.

Evolution of the Israeli forestry in the Mediterranean region from pure even-aged pine plantations to mixed uneven-aged forests

Omri BONNEH

The planted forests in Israel are at present multifunctional, designated primarily for the provision of ecological services. Afforestation in Israel, which begun 100 years ago by Keren Kayemeth LeIsrael (KKL), the Israeli Forest Service, was characterized in its early days by dense pine plantations dominated by Aleppo pine (*Pinus halepensis*). A massive dieback of 40-year-old planted Aleppo pine stands, attributed mainly to the Israeli pine bast scale (*Matsucoccus josephi*) outbreak in the early 1970's, led to the recommendation to use other pine and coniferous species, mainly *Pinus brutia*, instead of Aleppo pine.

In 1990, the KKL Forest Department revised its forest policy in order to create mixed, multi-layered, and well spaced forests with a higher tolerance and a better resilience to climate change impacts such as drought, fire, and insect infestation. Since then, modifications of this policy have been made from time to time to strengthen the forest sustainability by increasing its structural and age diversity.

Based on the new forest policy, a careful point site preparation that preserves existing native broadleaf trees is being applied in new plantations, and planting is carried out by using a mixture of coniferous and native broadleaf species. Broadleaf seedlings are either randomly scattered between the conifers or, alternatively, planted in separate patches of variable sizes to create a complex mosaic pattern. Post planting treatments, such as tree shelter installation, mulching, and irrigation are being applied in order to increase native broadleaf survival and enhance their growth. In the same way, post-disturbance selective forest renewal strategy, which preserves trees that survived the disturbance, coupled with planting or nurturing natural regeneration of coniferous and native broadleaf species, provides an opportunity to transform pure even-aged stands into mixed uneven-aged forests.

The new forest policy also recommended to increase the spacing between the pine trees, and consequently their resilience. Opening the forest cover through implementation of heavy release thinning, mainly in young stands, aimed also to encourage the establishment and growth of understory naturally regenerated and planted native broadleaves. In mature stands, the length of the thinning cycles increased from 7 to 10-15 years, and accordingly thinning intensities increased from 20% to 30% of the standing volume.

Adaptive management of *Pinus nigra Arn*. stands when fire risk is present

José Ramón GONZÁLEZ OLABARRIA, Jordi GARCIA GONZALO, Blas MOLA YUDEGO, Timo PUKKALA

The present paper aims at the establishment of management rules for *P. nigra* stands in Catalonia (Spain) addressing the risk of fire, based on a stochastic version of the simulation-optimization system RODAL The system was used to optimize the management of forest stands under several conditions by combining changes on economic and fire related factors, or allowing the choice of different silvicultural practices. A total of 90 scenarios for simulation were performed, used afterwards as the basis for formulating flexible forest management rules, adapted to multiple planning problems.

The planning problems accounted for varying fire risk, site qualities, thinning methods, and economic parameters such as discounting rate and possibility of subsidize post-fire planting operations. The formulated management rules corresponded to basal area thinning limits, percentage of the basal area to be removed during thinning, and tree diameter triggering regeneration cuttings.

Scots pine growth is favoured in mixed pine-beech stands in low fertility stands

Ester GONZÁLEZ DE ANDRÉS, Juan A. BLANCO, J. Bosco IMBERT, Federico J. CASTILLO

In recent decades, forest management focus has changed from mono-specific plantations towards close-to-nature mixed forests that could better supply ecological, economical and socio-cultural goods and services. Scots pine (*Pinus sylvestris L.*) and European beech (*Fagus sylvatica L.*) are two of the most important forest species in Europe and Spain, in particular in the Pyrenees. However, in Navarra province, where these species constitute the two most widespread forest trees species, mixed pine-beech forests occupy only a small area, as pine has been historically favoured against beech. Therefore, scarce information is available about mixed stands growth trends in the region.

To fill this information gap, the aim of this study is to estimate the growth trends of pine and beech when growing in pure and in mixed stands. Field and literature data were combined to calibrate the ecosystem model FORECAST to simulate production and biomass accumulation over 150 years on two contrasting sites in the Western Pyrenees: a highly productive Mediterranean forest (Aspurz, 625 m a.s.l.) and a low productive alpine site showing more continental conditions (Garde, 1335 m a.s.l.). Keeping total stand density constant at 5000 trees ha-1, five different species mixing density ratios have been considered: absence of one of the species, 1:1, 2:1 and 1:2 (pine:beech). Total stand biomass (beech plus pine) was maximum with a 2:1 pine:beech density ratio at both sites, supporting the hypothesis that mixed stands are more productive as site resources are more completely used.

For beech in both forests and for pine in Aspurz (the more fertile site), the results showed a non-linear response of tree accumulated biomass at year 150 to increasing species tree density. It appears that the effects of competition of one species on the other are not reciprocal. However, an increase of pine biomass growth was observed in mixed stands compared to pure stands in Garde (the less fertile site), although beech reduced its productivity when mixed with pine at both sites. This contrasting response of pine to the presence of beech appears to be controlled by competition and facilitation processes that are modulated by site quality conditions. On low fertility sites, pine benefits from the nutrient input from beech litter that reduces growth limitations in pine. In contrast, on fertile sites the highly competitive nature of beech results in reduced pine growth.

Our results also show the utility of ecosystem-level models to explore interspecies competition in long time scales.

Difficulties in natural regeneration of *Pinus pinea* L. and *Pinus pinaster* Ait. in the sandy areas of the Castilian Plateau

Francisco Javier GORDO, Rebeca MARTÍN, Luis Ignacio ROJO, Rafael CALAMA, Sven MUTKE, David CUBERO

Natural regeneration in the dominant pine forests of *Pinus pinea* L. and *Pinus pinaster* Ait. is a problem in the sandy areas of the Castilian Plateau (Valladolid, Spain). The fall of the ground water level due to over-exploitation by agriculture can difficult the regeneration further.

The present study analysed which are the factors that most affect natural regeneration in sampling stands with difficulties for regeneration by the shelterwood method.

Annual regeneration have been surveyed for over a decade by the Forest Administration (Department of Environment Valladolid), in collaboration with the INIA-CIFOR and the University of Valladolid. Since 2001, 2,268 plots have been set up over an area of 4,000 hectares that comprise 32 forests management units with 156 stands. Other available data sources are forest inventories and groundwater level series (1973-2013).

The low success and the difficulties found for the natural regeneration of *Pinus pinaster* in the studied region is alarming, both in pure stands and when mixed with stone pine. In the data obtained in the inventories in stands with natural regeneration classifies as “very difficult”, there wasn’t any significant linear correlation between stand density attributes, e.g. adult trees per hectare (DBH larger than 20 cm), crown cover FCC or basal area BA (m2/ha), and successful seedling densities. These inventories showed that 98% of the sampled plots had values of adult tree density lower than 150 tree/ha, 87% of the plots had crown covers below 40% and in 77% of the plots the basal area is lower than 12 m2/ha. Annual counts in stands with natural regeneration classified as “very difficult”, at least 75% with less than 50 seedlings/ha, coincided with mature trees densities in 73% of the plots below 150 trees/ha. Moreover, most of the studied stands are in areas with problems of over-exploitation of the aquifer, with decreases of the groundwater level in more than 25 m.

The employment of shelterwood method for natural regeneration with less than 150 trees/ha and BA below 12 m2/ha after preparatory and seeding cutting hampers seedling establishment, though other important factors exist that can cause regeneration failure of Pinus pinea and Pinus pinaster

Relation between NDVI values and watershed morphometry to determine post-fire regeneration and its evolution over time

Javier HEDO DE SANTIAGO, Manuel Esteban LUCAS BORJA, Eva María RUBIO CABALLERO, Tarek DADI, Jorge DE LAS HERAS

Forest fires are one of the most drastic disturbances in Mediterranean ecosystems. Post-fire regeneration is closely related to topography. Knowledge on the behaviour and resilience of post-fire communities is important to develop tools for an adequate forest management.

This work presents an innovative study based on remote sensing tools to evaluate the relations between the watershed morphometry and the post-fire forest regeneration and its recovery dynamics over time.

In summer 1994, several large forest fires burned almost 450.000 hectares in Spain. Our study is based on one large fire occurred South-Eastern of Spain, burning around 12.900 hectares of forest in Yeste (Albacete). The predominant tree species are mainly conifers as Aleppo pine and Maritime pine.

Watersheds in the study area have been determined using Digital Elevation Models (DEM) and GIS tools (SEXTANTE, extension of the gvSIG desktop). Forest regeneration has been determined by using the Normalized Difference Vegetation Index (NDVI). Compactness coefficient (Gravelius index), shape factor ratio, elongation ratio and circularity ratio have been obtained to characterize the watershed morphometry.

Our results showed that there is a correlation between post-fire regeneration and watershed morphometry. NDVI values in circular watershed were lower than in lengthened watershed.

Our conclusion is that this study is interesting to decision making, aimed to optimize resources and improve the management of burned areas.

Are Mediterranean pine forests resilient to recurrent fire events? Analysis of stone and Brutian pine stands in Lebanon

Carla KHATER, Rita EL-HAJJ, Chadi ABDALLAH

Lebanon is a mountainous country located on the eastern shore of the Mediterranean Sea. Although it is one of the smallest countries of the Middle East, it remains one of the rarest hosting both coniferous and broadleaved forests. Of the 13% forest cover, about 20% (i.e. 27 hectares) are composed of pine stands (*Pinus pinea* and *Pinus brutia*). Fire events are very common in Mediterranean forests especially in early-mid autumn. Forest stands located on steep hill slopes seem to be most vulnerable to such incidents. However, Pines have developed inherent adaptive capacity to fire and are able to maintain viable spots in spite of recurrent fire events.

This study analyses the vulnerability and resilience of pine forests in view of climate change and anthropogenic pressures in Lebanon, while assessing their exposure, sensitivity and adaptive capacity to key stress factors, mainly fire. It consequently evaluates the economic losses related to fire episodes in both stone and Brutian pines and highlights key accompanying species associated to post fire vegetation dynamics.

Results exhibit that stone pines in Lebanon are associated with high economic revenue (22,500$ par hectare), while losses related to fire episodes are estimated at 114,000$ per hectare for stone pines and 21,000$ per hectare for Brutian pines. Some key management practices can be suggested to improve pine forests resilience in Mediterranean environments such as phyto-sanitary thinning and selective pruning of pine stands to decrease sensitivity towards fire events, sustainable pine forests understory maintenance, preservation of cones on the ground to favor spontaneous re-sprouting after fire, etc.

In conclusion, even if pine forests are tolerant to fire, recurrent events considerably challenge their adaptability. Besides, in the current trend of climate change, if no adaptive measures are efficiently undertaken, the resilience of pine forests might be seriously defied.

Stand-level patterns of mortality of *Pinus sylvestris* in Northeast Spain

Roberto MOLOWNY-HORAS, José María MARCOS, Paulo SANTOS, Francisco LLORET

Drought-driven die-off and mortality are likely to induce deep impacts on the structure, functioning and services provided by forests since climatic scenarios project an increase of extreme episodes. Although relevant advances have been obtained on the understanding of the patterns and causes of tree mortality, there is a general lack of knowledge about the potential of these events to induce sudden shifts on forest composition and structure.

In this work we present some preliminary results of an on-going statistical analysis of the structure of P. sylvestris-dominated stands in Northeast Spain affected by tree mortality. We surveyed 22 stands of 10-m radius at different locations where the number of dead P. sylvestris tree was visually much higher than the surrounding forest. Likewise, 22 apparently unaffected nearby tree stands were similarly selected and sampled as controls. Juveniles were classified into three size classes and counted. Adult trees were counted and their diameter was determined. Their status, whether dead or alive, was identified and increment cores from dead and live trees were obtained for selected individuals when possible.

We compared the number of dead and alive juvenile trees in control and mortality-affected tree plots for the three size classes. We did not detect significant differences between juvenile numbers in drought and control tree stands (ANOVA test, $p\text{-value}<0.05$). These results suggest that the observed episodes of drought did not affect tree recruitment to a measurable extent.

As expected, the number of dead adults was observed to be higher in drought than in control stands (paired t-test, $p\text{-value}<0.05$). The opposite was true for live trees, i.e. there were many more adult trees alive in control than in drought stands. Furthermore, we examined size (diameter) distribution of adult live and dead trees by carrying out a series of two-sample Kolmogorov-Smirnov tests between tree size distributions for drought and control stands. We found that only in 27% of plots the size distribution of dead trees was significantly different between drought and control stands. For live trees there were significant differences in 36% of all plots.

These preliminary results suggest that tree mortality may be high and it often does not show a distinct dependence on tree size. Therefore, it does not always substantially modify the size distribution of the population, including recruiting individuals.

Response to thinning and pruning of Black pine

Daniel MORENO-FERNÁNDEZ, Mariola SÁNCHEZ-GONZÁLEZ, Isabel CAÑELLAS, Guillermo GEA-IZQUIERDO

Pruning treatment allows obtaining knot-free timber to increase the worth of the highest-value wood products. Also, in Mediterranean areas, pruning is often carried out to reduce the risk and severity of forest fires reducing the amount of biomass and break the fuel vertical continuity between the surface and crown. However, the effect of pruning on growth is discussed and the knowledge about the tree response to the simultaneous development of thinning and pruning scarse.

The objective of this study was to analyse the effect of the interaction of thinning and pruning on tree and stand level and annual radial growth of black pine (*Pinus nigra Arn*.) in Central Spain. We used long-term data from a trial installed in Guadalajara in 1993 when the stand was 26 years old. At the installation moment, four treatments of thinning and pruning with four repetitions in 16 plots (0.1 ha) were evaluated: thinning from below pruning the best trees, thinning from below without thinning, selective thinning pruning crop trees and control treatment. The second thinning was applied in 2006. Five dasometric inventories have been carried out so far. Additionally, at the beginning of 2013, we collected ten cores per plot which were used to register the ring-width, the annual radial growth, in order to find differences between pruned and not pruned trees. For the analysis of the data from dasometric inventories, we used a repeated measures analysis of variance mixed model to evaluate the effect of the thinning and pruning on diameter, height and basal area increment, including an independent-distance competition index. Moreover, we used a semiparametric mixed model with smooth penalized splines including climatic covariates to describe the trend of the annual radial growth with time of each treatment.

Both the results of the analysis of variance and the smooth penalized spline model showed that pruning did not reduce the height growth, diameter increment or annual radial growth. Also, trees subjected to thinning, both with and with pruning reached larger annual radial growth and larger diameter increments than those subjected to control plots. Regarding basal area increment, we did not find statistical differences among treatments. Therefore, we recommend the application of thinning and treatment to get clear-wood and increase the products value. Furthermore, the amount of biomass and the fuel vertical continuity between the surface and crown can be reduced to decrease the risk of crown fire without a loss of yield.

The role of nutrient status on the root development of Iberian pines at seedling stage

Rodrigo A. MARTÍNEZ CATALÁN, Andrei O. TOCA, Juan OLIET, Pedro VILLAR-SALVADOR

Reforestation success with Iberian pines are conditioned by factors such as nursery practices, environmental conditions and seedling attributes. Functional traits such as root growth capacity are critical for the establishment of planted and naturally-regenerated seedlings. Nutrient content of seedlings increases root growth and survival of several Mediterranean species. At interspecific level, Iberian pines populations segregate along a rainfall, temperature and soil properties, and root growth capacity should match this gradient.

In this study, we have evaluated the importance of nutrient status on the root dynamics during the early establishment of seedlings in three ecologically contrasting Iberian pines (*Pinus pinea* L., *P. pinaster* subsp. mesogeensis and *P. nigra* Arn.).

Three N fertilization treatments were differentiated: 1) low and 2) high N rates (20 and 150 mg N, respectively) applied before the hardening phase in the fall and 3) an autumn fertilization treatment (60 mg N before the hardening phase + 40 mg N during the fall). In spring, seedlings were transplanted into rhizotrons and the root elongation, number of roots, maximum depth, height and diameter of seedlings was weekly monitored for 10 weeks. Moreover, accumulated root length and mass at the end of the study was measured.

During the first weeks, all species showed a common root growth pattern consisting in the production of a low number of roots with a high elongation rates. Then, the pattern turned to a lower growth rate per root unit but with a higher number of roots. *Pinus pinaster* showed the highest root growth, followed by *P. pinea* and *P. nigra*. Roots of *Pinus pinea* showed the fastest growth in depth, followed by *P. pinaster* and *P. nigra*. Root growth showed antagonism with shoot growth only in *Pinus pinaster*. New root mass at the end of the study was greater in the seedlings cultivated with higher N fertilization. However, differences in response between high and autumn fertilization treatments were species specific, with *P. pinea* showing maximum response to autumn fertilization with regard to root growth rate and depth.

Root growth pattern across species is related to their ecological niche, with the Mediterranean pines, *P. pinea* and *P. pinaster* that thrieve in drier sites, developing larger and deeper root system than the mountain pine, *P. nigra*. Besides, autumn fertilization is a promising tool to efficiently improve root growth after planting with less fertilizer use.

Influence of thinning intensity on stand structure and growth dynamics of Scots pine in a mixed forest from the western Pyrenees

Irantzu PRIMICIA, Rubén ARTÁZCOZ, J.Bosco IMBERT, Fernando PUERTAS, M. Carmen TRAVER, Federico J. CASTILLO

Scots pine (*Pinus sylvestris*) forests are being transformed into mixed stands of Scots pine and beech (*Fagus sylvatica*) in central Europe and in the western Pyrenees, due to the multiple benefits of the coexistence of both species. However, little is known about the response of this type of woodland to forest practices.

The main objective of this study is the analysis of the thinning effects on the growth and stand dynamics of Scots pine in a mixed Scots pine-beech forest at the west-southern limit of its distribution area. The study site is a mixed stand dominated by Scots pine (regenerated in the mid-1960s), with beech, which cover all canopy strata, as the second tree species. The experimental design comprises 9 plots (30 x 40 m) where three thinning intensities were applied in 1999 (0, 20 and 30% basal area removed, hereafter control-C-, moderate-M- and severe-S- thinning) and 2009 (0, 20 and 40%). Within each plot pure pine (PC) and mixed pine-beech (MC) patches are distinguished. In 1999, all pine trees were georeferenced, marked and the diameter at breast height measured. The inventory was repeated in 2009 and 2014.

Pine density was higher in S than in C and M plots at the onset of the study, similar among treatments in 2009, and higher in C plots at the end of the study. Stand volume was higher in C than in M and S plots ($P = 0.08$) and in PC than in MC ($P < 0.001$) in the three inventories. However, differences in pine growth between canopy types (PC > MC) increased over time, except in M plots, where it was similar in PC than in MC. The enhancement of tree growth after thinning was similar or lower in S plots relative to M plots. This result might have been due to the disparities in the stand structure among thinning intensities before the study started and the high mortality in M plots during the second period (2009-2014).

Our results suggest that in this area and in terms of wood production, moderate thinning could be an appropriate forest practice at early pine age, as it produced similar tree growth than the severe thinning. Furthermore, it counteracted the negative effect of beech on pine growth observed in severe thinning. Nevertheless, the consistency of these patterns should be verified after following thinnings.

Spatial and temporal influence of tapping on the xylem anatomy of Pinus pinaster Ait. trees subjected to different tapping methods

Aida RODRÍGUEZ GARCÍA, Rosana LÓPEZ RODRÍGUEZ, Juan Antonio MARTÍN GARCÍA, Félix PINILLOS, Luis GIL SÁNCHEZ

After decades of decline of the tapping activity, the sector has recently experienced a resurgence with some attempts at mechanization. Maritime pine (*Pinus pinaster* Ait.) has been the chief species, and nowadays the only one tapped for oleoresin in the western Mediterranean countries. The oleoresin flow in *P. pinaster* is associated to the anatomy of the interconnected and widely developed resin canals, which synthesize and store oleoresin.

In this study we evaluated the influence of the tapping wound and of different tapping methods on the wood anatomy. Eight previously unwounded mature trees were tapped during five months with 4 different methods (mechanical and traditional, ascendant and descendant) in 2011. Nine cores per tree were collected 30 months after tapping (January 2014) from tissues surrounding the tapping wound, at three different orientations (above, below and aside) and at three different distances from the wound boundaries (3, 15 and 30 cm). Six anatomical variables were measured (cross section) in the 2010-2013 growth rings: the number of axial canals per mm2, the area of axial canals per mm2; the mean size of axial canals, and the radial increment of earlywood, latewood and growth ring.

The strongest xylem wood reactions were found in the first 15 cm above and below the wound boundary. In the tapping year (2011), the increment of the growth ring decreased up to four times compared to control, unwounded, trees. By contrast, two years after tapping (2013), an important increase in latewood and growth ring increment was observed aside of the wound due to callus formation. One year after tapping (2012), axial resin duct frequency and surface were four times higher than in the previous year, but the mean size of axial canals decreased. However, two years after tapping (2013), the frequency, surface and size of axial canals returned to similar values than the control trees. Traumatic resin duct formation, incomplete lignification of tracheids and formation of suberin bands were observed above and close to the wound boundary only in the tapping year.

All the methods tested caused similar responses in xylem anatomy. The most significant difference was a higher increase in the frequency and surface of axial canals with the ascendant mechanical method. The variations on the canal system of pines should be taken into account to improve tapping techniques and resin yield.

Study concerning the *Pinus nigra* growth in Portugal

Alexandra Luísa RIBEIRO DIAS, Teresa de Jesus FIDALGO FONSECA, Maria Emilia GALVÃO MOREIRA DA SILVA, Maria João GASPAR, Ana Isabel CARVALHO, José Luís LOUSADA

In the middle of the 20th century, the plantation of black pine (*Pinus nigra* Arn.) through the centre and north of Portugal was emphasized in the forest policy. This communication presents the first broad results of an investigation regarding adaptation and potentiality of *Pinus nigra* as a mountain species in Portugal. It is presented information about 6 sites: 2 located in centre (Manteigas and Vale do Zêzere) and 4 in north of Portugal (Caminha, Marão, Paredes de Coura and Vila Pouca), representative of its existence in the country. The sampling sites were composed by mature forests with a minimum average of 52 years for the trees in Caminha and Marão and a maximum average age of 92 years for trees in Manteigas.

There is a maximum value for the diameter (average ± standard deviation) 40.1 ± 6.7 cm in Vila Pouca followed by Marão with 38.7 ± 7.1 cm. Concerning the average heights, it ranges from 26.9 ± 2.4 m in Caminha to 15.2 ± 1.9 m in Paredes de Coura. Analysis was performed to examine the growth of the tree in diameter using the Schumacher model, that describes the annual diameter increment for the trees population, calculated from a deterministic component using tree diameter and age, $d = \alpha\exp(\beta/t) + \varepsilon$, with d representing variable diameter (at 1.30m of height, cm), t refers to age (years), α and β are the parameter of the model and ε is the error term.

The results of the nonlinear fitting procedure provided similar β confidence limits in Manteigas, Marão, Paredes de Coura and Vale do Zêzere, between -36.2 for the lower limit and -29.2 for the upper limit, but the α confidence limits of these sites are quite distinct pointing out for the existence of differences in the asymptote values, that is, for the maximum values that can be attainable for the species in different sites. As for Caminha and Vila Pouca, they have similar α and β confidence limits, with α confidence limits between 56.4 and 52.2 and β confidence limits between -24.1 and -27.0, therefore similar development between these two areas are expected to occur, according to the estimated values of the Schumacher growth model results.

The coefficient of determination (R^2) for this analysis ranges from 0.81 to 0.97 for the dataset collected in Manteigas and Paredes de Coura, showing a strong linear association between the variables age and diameter.

Funding: Study supported by the FCT Doctoral Research Grant SFRH/BD/91781/2012.

Effects of thinning on tree partitioning in a *Pinus sylvestris* L. stand

Ricardo RUIZ-PEINADO, Álvaro RUBIO-CUADRADO, Francisco RODRIGUEZ, Gregorio MONTERO, Miren DEL RÍO

It is assumed that biomass partitioning could be modified by some factors as site, nutrients availability, tree crown class, tree age, etc. As thinning involves an alteration of the resources competition status of the remained trees, this silvicultural treatment might modify the pattern of biomass allocation in trees. Understanding biomass partitioning provides insights into tree functioning, while from a productive point of view the modification of the allocation to stem biomass due to thinning could be very significant.

This study aims at answer the following question: Is biomass partitioning being modified by thinning?

Biomass data from individual trees were collected from a thinning experiment set up by CIFOR-INIA in a *Pinus sylvestris* stand. The trial is testing three treatments (moderate thinning, heavy thinning and unthinned or control treatment), where three thinning operations from below were performed (1982, 1992 and 2002). In 2012, when the stand age was 52 years old, a new thinning operation was planned. 30 trees (10 for each treatment) were selected, cut and the different biomass fractions weighted for the objective of this study.

Foliage and woody biomass amounts were influenced by thinning. Trees in heavy thinned stands had higher and statistically different amounts of needle mass and lower and significantly different amounts of woody biomass than trees in moderate thinned and unthinned stands for a given tree size. Competition for light and space in dense stands achieve a bigger allocation for wood than for foliage.

However, significant differences were not showed for stem biomass, but lower values appeared for trees in heavy thinned stands. The highest values in crown biomass (branches plus needles) were found for trees in heavy thinned stands (treatments were not statistically different). Crown rise due to competition could influence the different allocation pattern, being crown ratio different between trees in unthinned and heavy thinned stands. So, heavy thinned trees showed higher branch biomass values than the other treatments and stem within the crown fraction were significantly higher in thinned than in unthinned treatment.

Trees in heavy thinned plots showed a plastic response to competition reduction allocating more biomass to foliage, whereas biomass partitioning under moderate thinning was similar than in unthinned stands showing only an ontogenetic allometric size effect.

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StarTree project and the use of stone pine, maritime pine and Scots pine forests for non-wood forest production

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StarTree is a pan-European project funded by the European Union through the European Commission\'s FP7 cooperation work programme to support the sustainable exploitation of forest resources for rural development. The main aim of the project is to show how Multi-Purpose Trees (MPT) and Non Wood Forest Products (NWFP) can be used to strengthen and diversify economic activities in rural areas by providing better understanding, knowledge, guidance and tools to support stakeholders in optimizing the management of MPT and developing innovative approaches for increasing the marketability and profitability of NWFP for a more competitive rural economy.

In the frame of this project key research organizations and specialized small and medium enterprises working on MPT and NWFP throughout Europe are collaborating to ensure and speed up the transfer of research and innovations to markets. StarTree relies on strong stakeholder engagement through case studies in 14 regions across Europe and in-depth case studies in 7 key areas, in order to inform the research and development of new tools and knowledge on NWFP and MPT. To achieve this, the Project is composed of seven work packages. The second one, about resource management, has the overall objective of developing silvicultural guidelines, models and decision support tools to enhance the profitability of MPT and NWFPs management by combining wood and NWFP.

Regarding Mediterranean pines, stone pine, maritime pine and Scots pine are being studied as MPT in five case studies: Alentejo (Portugal), Bursa (Turkey), North Karelia (Finland) and Valladolid and Catalonia (Spain). In addition, these pines and their non-wood forest products (stone pine nuts and resin from maritime pine and mushrooms) are being studied in more detail in four resource management in-depth case studies.

In this work we present the Resource Management work package approach within the StarTree project to study the use of stone pine, maritime pine and Scots pine forests for non-wood forest production.

Funding: The European project StarTree has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement Nº 311919.

The reforestations carried out in south-central Albania by using Mediterranean pines. Biometric and silvicultural aspects

Patrizia TARTARINO, Vittorio GUALDI

The study summarized below refers to a research focused on the results achieved through the reforestation carried out in Albania in the late 50s and the 80s of the last century by using pine trees, and in particular *Pinus halepensis* Miller, *P. pinea* L. and *P. pinaster* Aiton, and other mountain species, such as *P. nigra* Arnold and *P. pallasiana* Lamb.

The research began with the identification of the complexes of reforestation realized by the forest Administration in the south-central Albania, considering 15 complexes, located in different Albanian forest districts. These were subsequently analyzed with respect to:

- The physical, physical-biotic and biotic environment, referring to the involved hydrographic basin and to other areas involved, distinguished by geo-morphological landscape, bioclimatic level, and physiognomic unit of spontaneous vegetation surviving;
- The silvicultural interventions performed, with reference to the influence of the following parameters: area concerned, criteria followed in the preparation of the soil, choice of tree species and the provenance of the propagation material, on plant density obtained and the following cultivation care;
- The results achieved, particularly related to the setup and anti-erosion actions insured by the plants analyzed, many of whom are now affected by dynamic and spontaneous processes of naturalization, represented by the spread in their area, of many arboreous, arborescent and shrubs species.

The next step of the research activity has been the detection of biometric data in the largest and most successful reforestation complexes analyzed, and this has allowed to determine, per hectare, the values of the number of trees, of the basal area and of the canopy area, as well as those of the depth of the green and dry foliage.

The same work has been completed with the explanation of silvicultural propositions, related to the reforestation complexes analyzed and those to be carried out, distinguishing each other according to the objectives pursued, from one side naturalistic, including of water regulation, defense soil and qualification in the sylvan sense of biological diversity, and from the other side, production of wood.

The research carried out confirmed the importance of using, even if non-exclusive way, the species of Pinus, in reforestation realized and to be realized in the whole Mediterranean isoclimatic area, with the mainly naturalist aims, represented by the naturalization mentioned, to be favored by appropriate silvicultural interventions, properly defined with appropriate experimental protocols.

Relation between nitrogen fertilization and the frost resistance of four pine species

Ovidiu Andrei TOCA, Judit MAROTO DE MERCADO, Juan OLIET PALÁ, Pedro VILLAR-SALVADOR, Rodrigo MARTÍNEZ-CATALÁN

Low temperature is major environmental factor affecting growth, survival and distribution of plants. A growing body of evidence indicates that nitrogen (N) rich seedlings have higher field performance than poor N plants, due to their higher ability to rapidly produce new roots. Furthermore, N nutrition has an important role in the frost acclimation of pine seedlings that may be related with higher antifreeze protein concentration.

We analysed the influence of three N fertilization levels on the frost resistance of four Mediterranean pine species: *Pinus halepensis* and *P. pinea*, which live at low lands; *P. pinaster*, from mid altitude sites; and *P. nigra*, which mainly thrives in high mountain areas.

Seedlings were grown under three N fertilization regimes (high: 150 mg N, low: 20mg N and autumn fertilization: 40mg N+ 60mg N in autumn) for eight months. Frost resistance was measured in November 2012 and in January 2013 by exposing shoots and roots of seedlings to an artificial frost test. Seedling needles damage was assessed by chlorophyll fluorescence while roots damage was determined by electrolyte leakage (EL). Finally all seedlings were assessed by visual evaluation of needle damage (VDI) two months after the frost test.

N fertilization significantly improved the frost resistance of all species, specially in shoots, with autumn fertilization stimulating maximum hardening. However, the pattern in roots was not so clear, as the effect of fertilization on frost resistance of roots depended upon test temperature, season and species. Chlorophyll fluorescence and VDI showed similar shoot degree of damage, while only VDI technique in roots, but not EL, allowed a precise discrimination among fertilization and species. In addition, the mountain species *P. nigra* showed the highest frost resistance, followed by *P. pinaster* and finally *P. pinea* and *P. hapelensis*, which were the most vulnerable to frosts.

In conclusions, the geographical distribution of pine species seems to be correlated with low winter temperatures. Our results evidence that this distribution differences might be attributed to differences in pine frost resistance. Also, we evidence that N nutrition, mainly when applied in the autumn enhances seedling frost resistance.

Evaluation of nonlinear height-diameter models for *Pinus halepensis* Mill. in Northern Greece

Thekla TSITSONI, Dimitrios RAPTIS, Dimitrios ZAGAS, Theocharis ZAGAS

Tree height prediction from diameter at breast height consist an important function for silviculturalists and forest managers worldwide. Tree height estimation is critical for growth and yield models as well as for timber volume and wildfire models.

In the current research several nonlinear models were fitted in a total sample of n=1482 Aleppo pine (*Pinus halepensis* Mill.) trees located in Kassandra peninsula, Northern Greece, where Aleppo pine species reaches its optimal growth. The data were derived from 52 installed sample plots, covering the majority of the site indexes of the peninsula. The performance of each nonlinear model was based on a number of criteria such as the adjusted R squared (Radj2), the root mean square error (RMSE) and the Akaike information criterion (AIC).

Although many of the tested models performed well producing quite similar results, Richard's model accounted for the largest proportion of height variations (R2 = 60,7%), predicting as most accurately the height variable. The exported functions should be restricted only to the specific area since no similar functions referred to Greek conditions, are available for comparison and validation.

The role of thinning treatments on architectural traits of *Pinus halepensis* in dense post-fire Mediterranean forest

Diana TURRIÓN, Susana BAUTISTA

This research focuses on analyzing forest management practices that aim to improve functioning of post-fire Mediterranean *Pinus halepensis* forests. Specifically, this work aims at determining the effect of the intensity and spatial structure - pine density, spatial pattern - of a variety of thinning treatments on dense young post-fire pine communities, particularly the effects on water availability dynamics, tree architecture, and pine growth.

The work was carried out at three experimental sites in SE Spain. Three thinning treatments were applied in late winter 2009-2010, which resulted in two types of pine stands: 600 trees/ha, regular pattern (600R); and 600 trees/ha, aggregated pattern (pines were left in clumps of 20 trees) (600A). These treatments were also compared with control areas with no thinning applied. Thinning treatment varied soil moisture, with 600A treatment, showing the highest soil moisture one year after treatment application and 600R showing the lowest soil moisture values three years after thinning application.

Architectural traits of pine trees were highly sensitive to competition and climate variability. Before the thinning treatment, shoot length, branching rate, and number of leaves of pine trees slightly decline with pine aging. After the thinning, all these traits showed significant higher values in thinned areas than in control ones, reflecting the constraining role of pine competition in the architectural development of pine trees. Furthermore, the response of the architectural traits of pines from the thinned areas clearly matched the inter-annual climatic variation, while the control pines continued their age-dependent decreasing trend for all the traits assessed; no major differences were found between the regular and aggregated spatial patterns. The growth rate of tree diameter (DBH) was higher for the thinned treatments, even just one year after the treatment application, being 600R the treatment that showed the highest growth rate in tree diameter (DBH).

These results provide insights in the interaction effect of competition and climate variation on pine development, and useful information for the management of dense post-fire pine stands in Mediterranean areas.

Analysis of the Tunisian pine nut value chain

Gisa Henrike MARGGRAFF

Non-wood Forest Products (NWFPs) make a significant contribution to local socio-economic development and poverty alleviation. In Tunisia pine nuts are among the most promising NWFP in terms of socio-economic benefits. However, the value chain faces several challenges that hamper the valorization of pine nuts.

In 2014, the Tunisian Forest Administration (DGF) and GIZ have conducted an analysis of the pine nut value chain to evaluate the current situation and economic reality and to identify recommendations for improving this chain.

The study analyzed the following aspects:

A) Organization of the value chain: Which are the different functions of the value chain? Which operators are taking these functions? How are they linked (business links)?

B) Economic analysis: assessment of production costs, transactions costs, value added, income;

C) Market: market characteristics, demand and growth potential, conditions of market access;

The study is based on the methodology "ValueLinks" - a systematic compilation of action-oriented methods for promoting economic development with a value chain perspective, developed by GIZ. The consultants conducted a literature analysis, a data research and semi-structured interviews with selected stakeholders of the chain. Potential service providers and DGF were consulted to discuss framework conditions and options for improving the chain value. The results were presented at a workshop during which actions and recommendations to upgrade the value chain were identified.

The study showed that the collection of pine nuts is a lucrative business, particularly at the level of transformation. There is a huge demand on the market that isn't satisfied. Throughout the value chain jobs and income are created. Nevertheless, there major constraints that affect the value chain: a) lack of knowledge of good post-collection practices, b) poor business skills, c) an inhibiting regulation, d) overexploitation, e) illegal and premature collection − also discouraging an increase in professionalism and hindering the access to business development services, f) the management of stone pine plantations − the rule of "first come, first served" is inconsistent with a sustainable management of these forests.

Key success factors for upgrading the value chain are: a) creation favorable framework conditions (law), b) improvement of post-collection practices, c) clarification of roles between the public sector (DGF) and the private sector (value chain actors), d) access to business development services, e) new vision of co-management, f) immediate actions to prevent premature collection, such as pilot models for co-management, harvest control by authorities and sensitization activities, etc.

Addenda Poster Session *Abiotic interactions and Climate change*

Effects of water stress on germination in six provenances of *Pinus sylvestris* seeds

Jani PIRES, Maria João GASPAR, Alexandra BARROS, Maria Emília SILVA, José Luis LOUSADA, Ana CARVALHO, José Eduardo LIMA-BRITO

Pinus sylvestris L. is widely distributed in Euroasia and constitutes the pine species with largest natural distribution, being Portugal its southwestern limit. Most of the actual Portuguese Scots pine populations resulted from afforestation, but two populations at "Serra do Gerês" that have been considered native, has long surprised botanists and ecologists. During the adaptation process, these populations endured environmental changes that modulate its distribution, natural regeneration and phenotypes. Under the future climate scenarios, one of the most important factors that might affect the natural regeneration of forests is the seed germination capacity, once water supply is an important environmental factor. The objective of this work was to study the effect of water stress on germination capacity of seeds from the autochthonous populations of "Serra do Gerês", and compare it with 5 foreign provenances: "Puebla de Lillo" and "Montes Universales" both from Spain, Riga (Latvia), Germany and Sweden, representative of natural area of distribution of this species. Seeds were subjected to 5 five levels of water potential achieved by different concentrations of polyethylene glycol 6000 (PEG) for 42 days in a controlled temperature growth chamber at 24 ± 0.5 °C with a photoperiod of 12 h.

The results showed that treatments and provenances were a highly significant source of variation for germination capacity (CG) explaining respectively 68.2% and 19.7% of the total variation. Concerning germination rate (GR) treatments were responsible for 46 % of the variation, while provenances explained 15.6%, with significant differences for both sources of variation. In this study, lowering the water potential to -2 bars increased the percentages of GC and GR in most provenances. No significant differences were observed between "Serra do Gerês", Germany and Riga for CG, and these weren´t adversely affected even when moisture stress reached -8 bars, with values higher than 70%. For GR, "Montes Universales" was the only provenance that significantly differed from the remaining, presenting the lowest value.

The mean germination time (MGT) was significantly affected by PEG concentration, explaining 60% of total variation, although differences were only observed for water potentials lower than -4 bars. Provenances were also significantly different, being responsible for 28,4% of MGT variation. In average, seeds from "Serra do Gerês" presented the highest germination capacity and the shorter germination time.

These results can be useful to understand the adaptive behavior to water stress of *P. sylvestris*.

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Addenda Poster Session *Stand dynamics and forest management*

Evaluation of wood quality and growth in Portuguese *Pinus sylvestris* adult trees

Claudia FERNANDES, Maria João GASPAR, Jani PIRES, Maria Emília SILVA, Ana CARVALHO, José Eduardo LIMA-BRITO, José Luis LOUSADA

Pinus sylvestris L. presents great ecological amplitude, and is important at environmental and production levels. It is the most widely dispersed Eurasian conifer, being Portugal the westernmost limit of its distribution. Wood has a record of the interactions between the tree and the environment. The anatomical changes along the growing season are easily revealed by an increase in ring density, forming well defined patterns, earlywood and latewood in each annual ring. In conifers, these patterns are distinct in morphology, chemical composition and wood properties. Wood quality can only be defined in terms of particular end use, and may involve several traits as density, chemical composition and mechanical properties. Chemical composition can influence the physical properties of different types of wood, while mechanical stiffness and strength of wood are combinations of its physical, chemical and anatomical properties. Nevertheless wood density is considered one of the most important characteristic or indicator to wood quality. However, wood density is not a singular trait, but the sum of several density components, which means that the overall density will be the result of the innumerous combinations between its components.

The objective of this study was to evaluate wood quality, in terms of mean values, of 90 adult Scots pine individuals, from five representative stands in Portugal, namely, Gerês, Marão, Peneda, Serra da Estrela and Vinhais. The evaluation was carried out by the analysis of wood density components, by x-ray microdensitometry, chemical properties, by NIR spectrophotometry and mechanical properties by bending tests.

The results revealed that the trees from Gerês and Marão presented, in a general way, higher values for the components related to density, namely Ring Density, while Serra da Estrela and Peneda showed the lowest. Regarding the components associated with growth (earlywood, latewood and ring widths), Marão and Peneda showed higher values, contrary to Vinhais and Serra da Estrela. Concerning the chemical properties, the higher extractives content as well as H/G ratio was obtained in Vinhais, whereas the lowest were in Peneda and Marão. On the mechanical properties, both Modulus of Elasticity and Rupture were greater in Gerês and Marão, while Vinhais and Peneda exhibited the lowermost values.

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Addenda Poster Session *Stand dynamics and forest management*

Hydric and photosynthetic functioning of *Pinus laricio* in a Corsican natural stand

Gauthier LAPA, Frédéric MORANDINI, Eric LEONI, Lila FERRAT

Pinus nigra ssp. laricio (Poir.) Maire var. corsicana (Loud.) Hyl., endemic species of Corsica, France, suffers from a lack of physiological data that could be useful in order to assess its sensibility to environmental disturbances (climate, fires...). We choose to investigate sap flow and photosynthetic parameters in a site located at 1200 m elevation, at the boundary between the supramediterranean and the montane zones, with hot and dry summer and frequent frosts in winter.

Sap flow has been measured continually since July 2013 by the Granier's method, it was greatly correlated with vapour pressure deficit (VPD). Both of them were more important during summer. Since mid November they have been very low, due to winter condition. An exception was measured during September, with a decrease of sap flow while VPD was high, probably due to low water availability.

Photosynthetic parameters have been measured each month since December 2013 using two methods: chlorophyll fluorescence and gas exchanges. Three fluorescence parameters are being monitored: the maximum quantum yield of photosystem II (Fv/Fm), the quantum yield of PSII (ϕ PSII) and the non-photochemical quenching (NPQ). Gas exchanges measurements were allowed to estimate three parameters: the maximal electron transport rate (Jmax), the maximal carboxylation rate (Vcmax) and the triose-phosphate utilization (TPU).

The ϕ PSII and Fv/Fm were low between December and March and increased significantly in April. The NPQ was negatively correlated with the ϕ PSII. These results show an increase of photosystem II efficiency and a decrease of energy dissipated as heat in April compared to winter months.

Gas exchange parameters (Jmax, Vcmax and TPU) were all positively correlated. The Jmax and Vcmax were both greater in April than in December. The TPU didn't change significantly during these four months. These show an increase of the RuBP carboxylation by the RuBisCO and the RuBP regeneration by electron transport, and therefore an increase of enzymatic performance through Calvin cycle.

This preliminary study will be completed by a year of measurements, and will be discussed with regards to forest management.

Keywords: *Pinus laricio*, chlorophyll fluorescence, sap flow, gas exchanges

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