



**GLOBAL CHANGE AND MEDITERRANEAN PINES:
ALTERNATIVES FOR MANAGEMENT**

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The Mediterranean Forest Research Agenda

(Invited communication)

Dr. Ricardo Alía

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Mediterranean forest ecosystems provide multiple goods and services (especially noteworthy is the importance of nonmarket values) including an exceptional richness in terms of biodiversity, which are crucial for the socio-economic development of rural areas as well as for the welfare of the urban populations of the Mediterranean region. Several challenges have emerged in a context of global change that need to be addressed to ensure the sustainability of Mediterranean forests:

- How will climate and land use changes impact Mediterranean forest ecosystems?
- How to address forest and fire management concerns in a global change context?
- How may governance, policies and economic instruments ensure the provision of valuable forest goods and services?
- How to manage multifunctional forests and woodlands in multiple-use landscapes?

Meeting these challenges calls for sound management practices based on improved and enlarged knowledge, targeted education and capacity building in order to bridge the knowledge and expertise gap between countries, institutions and science and society in general.

Forest research in the Mediterranean region is handicapped by its fragmentation, its limited means, and occasional outdated and isolation. In addition, the low benefits that Mediterranean forests provide to forest-based industries – compared to other European forests – make it difficult to attract interest and funds from the private sector. For this reason, new ways to overcome this situation must be implemented through: research partnerships, networking, capacity building, higher education programmes, knowledge transfer and long-life learning. In this context, research cooperation with other Mediterranean Climate Regions (MCR) should be enhanced to share knowledge in order to address common scientific challenges and needs.

The European Forest-Based Sector Technology Platform (FTP) has provided the framework for the Mediterranean forest research community to develop the Mediterranean Forest Research Agenda (MFRA) as part of the Strategic Research Agenda (SRA) in order to

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highlight the main pan-Mediterranean forestry challenges as well as the scientific priorities, objectives and outcomes to address them.

MFRA aims at networking and coordinating research at Mediterranean level, requiring a coordinated effort by the research community and related stakeholders (forest owners, NGOs, companies, public administration, etc) to utilise in an efficient and effective way the available international and national research funding resources.

MFRA, based on a shared and common vision on these challenges, is aimed at ensuring the sustainability of Mediterranean forests and the goods and services they provide by advancing and sharing knowledge on forest ecosystems functioning, and by developing new tools for management and governance in a context of global change. In this respect, the most innovative development of sciences (climatology, economics, decision science, biology, ecology, information technology and geomatics, etc.) should be adopted and adapted by forest science. Education and knowledge sharing through strengthened capacity building are seen as major components of MFRA.

MFRA is structured around four strategic research priorities – selected on the basis of their intrinsic importance and significance for policy decision-making – to provide a scientific framework with which to meet the important challenges ahead.

The implementation of MFRA will allow the creation of a Mediterranean forestry knowledge triangle of research, education and innovation as well as a geographic triangle with its vertices in Mediterranean Europe, North Africa and the Middle East. Both concepts will play a key role in a knowledge-based sustainable Mediterranean society.

Genetic signatures of demographical and selective events in Mediterranean pines

(Invited communication)

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Pines are widespread in the Mediterranean basin where they have keystone ecological and economical roles. Genetic diversity in pines has traditionally been studied by means of neutral molecular markers and common garden experiments. Only recently the development of genomic tools has allowed the identification of candidate genes potentially related to growth and fitness in these species, which may provide a new generation of 'adaptive' markers with application to conservation genetics and breeding. Identification of allelic variation with ecological or evolutionary significance is not easy. In this talk, I present two case studies based on candidate genes and wide-range sampling of natural populations. In Aleppo pine (*Pinus halepensis* Miller), we first used coalescence simulations to fit demographical models and found an east-to-west colonization pattern with loss of nucleotide diversity in the westernmost populations (Spain and North Africa) when compared to eastern ones (Greece and Israel). Second, we conducted neutrality tests and hypothesized that the colonization of the western Mediterranean could have been accompanied by recurrent natural selection events. In maritime pine (*Pinus pinaster* Aiton), first, population genomic methods based on the identification of outlier loci and, second, correlations between allelic variation at SNPs (Single Nucleotide Polymorphisms) and environmental traits (mainly temperature and precipitation) were used. Different polymorphisms (SNPs) and haplotype variants from candidate genes related to drought response (e.g. some dehydrins) were correlated with climate as well as showed uncoupled patterns of divergence across species and within-species polymorphism. These two examples illustrate the power of different methods to detect selection in nature and the adaptive role of

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candidate genes, a required information for the application of adaptive markers in conservation and breeding programs.

DIEBACK AND FIRE INCREASE MORTALITY RISK IN MEDITERRANEAN PINES

(Invited communication)

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The western Mediterranean Basin is one of the world areas most susceptible to global change. Climate models predict increases of mean annual temperatures of 3-4°C during the next century, and reductions of annual precipitations reaching 50% in summer. These extreme climatic episodes have important effects on water availability, which has a central role in forest dynamics, as extreme episodes of water stress and the recurrence of droughts are believed to be the main climatic factors inducing forest dieback. Moreover, changes in the fire regime have recently been detected in many areas of the Mediterranean Basin. These changes, due to increasing fire climatic risk, changing management policies, fuel accumulation, and increasing ignition sources, have uncovered a trend towards an increased frequency of large-scale fires, which are responsible for the largest fraction of burnt land, and a higher incidence in non-Mediterranean areas.

Pines are important vegetation components of the Mediterranean Basin. Results of this study indicate that, for these species, risks associated to drought and fire have been increasingly high in recent decades. On the one hand, mortality of the different pine species, measured as the amount of standing dead trees between the censuses of the second and the third Spanish forest inventories, has increased four- to eight-fold. Moreover, and although it is widely accepted that fire has favored pine species distribution throughout their natural range in the Mediterranean Basin, the results obtained in other studies of our group show that post-fire regeneration of many pine species is very difficult because they do not have any efficient post-fire regeneration mechanism. The extrapolation of the changes predicted by these results with simulation models points to important consequences on the overall distribution of many pine species in the Iberian Peninsula.

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Growth and yield modeling and simulation of even-aged *Pinus brutia* Ten. stands in Middle East

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Pinus brutia Ten. naturally grows in the Eastern Mediterranean region and represents the most widespread conifer species in Syria and Lebanon. It is important for multi-purpose forestry owing to its high ecological value and economic importance. Anthropogenic pressure was dramatically intensified during the last century and forest surface was strongly reduced in Middle East. Nowadays, global change mitigation and adaptation represents an additional new challenge for *P. brutia* forests management. The lack of information in the region on stand dynamics and the absence of science-based forest management guidelines made it necessary to start a transnational research project on *P. brutia* modeling. 133 semi-permanent sample plots were established to capture the whole range of variation in site quality, stand age and stand density of *P. brutia* in Syria and Lebanon. Afterwards, site index, distance-independent diameter increment, height and self-thinning models were fitted separately for each country. The guide curve method was used to fit a site index model. The data for a 10-year period diameter growth model consisted of growth measurements of two past 10-year periods in 5 to 110 year-old stands. The self-thinning model was developed by selecting plots which were assumed to have reached the self-thinning limit and fitting an equation between number of trees and mean diameter. The site index (dominant height at 50 years) of the plots varied between 8.1 and 32.3 meters. Diameter increment was modeled as a function of different variables representing site (slope, aspect, elevation, site index), size (dbh) and competition (stand basal area, BAL). The site index, self-thinning and individual-tree models fitted are the first ones developed in Syria and Lebanon for predicting dynamics of even-aged pure *P. brutia* stands. The set of models enables the simulation of forest stand dynamics on an individual-tree basis. Such models will allow, with the aid of optimization techniques, finding optimal forest management guidelines for *P. brutia* forests based on different management objectives.

Key words: individual-tree model, stand dynamics, Turkish red pine, Calabrian pine, Mediterranean forestry, Syria, Lebanon

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Predictive modelling of climate suitability for *Pinus halepensis* in Spain

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The response of Mediterranean pine species distribution to global change is a key feature of forest management in a changing environment. Climate suitability models are valuable tools for understanding and anticipating the effects of climate change on species distributions. Logistic regression was used to model climate suitability for *Pinus halepensis* in Spain, using National Forest Inventory as training sample. Predictive performance was evaluated using ICP Forests Level I grid as independent validation sample. The same independent sample was used to assess predictive performance of some previously available suitability models for *Pinus halepensis* in Spain. Results show good predictive performance for the logistic regression model, considering both discrimination and calibration. The logistic regression model outperformed other models previously available for *Pinus halepensis* in Spain.

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Short-term effects of overstory reduction and slash mulching on ground vegetation in a Mediterranean Aleppo pine afforestation in SE Spain

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We have studied the short-term interactions brought about by overstory reduction and slash mulching and their effects on ground vegetation in an Aleppo pine woodland in south-east Spain. The data concerning floristic richness (no. species) and above-ground biomass of species (g) were measured as dependent variables in 0.5 x 0.5 m quadrats in an overstory reduction vs. control area (treatment factor) during the Spring of 2006. The data were analysed by ANCOVA, in which slash-mulch weight (g) was introduced as covariate. Relationships between variables were examined using linear regression, and variations in floristic composition were ascertained by means of principal component analysis (PCA). A total of 32 ruderal herbaceous species were registered, none of which was exotic. Most of them occurred more frequently in the overstory-reduction treatment compared to the control area and only a few species were found to clearly prefer the control treatment. In general, overstory reduction led to a significant increase both in floristic richness and above-ground biomass. Slash mulching, on the other hand, encouraged the appearance of a greater quantity of above-ground biomass (in different ways depending upon treatment) although species richness did not improve, even to the extent of declining in the control area. On the basis of our findings, overstory reduction seems to increase species richness and productivity in Mediterranean reforested woodlands on degraded agricultural land with a great density of trees, at least in the short-term. Large quantities of mulch accompanied by high tree density would seem not to favour species richness.

Keywords: above-ground biomass, species richness, forest management, herbaceous layer, semi-arid.

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Spatial and temporal patterns of Spanish black pine natural regeneration forests in Mediterranean mountains areas.

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Factors restricting natural regeneration success of Spanish black pine (*Pinus nigra* Arn. ssp. *salzmannii*) at the earlier stages are especially complex and some of them not completely understood. They include year-to-year variability in seed production, post-dispersal seed predation, suitable medium for seed germination and seedling survival, diseases, variable environmental conditions and might vary annually and for a given year with local conditions and season. During the years 2005, 2006 and 2007 the seed rain, magnitude of seed losses due to post-dispersal seed predation, the effects of stand density and soil treatment on seed germination and seedling survival and early seedling growth were evaluated in managed Spanish black pine forest in Cuenca Mountain (Spain) across two forest types: upland limit location and typical location of Spanish black pine forest stand. Results show that the processes linked at the beginning of the recruitment do not predict good expectancies for typical or relict Spanish black pine forest in non-masting years, being especially problematic in those areas where this specie reaches their altitudinal limit. Good years recruitment has to be preceded by a good seed production, in which case post-dispersal seed predation is not as important factor as if low seed fall is noted. Predators present different seed removal rates depending on the season of the year and forest ecosystem location, being seed predation an important limitant factor in natural regeneration of Spanish black pine in poor-year seed productions. Moreover, seed germination, seedlings survival and initial seedling growth are influenced by stand density and soil treatment. In typical forest areas higher basal area values providing high shade are necessary, whereas for relict forest areas lower basal area intervals with great growing space needs to be promoted.

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Temporal pattern of seed production and seedling establishment in *Pinus sylvestris* and *Pinus pinea* naturally regenerated stands in Central Spain

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The aim of the study was to assess and compare the temporal pattern of seed production, nascence, survival and development of established seedlings in two Scots pine (*Pinus sylvestris*) and one Stone pine (*Pinus pinea*) naturally regenerated forests in Central Spain. Studies were based on a 5-year monitoring period (2005-2009) of 0.5 ha permanent sample plots (three for *Pinus sylvestris* and six for *Pinus pinea*) located in differently managed mature stands. Within each permanent plot, 10 (*Pinus sylvestris*) or 20 (*Pinus pinea*) sampling subplots were installed systematically at the beginning of the regeneration process. Germination, seedling survival and height growth were recorded twice per year, in order to monitor the presence of new seedlings and both winter and summer survival of seedlings. Seed rain for each subplot was monthly estimated using seed traps. Light environment at each subplot was estimated by hemispherical photographs. Climatic conditions were continuously recorded using HOBO weather stations. Temporal pattern of regeneration success in both species showed a large dependence in year-to-year conditions. In addition, our results for *Pinus pinea* indicate that regeneration success is mainly controlled by seed availability - with a high interannual masting habit in seed production -, germination conditions and seedling survival during first summer period after nascence. On the other hand, the establishment and growth of *Pinus sylvestris* seedlings depends on the micro-environmental conditions (light and water availability during summer), closely related to the regeneration fellings applied. These results conforms the basis for discussing and comparing the different strategies in natural regeneration for both species.

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Performance of modelling techniques for the prediction of forest site index: a case study for pine and cedar in the Taurus Mountains, Turkey.

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Forest research has a long tradition in studying the relationship between stand productivity and abiotic and biotic site characteristics, such as climate, topography, soil and vegetation. Many of the early site quality modelling studies related site index (i.e. the dominant height of a forest stand at a reference age) to environmental variables that could be measured in the field relatively easily and at low cost, using basic statistical methods such as linear regression. Because most ecological variables show a typical non-linear and a non-constant variance distribution, a big source of error remained unexplained with the use of these linear models. More recently, the development of more advanced non-linear and even non-parametric and machine learning methods provided opportunities to overcome these limits. Nevertheless, these methods have also drawbacks. Due to their increasing complexity they are not only more difficult to implement and interpret, especially the 'black box' methods, but also more vulnerable to 'overfitting'. The challenge is located in choosing the appropriate modelling technique for a specific situation. In this study, five different modelling techniques for predicting the site index were compared and evaluated, including multiple linear regression (MLR), classification and regression trees (CART), boosted regression trees (BRT), generalized additive models (GAM), and artificial neural networks (ANN). 167 sample plots were distributed over homogeneous stands of three important tree species of the Taurus Mountains of Turkey: *Pinus brutia*, *Pinus nigra* and *Cedrus libani*. Soil, vegetation and topographic conditions were measured in detail and related to the site index with the five earlier mentioned modelling techniques. Except for the CART-method all methods evaluated in this study showed an improved prediction performance over the traditionally used MLR. ANN showed the overall best performance, but the complexity of the model, the training and testing effort and the interpretability taken into account, BRT and especially GAM present themselves as good alternatives.

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Role of Mediterranean pines on CO₂ uptake and storage: Aragon a case of study.

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On the framework of a global estimation of the CO₂ stored on woody vegetation in Aragon (a Spanish region of ca. 50.000 Km²) and the role of forests as CO₂ sink, some key species living in the region evaluated were used for modeling different forest management and silvics alternatives for Carbon sequestration optimization. Estimates of biomass and CO₂ conversion were calculated on the basis of allometric equations calculated for Spanish species from National forest inventory raw data. Quantitative and qualitative data on CO₂ stored and fixation rates from Mediterranean pines compared with total vegetation are presented. Four different management scenarios were applied in *Pinus halepensis* and two in *Pinus sylvestris* and *Pinus nigra*, for evaluating the consequences of silvics on Carbon sequestration. An extra species (*Quercus pyrenaica*) was included on the study and global data are presented for comparative purposes. CO₂FIX (Nabuurs et al., 2002) software (biomass and soil modules) was used for modeling and simulate the different scenarios. In the light of this model tool up to 70% of increment of CO₂ uptake can be achieved on the best practice for Carbon sequestration practice in Aleppo pine.

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Carbon Stocks in Portuguese Maritime Pine Stands

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One of the Pan-European Criteria for the Sustainable Forest Management is the Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles. Carbon dioxide (CO₂) is the most important anthropogenic greenhouse gas. Its annual emissions increased by about 80% between 1970 and 2004 according to the 2007 report from IPCC, being the main responsible for the changes in the world climate. Today, the carbon sequestration is among the most important services that are expected from the forests. Growth and yield models should be able to predict carbon stocks in forests from National Forest Inventory data. Carbon pools in a forest ecosystem are generally partitioned into live trees, understorey vegetation, forest floor litter, coarse woody debris, and soil. A study was recently carried out in three regions from the distribution area of maritime pine (*Pinus pinaster* Ait.) in Portugal, aiming to quantify the carbon stocks in the understorey, forest floor, dead wood and soil. A total of thirty 500 m² plots (10 in each region) were established. In each sampling place, the distance to the plot centre and the azimuth of all trees were registered. Dendrometrical and qualitative variables were also taken. A 1x1 m plot was used to sample understorey vegetation. Forest floor (L and F+H layers) was sampled using a quadrat of 50x50 cm. Concerning the dead wood, snags were measured for dbh and total height when they were present in the plot area. Logs were sampled by the line interception method, using 4 transects of 25 metres in the directions N-S, E-W, NW-SE and NE-SW, passing through the plot centre. Both for logs and snags 3 decomposition classes were considered. Mineral soil was collected from the depths 0-10 cm, 10-30 cm and 30-60 cm. This data is being analysed and hopefully will be incorporated in a growth and yield model in order to predict carbon stocks in different forest management scenarios which is important for the equilibrium between timber production and carbon sequestration.

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Tree survival and stand structure in maritime pine (*Pinus pinaster*) remnants resulting from wildfire in Northern Portugal

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Maritime pine (*Pinus pinaster*) stands are highly flammable and, consequently, are prone to stand-replacement fire. However, the species has morphological traits that allow survival to surface fire. In this study we have sampled groups of live trees or remnant stands of maritime pine in northern Portugal. Sampling was restricted to fire events that occurred three or more years before, such that secondary tree mortality induced by biotic factors would be accounted for. The study sites were located by combining analysis of aerial photography with field inspection. The collected information included physiographic elements, basic fuel data, descriptors of dead and live tree morphology, and fire severity metrics. The shape and dimensions of each pine patch were assessed, characteristics of the surviving trees were averaged over the site, and additional stand structure descriptors were determined (basal area, distribution by size class). The number of fires that each pine patch experienced was determined from the Forest Service fire atlas which combines remote sensing and ground data. The residual stands have burned one to 9 times since 1975, sometimes in consecutive years. An herb layer develops after fire in *Cytisus* spp. the prevailing shrubland type in most of the sites, which probably explains why the fire interval can be so short. The mean fire return interval was 15 years, ranging from 3 to 31 years. Mean dbh of live and dead trees was 28 and 14 cm, respectively, but a tree with a 10-cm dbh had a 50% probability of surviving fire. On average, live trees had a bole char height of 3.7 m and retained 64% of their crown length. We describe burn severity and stand structure in relation to the fire regime. Fire management implications are discussed.

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May adaptive differentiation be confounded with epigenetic plasticity? The case of Mediterranean stone pine

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A better understanding of the ecological and genetic adaptive capacity of Mediterranean pines in response to environmental changes is needed to define new adaptive management regimes under the climate change. The case of the Mediterranean stone pine, *Pinus pinea* L., may illustrate in this context the complementary mechanisms of genetic adaptations and epigenetic acclimations. The local populations of stone pine seem to be well adapted to different climate zones along its distribution range. But recent molecular studies revealed it to be extremely genetically depauperate for a widespread tree. In this context, common garden experiments have found only slight differences in adaptive traits (survival, ontogeny and growth) between proveniences, being these differences masked by a common steep stable reaction norm of all accessions in dependence on site and microsite. Phenology and growth parameters correlated with the mean temperature in origin, similarly to the epigenetic acclimatisation described for other conifers, where these effects of epigenetic memory of cold and warm embryo formation have been interpreted as a mechanism of adaptive phenotypic plasticity that improves the fitness of the same genotype in different environments. In epigenomics, the findings point not only to a life-long epigenetic gene regulation during embryogenesis, but even to a epigenetic inheritance over several generations - thus the divergent phenotypes expressed by different accessions might not only be due to proper genetic divergences, but also due to the specific epigenetic load of their ancestors. 200 years after Darwins birth, the consequences of this possible epigenetic inheritance must be stressed for field work in quantitative genetics: if a reversible, but inheritable acclimatisation by epigenetics acts like a buffer between genotype and expressed phenotype, even the potential reaction norms of plant populations evolving under the ongoing climate change might be others than predicted from experiments with in situ sampled accessions.

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Index selection for growth and wood quality traits for parental selection in *Pinus pinaster*

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Pinus pinaster Ait. (maritime pine) is one of the most important native species in Portugal, occupying 30% of the national forestry area and representing 11% of the total value of forest product exports in 2000. The economic importance of this species has led to the development of genetic improvement initiatives. The use of index selection is an attractive option for tree breeders allowing the combination of several traits. Knowledge of all genetic parameters enables the application of multi-trait index selection, which combines all information on phenotypic performance and genetic structure. Considering two possible final use scenarios, namely solid wood or pulp production, expected genetic gains were estimated for several families based on multi-trait selection indices. This study aims to contribute to the Portuguese *Pinus pinaster* breeding programme, which is reaching the third generation, adding information on wood traits namely: ring density (RD), spiral grain, radial modulus of rupture, radial modulus of elasticity and lignin content, of 46 open-pollinated families from a 17-year-old progeny trial located in Leiria. The expected gain obtained indicate that an increase of 15% can be achieved in RD, simultaneously with a 1% increase in diameter growth as well as, it is possible to get a 3% decrease in lignin content and increases of 15% and 5% in ring density and diameter growth, respectively. Our results support the application of multi-index selection indices, to achieve simultaneous family improvements in growth and wood quality traits for the two final use scenarios considered.

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The Italian network of Mediterranean Pines (*Pinus sect. Halepensis*), their possible use in view of the Global Change effects

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As widely known, the Mediterranean Region is really hard for forest ecosystems. In this area both kinds of climate, the temperate and the sub-tropical one, are overlapped and the ecological equilibria are always endangered. Also the human history influenced since several millennia the distribution and the existence of those ecosystems and, nowadays, it seems that the climate change will increase the risks for forest tree populations with its negative impact. The Italian field experimental network concerning Mediterranean Pines is approximatively based on: 45 provenances, from the natural range of the different Mediterranean regions 150 maternal half-sib families of *P. halepensis*. This material, planted over all the national territory, was obtained through the collaboration among different international organizations, mainly in the framework of IUFRO, FAO-Silva Mediterranea, or directly supplied by CRA-PLF/Roma and CRA-SEL. Several adaptive trait (mainly frost resistance) surveys were carried in laboratory and data collected were confirmed in field tests, along the time, after extreme events. The different behaviour of provenances as well as between species was highlighted. Nowadays new studies are being addressed to put on evidence the behaviour of materials in extreme drought conditions and/or in extreme dry events. The about 30 years old ex situ field test network assumes nowadays an important meaning not only for conservation or woody production, which is marginal, but mainly for studying adaptive traits in view of the climate change effects (i. e. drought resistance/tolerance).

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Impact of Climate Changes on Mediterranean Forest Ecosystems

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The climate changes represent more and more a reality to be controlled and of which it is necessary to seek to limit the impacts. On a sphere scale, we expect an increase in the temperatures as well as sea levels and a multiplication of the exceptional weather phenomena. The climate will change probably more quickly than the natural response time of the forest species through mainly the phenomenon of migration. According to forecasts, certain ecosystems will be unable to adapt to the rhythm of the changes. The food production will suffer from it, just like the water provision. In Morocco, the climatic tendency will appear by an increase in the annual average temperature which could reach 1.1°C by 2020, as well as a disordered state of seasonal precipitations. The vegetable associations of the desert places were extended towards north by gaining approximately a few tens, even a hundred km. At the national level, on the few 7.000 species inventoried, the quarter is regarded as rare or is threatened. The species of flora of high mountains characteristic of the cold zones which lodge a big number of rare species, threatened and endemic are touched. The dendrochronologic study of the cedar also highlighted a loss of strength of growth of the trees of 30%. From the faunistic point of view, a considerable number of animal species in Morocco disappeared these last decades. In the case of mammals 6 species disappeared between 1925 and 1956, including *Oryx gazella dammah*, *Addax nasomaculatus*, *Gazella leptoceros*, and *Alcelaphus* and 2 carnivores (Lion of the Atlas and Serval). As regards the birds, at least ten species disappeared since the beginning from this century like the Ostrich with red neck. About thirty others (approximately the tenth of the total avifauna of the country) is threatened today of extinction. In 2020, the water potential is likely to decrease with the increase in the temperatures and the stressing of the phenomena of evaporation and evapotranspiration. In 2001, a study estimated that the average's flow of surface and underground waters will drop by 10 to 15% between 2000 and 2020. As, and under the effect of climate changes, we estimate that 50% of the wetlands were lost during the 50 last years. In Morocco, nearly 93% of the territory is located in bioclimats arid and semi arid. In fact, it is predisposed more than elsewhere with the phenomenon of desertification. The surface of the cultivable grounds which disappears under sand is estimated at more than 22.000 ha per year. In addition, the potential of production of the pastures is also affected, the level of

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contribution of the forest is 17% in normal year passes to 28% in the event of dryness, the forests then undergo strong pressures in the form of topping, of stripping and trampling . The reduction in phytomasse will also generate a competition between wild animals and pets.

Identification and characterization of genes induced by water stress in *Pinus pinaster* Ait.

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Current climatic models forecast an increase of 1.5-4.0°C in annual average temperatures over the next one hundred years, together with disturbances in the annual rainfall regime. All these models agree in pointing out the Mediterranean basin as one of the most potentially dramatically affected areas. Decrease of annual rainfall is expected in this region, together with an increase, in depth and duration, of seasonal drought. In this scenario, understanding of the molecular and physiological basis of drought stress response in Mediterranean forest species is of the utmost importance. Our model species, maritime pine (*Pinus pinaster* Ait.), is one of the most common conifer species in the Western Mediterranean, profusely used for afforestation in the Iberian Peninsula due to its frugality and ecological amplitude. Notwithstanding its relatively reduced geographical range, the species is adapted to a wide range of ecological conditions, particularly in relation with rainfall regimes and water availability. We hereby report the identification of genes induced in maritime pine by polyethyleneglycol (PEG)-induced water stress in hydroponic culture. Subtractive cDNA libraries (SSH) have been constructed and screened. The putative function of selected genes has been determined by homology with available sequences in public databases (GenBank, NCBI). Selected genes are included in a microarray to follow their stress-induced expression pattern in different tissues. Drought treatment on soil has been performed in order to follow expression pattern of the same genes upon water stress closer to that faced in natural conditions.

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COMPARISON OF GST and QST in *Pinus brutia* BREEDING POPULATIONS WITH RESPECT TO POSSIBLE CLIMATE CHANGES IN THE EASTERN MEDITERRANEAN REGION

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Turkish red pine (*Pinus brutia* Ten.) is mainly distributed the eastern part of the Mediterranean basin. Due to the wide distribution range in different ecological regions, Turkish red pine tree improvement program in Turkey has been concentrated in five main breeding zones based on major climatic and geographical gradients along early genetic test results. To address the possible effects of climate changes on Turkish red pine breeding program, the distribution of genetic variation for quantitative traits (QST) (diameter at breast height, height at ages 4 and 8 and volume at age 8) and molecular markers (GST RAPD data) was estimated for each breeding zones. Diversity estimates in each breeding zones for molecular and quantitative traits are almost concordant, with GST generally exceeding QST, except for height at age 4 in Middle elevation breeding zone of the Mediterranean Region. The comparative analysis of GST and QST indicate that the phenotypic selection is favoring similar phenotypes in different breeding populations. According to climate change scenario in the eastern Mediterranean Region, average annual temperature would increase 2-6 °C and annual rainfall decline 20% between 2070 and 2010 in where Turkish red pine has its natural range. Considering current annual temperature and rainfall ranges (10-25°C and 400-2000 mm) and possible increase in annual temperature and decrease in precipitation due to climate changes, the increase of compartmentalization in turns genetic diversity populations in the breeding zones will be a wise practice since there is low population differentiation in the breeding zone and large variation among the ecological conditions.

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Variation of early reproductive allocation in multi-site genetic trials of Maritime pine and Aleppo pine.

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The onset of the reproductive stage and early reproductive allocation (reproductive vs. vegetative biomass) are amongst the more variable traits in forest species, defining different life history strategies. An early, intense reproduction is generally found in species or populations adapted to environmental constraints or frequent perturbations, while a vigorous vegetative growth and delayed reproduction can be more adaptive in fertile sites with higher levels of competition. Among Mediterranean pines, highly different early reproductive patterns seem to have been selected between and within species under contrasting environments and perturbation regimes. Especially, intraspecific variation in early reproductive features has an enormous potential for tree breeding and conservation programs directed to maintain or improve adaption of Mediterranean pines under a rapidly changing climate. On the other hand, besides ecotypic differentiation, phenotypic plasticity is considered another major mechanism allowing adaptation of forest populations to different environments. Multi-site genetic trials, with families of different provenances tested under several common environments are a privileged tool to unveil the different levels of plasticity and fixity of the ontogenetic program together with its genetic differentiation both within and between populations. We analysed vegetative growth and male and female reproduction in different multi-site progeny and provenance trials of *Pinus pinaster* and *Pinus halepensis* in Spain at their early reproductive phase. Preliminary results showed a marked differentiation among provenances for reproductive allocation, combined with highly variable heritabilities among sites and species. Reproductive allocation seems to show a higher differentiation among populations but lower heritability than growth in height or volume. Analyses are in progress to compare the levels of plasticity for reproduction and reproductive allocation, considering the spatial patterns of variation due to micro-environmental variations and the interactions between abiotic and biotic factors.

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ADAPTIVE GENETIC VARIATION IN ALEPPO PINE SPANISH PROVENANCES GROWTH RHYTHM TRAITS

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Pinus halepensis Mill. has a wide distribution in Iberian peninsula and the populations are locally adapted to very different and stressing environmental conditions. Adaptive traits such as those related to growth and phenology are optimal for understanding adaptation of populations to local conditions in wide distributed forest species. The timing of growth during the fifth growing period of families within nine populations from the Spanish natural distribution range was conducted in a provenance-progeny trial. Individual growth curves were fitted and a set of variables related to growth rhythm was obtained for estimation of genetic parameters. Multivariate analysis for grouping populations didn't show simple geographical patterns of variation and climatic approach is considered. A climatic index based on 19 bioclimatic variables (from worldclim model) is used to plot the additive genetic coefficient of variation by population. Some traits get their maximum in medium ranked climates which can be understood as a disruptive or directional selection but some others don't show any clear trend. Effects of natural selection and adaptive advantages on vigour and phenology of growth traits are discussed.

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Assessment of genetic variability in Portuguese mature stands of *Pinus sylvestris* L. using molecular markers

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Pinus sylvestris L. is widely distributed in Europe, preferentially, through northern cold regions. It is supposed to be native in Portugal but most of the exemplars have resulted from plantation. Nowadays, Portugal constitutes the upper occidental limit of its distribution. As far as we know, the *P. sylvestris* stands located at the North of Portugal were never studied at the molecular level. Thus, with this study we intend to analyse the genetic diversity in individuals from three stands at the North of Portugal using the inter-microsatellite (ISSR) markers. For that purpose, we tested 17 primers for the amplification of ISSRs in 30 individuals belonging to mature stands at three sites (ten individuals per site). Among the primers tested, we selected eight of them due to the production of a higher number of ISSR bands and the production of polymorphic patterns. The results were analysed for the presence/absence of band and each band was considered an ISSR locus. The pool of the ISSR data was used for the construction of an UPGMA dendrogram in order to evaluate a putative correlation between geographic area and genetic similarity. The ISSR markers proved to be useful in the assessment of genetic diversity among individuals belonging to the same stand (intra-local diversity) and among stands (inter-local diversity). *Pinus sylvestris* L. is widely distributed in Europe, preferentially, through northern cold regions. It is supposed to be native in Portugal but most of the exemplars have resulted from plantation. Nowadays, Portugal constitutes the upper occidental limit of its distribution. As far as we know, the *P. sylvestris* stands located at the North of Portugal were never studied at the molecular level. Thus, with this study we intend to analyse the genetic diversity in individuals from three stands at the North of Portugal using the inter-microsatellite (ISSR) markers. For that purpose, we tested 17 primers for the amplification of ISSRs in 30 individuals belonging to mature stands at three sites (ten individuals per site). Among the primers tested, we selected eight of them due to the production of a higher number of ISSR bands and the production of polymorphic patterns. The results were analysed for the presence/absence of band and each band was considered an ISSR locus. The pool of the ISSR data was used for the construction of an UPGMA dendrogram in order to evaluate a putative correlation between geographic area and genetic similarity. The ISSR markers proved to be useful in the assessment of genetic diversity

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among individuals belonging to the same stand (intra-local diversity) and among stands (inter-local diversity).

SOIL MOISTURE SPATIO-TEMPORAL BEHAVIOUR OF *Pinus pinaster* STANDS ON SANDY FLATLANDS OF CENTRAL SPAIN.

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Pinus pinaster stands in the center of the Iberian Peninsula show an ecological singularity, grow on a special hydrologic system: highly permeable soils due to their geological substratum (wind sands), and groundwater table near the soil surface showing short-term oscillations. Over the last few decades, this special superficial aquifer has been overused as a water resource, especially for irrigated crops, leading to a critical level of overexploitation that has caused a water sustainability crisis (rainfall variability does not allow for a sufficient level of aquifer recharge by natural means) and different environmental impacts. This current scenery of change make soil moisture one of the most determining factors of the spatio-temporal changes in ecological response, highlighting the need to go deeper into the knowledge and characterization of complex soil-tree water relationship. In this context, the main aim of the present work has been the evaluation of the influence of root zone soil moisture on the observed spatial response of *Pinus pinaster* stands. Volumetric soil moisture contents were measured in 11 forest sites, along a two years period, using time domain reflectometry (TDR). The results show that the dune morphology associated to the territory is the main driving factor, introducing very different water availability conditions between the monitored hydrological response units, which modulate maritime pine installation and development. The areas of topographic depression are the places more heterogeneous, with different soil moisture behaviours. In these areas, the hardwood forests (reforestation) that grow with the radical system connected to the water table can be the most sensitive to climate change. Consequently, in these pine ecosystems, the role of land form in variations of root zone soil moisture becomes essential and must be considered to develop adequate adaptive management models.

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Changes in the local nutrient cycle of softwood species caused by climate change

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Climate change is causing changes in plants to adapt to new environmental conditions. Trying to prove the existence of climate change with the extent of recent decades temperatures gives us no clear results. However, if we observe the changes produced in the physiological processes of plant species affected by altered weather conditions, we can state categorically that climate change is occurring. One of the most influential processes in the local cycle of nutrients in Mediterranean ecosystems is the leaf abscission. (Escudero y Del Arco, 1987). This process determines the speed of the nutrient cycle as a function of duration of leaf abscission. But also regulates the cycle of nutrients lost locally because it affects specially upon the process of nutrient retranslocation which entails the withdrawal of nutrients from leaves before they fall off (Del Arco et al., 1991). As the leaf abscission process determines the loss of nutrients, it also influences the residence time of nutrients in leaf biomass (Escudero et al. 1992) and, therefore, the conservation of nutrients in Mediterranean ecosystems. In this work, to show that there have been changes in these physiological processes as a result of climate change, we compared the values of the time and duration of leaf abscission process, retranslocación and residence time of nutrients in two conifer species (*Pinus halepensis* and *Pinus pinea*) taken by the research team three decades ago with those taken recently. The final result shows that there has been, over the years, a change in the leaf abscission process reflected in a time of maximum advance of abscission and an extension of the duration of leaf abscission. These changes are caused by the premature arrival of summer water deficit due to higher temperatures and increased transpiration. This is negative for the intensity of retranslocación of nutrients (Del Arco et al., 1991). If recycling of nutrients is carried out with less intensity, there are more losses and impoverishment of ecosystems dominated by these two species. However, the residence time of nutrients such as nitrogen and phosphorus is not affected because leaf longevity of both species is not significantly reduced.

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Climate change impact on carbon sequestration prediction in pine ecosystems based on the FOREST-BGC

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Growth and survival of plants as well as their geographical distribution are determined by the climate, particularly by temperature and precipitation. Seasonal variation of these variables is particularly important in climates with Mediterranean influence like Continental Portugal climate. The actual scenario, points out to global climate change, with direct negative impacts on terrestrial ecosystems, and repercussions in various sectors. Net primary production (NPP) is a key variable for ecological studies because it allows monitoring the impact of climate change on ecosystems. This is particularly important towards meeting Kyoto Protocol requirements, as the annual NPP represents the net amount of carbon fixed by plants through photosynthesis each year (Melillo et al., 1993). One way to estimate the NPP is to use ecophysiological models such as FOREST-BGC. The estimation of this variable was carried out with dendrometric data collected in stands of pine located in Boticas. After NPP estimation climatological and statistical analysis of daily time series of temperature and precipitation from the meteorological station of Vila Real were done. The next step of the study consisted on running the Forest-BGC based on climate evolution scenarios for Vila Real district, based on available climate series. Firstly temperature was the only variable changing, secondly the precipitation was varied and finally both climatic parameters were simultaneously varied. The results of NPP present different values for temperature and precipitation changing scenarios or for both parameters change.

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TEMPORAL VARIATION AND CLIMATIC INFLUENCE ON RESIN PRODUCTION IN MARITIME PINE

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Resin is an important product of Mediterranean *Pinus pinaster* Ait. forests in Central Spain. Nowadays, resin production profitability and thus, its sustainability, highly depends on resin market prices but especially on social factors. Some new resin harvest methods have been developed in the last twenty years that could improve the quality of the product, work conditions and efficiency of process. In order to compare new and traditional resin harvest methodologies in Mediterranean maritime pinewoods in Central Spain a R+D project is being developed since 2006 by CESEFOR. Within the framework of this project the present work has the objective of studying the pattern of tree resin production under two harvest methods taking into account its relation with climatic conditions. Data comes from two study sites located in the Northern Plateau of Spain. Each site has five replicates per treatment, with 40 trees per plot. Each tree was visited every 3 days during the four resin harvest campaigns 2006-2009. The traditional method consists on inducing resin flow with 8-10 horizontal chippings each campaign, applying commercial resin stimulant paste (sulphuric acid) every 14 days. The alternative method consists in 6 mechanic bark perforations connected with plastic bags. Temporal variation of resin production within years and within chipping intervals have been analyzed, as well as climatic and treatment effects. Due to the hierarchical structure of data (site, plot and tree) mixed models have been used for the statistical analysis. Results of the study allows the productive sector to adapt resin harvest to climatic change and global change through the optimization of resin harvest methodology (number of chippings, frequency of visits, length of harvest campaign).

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POST-FIRE ACTIVE RESTORATION AND ASSISTED NATURAL RECOVERING IN *Pinus halepensis* Mill. FORESTS

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The forest fires in the Mediterranean areas are an historical natural disturbance but also an ancient tool used by the human to manage the landscape. The Mediterranean ecosystems are used to be well adapted to this fire-prone habitat. For some time to now, their number, the burned surface, the period of fire risk, fire recurrence and severity have been increasing, mainly in the last decades. The problem is higher in dry and semiarid areas which suffer higher erosion (intense rainfall events) and the low water availability what could reduce the resilience of the ecosystem. According to the prediction of the climate change model scenarios, the precipitation is going to decrease but the severe drought events are going to increase. To face up to this problem, Forest planning should include consideration of fire risk, fire prevention and post-fire principles. Also, it must include the assessment of forest vulnerability and resilience to fires, such as initial floristic model recovering, soil erosion or runoff risks, flash floods, etc. Therefore, the identification of vulnerable areas (prior to fire events) and the restoration or assistance to natural regeneration of burned areas should be a major priority in forest planning. The post-fire ecosystem development should be included, taking into account vegetation types (adaptive strategies and resilience), stand structure and influence of climatic gradients (the same ecosystem may respond in a different way depending on climatic variables). In the long term, it could be considered also as a prevention and minimization tool, reducing the negative effects of wildfires in the ecosystems. The first step is to know the intensity and severity of the fire to preview restoration and protection techniques as soon as the fire was extinguished. Later, the assistance to natural recovering should be implemented accordingly to the post-fire conditions and natural regeneration success in order to support the natural processes or to improve the ecosystem development. Also, active techniques could be useful to restorate soil and vegetation in some areas. The final objective should be to implement ecosystem management strategies to recover and improve the ecosystem recovering, improving their resilience and promoting the mitigation of the effects of global change and the sustainable use of the ecosystem services. To implement it and support decisions with scientifically knowledge, we have been carried out several researches in burned areas in the Eastern and South-eastern dry Mediterranean area

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of the Iberian Peninsula. From early 90's to nowadays, we followed the natural regeneration in different pine stands and carried out different silvicultural managements in order to obtain the optimal tool to achieve the proposed objectives. We carried out some studies about the effect of the removal of burned wood after the fire in different periods and the inter and intra-specific competition of the Aleppo pine with other species, both above and below ground. In areas without natural regeneration we studied the optimal preparation (micorrhized) and provenance of plant seedlings for plant survival and success into reforestate the non-recovered areas. In different quality sites, we carried out scrubbing, pruning and several thinning intensities to check the effect on the demography, growth, cone and seed production and the seed quality. We tried also to distinguish their effect on biodiversity, allometric relationships and the induced differences in productivity and carbon storage. We found synergy with the obtained managements, the CBH (Canopy Base Height) was increased and we were reducing the active crown fire risk. The same result is not achieved through pruning, since it results in only a couple of meters of fuel reduction and could reduce the growth and productivity of the stand in the young stages. So the optimal thinning intensities applied in young naturally regenerated areas have been proven to increase the main species resilience and productivity including improvements for other objectives, such as diversity and soil protection.

Environmental gradients and morpho-functional characteristics of *Pinus halepensis* after reforestation

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Climatic predictions consider the Mediterranean region as one of the most important hotspots of climatic change in the world. Rainfall is expected to decrease and become more variable. In this scenario, it is determinant to increase our knowledge about the physiological and morphological traits of young plantations in response to increasing climatic aridity with the objective to design future strategies and make decisions about reforestation plans and results. With this purpose, we studied 15-year-old *Pinus halepensis* reforestations established simultaneously with the same genetic source, nursery cultivation and plantation techniques in an environmental gradient that includes dry and semi-arid Mediterranean climates in Southeast of Spain.

Our results show that some morpho-physiological characteristics of seedlings responded to a combination of rainfall and soil texture types. This relationship is consistent for growth and water use efficiency evaluated through the determination of carbon isotopic composition ($\delta^{13}C$) in wood samples, but is less obvious for other morpho-functional parameters like leaf area/sapwood area ratio, specific leaf area or wood density. However it has been found that these relationships are dependant on the climate type. In dry climate, growth increased and water use efficiency decreased with increasing rainfall and decreasing clay content in the soil. In semi-arid climates no clear trend for growth was observed, but water use efficiency tended to increase with increasing rainfall and decreasing clay content in the soil. Minimum water potential reached at the mid summer was strongly related to plant height regardless the climate type considered. These results suggest that *Pinus halepensis* acclimation to environmental gradients is mainly driven by a control of its water status that includes moderated plant development and increased water use efficiency at leaf level. The results in the present work should be taken into account for predictions about *Pinus halepensis* responses to reforestation and to improve the design of reforestation actions/plans in a framework of changing climate conditions/predictions.

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SITE INFLUENCE ON *PINUS PINASTER* AIT. STEM FORM OF 43 PROVENANCES ON 5 LOCATIONS IN CENTRAL SPAIN.

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Influence of phytoclimatic and physiographic factors on *Pinus pinaster* Ait. stem form parameter is analyzed. Stem form, measured on a subjective scale from 1-good quality to 9-poor quality according to straightness and verticality, were analysed at age of 19 and 34 years, on 5 test locations (four replicated complete block design of 43 provenances) in Central Spain. The influence of each design factor, as provenance, site and block and their interactions on stem form parameter is also analysed. Winter precipitation (December, January and February), Pw, precipitation of the warmest month, PMTMAX, and lowest monthly mean temperature, TMF, were calculated on each stand from which seed was collected. Potential radiation was computed using r.sun radiative transference model (©JRC Institute for Environment and Sustainability, 2003). As for the orographic effect it was analysed by computing an hemispheric viewshed with the DEM 250 MONA pro Europe provided by DG-Joint Research Centre of the European Commission. The spatial resolution of this DEM is of 0,0025° (approximately 278 m in UTM projection, Zone 30). Finally, cloudiness was obtained from cloud masks derived from multitemporal satellite imagery recorded on a daily basis by the AVHRR instrument on board of NOAA satellites (National Oceanic and Atmospheric Administration - NOAA. NESDIS/NCDC. Climate Services Division. Satellite Services Branch. USA). To this purpose, NOAA daily images for the period 1987 - 2004 (resampled at 1 km resolution) were provided by the Remote Sensing Laboratory of Valladolid University.

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Climatic causes of forest decline due to global climate change in Mediterranean pine forests in southeastern Spain.

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The current climate change involves an increase in extreme weather events like droughts. The impact of these events on the growth and vigor of Mediterranean tree species and their relation to processes of decay has not been evaluated taking into account the geographical and specific differences in growth response to climate. We report on the 40-year dendrochronological history of an artificial population of *Pinus sylvestris* L., *P. nigra* Arnold., *P. pinaster* Aiton., *P. halepensis* Mill. in southern Spain. *P. nigra* and *P. sylvestris* forests are in an advanced state of decline. The tree ring dataset exhibits a marked decrease after the 1994-1995 severe droughts. In addition, a reduction in growths occurred over the last 20 years, indicating the occurrence of small-scale climatic disturbances. *P. sylvestris* exhibit a marked growth decline in 1994-1995 in both locations (Baza-Filabres, Andalusia) for damaged and no-damaged trees. These symptoms or severe growth declines are less present in other pines and growth was more similar for damage classes along 1990s. The growth in all species presented a significant and positive relationship with precipitation in May and June of the year of ring formation. The growth of defoliated trees responded to water stress more than the least defoliated trees in Filabres. Basal area increment (BAI) was modeled as a function of tree size and environmental variables by means of mixed effects models. This trend was associated with decreased precipitation, and increased temperature. Our results suggest that stocking locations in sub-optimal Mediterranean pine species plantations in the southern Spain may be particularly sensitive to direct and indirect anthropogenic impacts and climatic variations, and represent important benchmarks for short-term studies of global change and forest impacts, the pines plantations in southeast of Spain will not be viable in the long run if the frequency of extreme droughts increases.

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Drought and Heat induced Forest Dieback in Algeria

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Algeria is affected by several disturbance of forest ecosystems (pine, cedar and oak), in particular those situated in the semi-arid bioclimatic areas, which are influenced by the climate of the Sahara desert. Atlas cedar (*Cedrus atlantica*) occurs in northeastern Algeria, distributed in scattered mountain populations near the limits of its bioclimatic tolerance between the Sahara Desert and the Mediterranean Sea. Since the onset of severe drought from 1999-2002 cedar forests have undergone mass mortality, affecting all age classes. While all Algerian cedar forests are affected, the magnitude of mortality varies along a steep moisture gradient, with die-off greatest (up to 100%) in the drier mountains nearest the Sahara, dropping to much lower mortality levels in the moister coastal mountains. Prolonged soil moisture deficits lead to decline and progressive death of cedar trees over a period of 1-3 years a variety of insects and fungi have continued to kill weakened cedar trees since the drought eased after 2002. The *Cedrus* mortality began as small patches on drier aspects in the arid near-Sahara mountains, eventually coalescing into large patches affecting all ages on all exposures. In contrast, only small patches of old trees on dry aspects have died in more mesic regions near the coast. This recent drought also triggered substantial mortality in other Algerian tree species, including *Pinus halapensis*, *Quercus ilex*, *Quercus suber* and *Populus alba*. Dendrochronological reconstructions of drought in Algeria show that this early 2000s dry period was the most severe drought since at least the middle of the 15th century, consistent with climate change projections for a trend of increasing aridity in this region. This paper highlights how physic and biotic factors of stress that can behave in a consecutive or concomitant way to induce this forest ecosystem die-off. This study is intended as a call to consider the role of different factors involved in this process namely: (i) Factors of predisposition, which weaken the ecosystems (Climate warming, reduction in precipitations ?) (ii) The Factors of incentive, which support the appearance of the imbalance symptoms. They act in an intense way over a short period, can be of physic origin (extreme climatic events) or of biotic origin (defoliator insects: Coleoptera, Lepidoptera or cryptogrammic agents). (iii) Factors of contribution that accentuate the disturbance: Abiotic stresses, xylophagous coleopters, fungus causing rot, ...

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Keywords: Algeria, *Cedrus atlantica*, forest die-off, drought, heat, massive mortality.

Effects of climatic change in the distribution of *Pinus sylvestris* L. stands in Spain. A previous phytoclimatic approach based on projected future climate conditions

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This paper presents some contributions to the possible effects of climatic change in the distribution of *Pinus sylvestris* L. stands in Spain. We study the phytoclimatic status of scot pine in current climate conditions (period 1951-1999) and in projected future climate conditions (2050) downscaled from the Global Climate Model Global Climate Model CCCMA (Canadian Centre for Climate Modelling and Analysis) and the emission scenario A2a. The phytoclimatic diagnosis follows a modified version of the Allué-Andrade phytoclimatic system. This calculation determines potential areas of high phytoclimatic viability for scot pine totalling 3.202.900 ha in current climate conditions and only 389.800 ha in 2050 conditions. In current climatic conditions the instances of highest phytoclimatic suitability occur in a range of altitude between 1600 and 2000 m and in projected future conditions between 2000 and 2400 m. The average altitude of occurrence is increased in 400 m (from 1364 m in current conditions to 1758 in projected future conditions). In phytoclimatic terms, the highest values of suitability correspond chiefly to the oroborealoid transitional to nemoral subtypes (VIII(VI)1 and VIII(VI)2) in current conditions but in projected future conditions the highest values correspond to areas currently assigned to oroarticoid transitional to oroborealoid subtypes (X(VIII)). The lowest scores of viability are found in the southern half of the Iberian Peninsula and in nemoromediterranean subtypes. The stands of *Pinus sylvestris* seem will not be viable in these areas and subtypes since 2050.

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RESPONSE OF POST-FIRE *Pinus halepensis* Mill. REGENERATION TO THINNING IN MEDITERRANEAN FORESTS OF SOUTH-EASTERN

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One among many of the great fires occurred in 1994 in Spain devastated large areas of Mediterranean forests in the south-eastern part of the country. More than 24000 hectares of natural stands of *Pinus halepensis* were affected, mainly in Murcia. Natural regeneration after fire was explosive and seedling density was excessive in almost all burned areas. 14 years after fire, Murcia Forest Service started a project (REPLANT) to improve stand conditions, carrying out different management practices: pre-commercial thinning, reforestation, phytosanitary treatments... In relation to pre-commercial thinning, it can promote the development of remaining seedlings. In addition, pre-commercial thinning is a good tool in order to reduce fuels that could contribute to wildfires. The study zone was located in the surroundings of the Sierra del Cerezo (Moratalla). Twenty nine 5-m radius plots were established in June 2009, covering different ecological and silvicultural situations: year of the thinning, with categories T2 (two years ago), T3 (three years ago), T4 (four years ago), T5 (five years ago) and T0 (without thinning) and exposition, with U (north aspect) and S (south aspect) categories. In each plot, the height, basal diameter and diameter at breast height of all trees were measured. Pine cones were counted and classified in three groups according to their ages. Companion vegetation was typified (species, coverage and height). Three trees per plot were chosen and were cut into five pieces. Sample discs were extracted and labelled for laboratory procedures. Tree rings were counted and diameter growth was calculated by means of a scanner and the program Windendro®. The objective of this work was 1) to analyse the effect of pre-commercial thinning on regeneration growth by means of dendroecology and 2) to analyse some regeneration variables and reproductive aspects in relation to the thinning.

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Descriptive statistics and principal component analysis of environmental variables in *Pinus halepensis* Mill in Castilla and Leon (Spain)

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In this study we focus on the principal component analysis (PCA). The PCA is a technique used to reduce the dimensionality of a dataset in which many interrelated variables. The objective of principal component analysis (PCA) is to reduce the size of a set of variables "p" to a set of fewer variables to improve the interpretability of data. In our case, the analysis is performed with fourteen environmental variables in order to reduce them to fewer, losing as little information as possible and analyze the relationship of factors with the initial variables. Then carried out the analysis of variance (ANOVA) for the fourteen variables under study: Evapotranspiration (ETP), Total annual precipitation (Tap), Rainfall for winter (Rw), Precipitation fall (Pf) Precipitation spring (Psp), Summer precipitation (Psu), Autumn precipitation (Ap), Precipitation maximum temperature (MaxT), Average temperature (AT), Minimum temperature (MinT), Drought (D), Slope (S), Height (H), Soils (S). From the extraction of factors is better understood the structure of environmental variables for the establishment and development of *Pinus halepensis* Mill in Castilla y León (Spain). According to the analysis, the variables that better reflect physiographic-climatic characteristics of the territory for *Pinus halepensis* have been seven: ETP, Psu, Rw, Ap, Psp, Tap and MaxT.

The principal component analysis (PCA), has allowed us to establish a model for estimating the quality of bodies and elucidating the potential areas of distribution of the species. The best areas have been located in the provinces of Palencia and Valladolid, in the Duero basin in the lake areas corresponding to the "Facies Cuestas".

Keywords: Principal Component Analysis (PCA), Environmental variables, *Pinus halepensis* Mill, Potential areas of distribution.

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Predicting growth of radiata pine plantations in Chile under climate change scenarios by a simple approach using yield tables and a process-based grow

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Future climate scenarios have been predicted for Chile and downscaled to local predictions for annual and monthly mean temperatures and precipitation. Given these predictions, timber industry and the Chilean government have raised questions about the likely changes in tree growth and productivity and about the consequences for the economy. As part of a larger research effort to develop forest management adaptation strategies for climate change, this work presents a simple approach to estimate the growth under climate change scenarios A2 and B2 for unmanaged radiata pine (*Pinus radiata* D. Don) plantations in three different zones in Chile, representing high, medium and low productivity areas. Using as a reference the yield tables produced by the empirical growth and yield simulator RADIATA, and the yields derived from 3-PG, a process-based yield model for forests, we developed yield tables for these plantations under climate change scenarios A2 and B2 scenarios. The prediction uses the signal derived from 3-PG, that is driven in part by meteorology, and the relationships between the yields estimated from RADIATA and 3-PG under current climate conditions. Results indicate productivity will be deteriorated to different degrees in low and high productivity zones while the medium productivity area indicates a slight increase in productivity. Research is extending the analysis to different site indexes stands within each productivity zone.

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Regenerative strategies of *Pinus pinaster* and *P. radiata* in relation to fire

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Pinus pinaster Aiton y *Pinus radiata* D. Don are two of the most widely used species in forestall repopulation throughout the world. Both species are obligate germinators. This study analyses the regenerative strategies of these two pine species, mainly from information obtained in the NW Iberian Peninsula. Both species have an aerial seed bank available from seeds stored in their cones. This characteristic protects the seeds from depredators and the high temperatures generated during wild fires. However, the serotinity of both species is different: low in *P. pinaster* and high in *P. radiata*. Because neither of the two pine species can resprout, the temporal and spatial continuity of their populations depends entirely on germination. High temperatures either do not modify germination or they inhibit it, especially in the case of very high temperatures and/or prolonged exposition. The ash resulting from a wild fire generates similar responses: at low concentrations germination is not modified and at high concentrations inhibition is notable. Moreover, it has been proven that the smoke does not affect the germination of *P. pinaster* and, possibly, that of *P. radiata* either, because it does not modify the germination of other species that have a similar germinative behaviour. The age of the seeds before germination has been another of the factors studied in relation to fire that has shown different results in *P. pinaster* and *P. radiata*. The seeds of *P. pinaster* of different ages do not present important variations in their response to the fire factors. On the contrary, the *P. radiata* seeds present significantly higher germination rates the younger they are. The group of regenerative features relevant to the germination strategy and their intensity allow us to understand and predict the responses of pine populations to disturbances caused by fire.

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Combined tools to estimate stand carbon stocks for a Mediterranean pine (*Pinus pinea* L.) using inventory data

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We present the results of a study carried out in Portuguese *Pinus pinea* L. that intended to evaluate the carbon stock and sink capacity of stands managed for pine nut production (AGRO/8.1/543/2004 “Carbon sequestration and sustainable forest management in south Portugal”). Here we present a set of combined tools for forest managers concerning carbon factors and equations that allow estimating stand-level carbon stocks in *Pinus pinea*, regardless of the tree inventory information available. We provide a quantification of the errors on using species-specific allometry and expansion factors compared with generalized methods. The higher error percentage reached 38% using the biomass expansion factors (BEF) approach, meaning that generalizations can lead to highly biased forest carbon stock estimates. For this we harvested 53 trees in centre and south Portugal covering different sizes (min-7 max-56 cm), ages (10 to 50 years) and spacing (20 to 580 trees. ha). Aboveground biomass and volume equations were developed as well as BEF by component. Basic wood density and component carbon concentration was calculated and a preliminary root/shoot ratio was computed using 6 trees, where root system was completely excavated. The results indicate that the aboveground biomass allometry in *Pinus pinea* is considerably different from other pines. Stand conditions affected biomass partitioning, mainly the crown biomass, and the BEF aboveground and allometric equations developed account for these characteristics. Wood basic densities also vary statistically between tree dimension classes, highlighting the need for stand-dependent factors. No significant differences were found between using the carbon concentration by component and the 0.5 conversion factor. The preliminary root/shoot ratio of 0.3 is consistent with other studies on pines.

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Seasonal changes in the physiological activity of regeneration under a natural light gradient in a *Pinus pinea* regular stand

Pardos M., Puértolas J., Madrigal G., Garriga E., de Blas S. & Calama R.*

We studied the seasonal changes in the relationship between soil water availability, physiological responses and water stress along the day, of natural regenerated *P. pinea* seedlings, under a natural light gradient in a *P. pinea* regular stand in Central Spain. Regeneration was divided in four age classes: 1-year old seedlings, 2-years old seedlings (6-20 cm), 21-50 cm and 51-200cm. Measurements were made each month at predawn (chlorophyll fluorescence and leaf water potential), in the morning (chlorophyll fluorescence and gas exchange parameters) and at midday (chlorophyll fluorescence and gas exchange parameters and leaf water potential), during 2007 and 2008 growing periods and in winter. Soil water moisture and height were also recorded in the same dates. Leaf water potential (which ran in parallel to soil moisture) was minimum during mid-summer, but recovered in the fall. During summer, 1-year old seedlings showed the highest water stress. Chlorophyll fluorescence showed minimum values in summer, but mainly during winter. Again, 1-year old seedlings showed the steepest decline in chlorophyll fluorescence, in comparison with the other age classes. Gas exchange parameters also showed a remarkable seasonality. Our results showed the clear seasonality of the physiological measurements, which was more remarkable than differences due to the age class. However, it is worthy to note the different physiological behaviour of seedlings according to their age, during the dates when environmental conditions were limiting. In those dates, seedlings under 20 cm (one and two years old seedlings) were highly stressed. Our results showed how summer drought affects to the earliest stages of *Pinus pinea* seedlings and is a major constraint to *Pinus pinea* regeneration. Increased intensity of summer drought, as predicted by global change scenarios for the Mediterranean region could be a serious threatening to *Pinus pinea* early regeneration stages.

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Regional Stem Profile and Volume Equations for Brutian Pine in Western Mediterranean Region of Turkey

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Brutian pine (*Pinus brutia* Ten.) is the most common and important commercial tree species in Turkey with a current standing volume of approximately 270 million m³, occupying areas of about 5.4 million. With ever changing market conditions, there is a need to accurately estimate tree volumes utilizing multiple upper stem merchantability limits. This is not currently possible with the existing total stem volume tables for this species. Differences in tree form and taper can be influenced by climatic fluctuations, site quality, tree species, stand age, stand density, and defoliation. Taper functions have been commonly used as a means to express mathematically the change in stem diameter based on the interaction of these factors. If tree taper can be accurately described, then volume for any merchantability limit can be accurately predicted. We present taper and volume equations for brutian pine that necessary for scientific management and practical forestry operations of the species. Some segmented taper equations were used to develop compatible volume and taper equations for Brutian pine in Mediterranean Region of Turkey. Parameters for compatible volume and taper models were simultaneously estimated using seemingly unrelated regression fitting procedure to volume based on an overlapping bolt method. The statistics indicated that the segmented taper models provide needed merchantable stem volume and diameters estimates to any point in the along the stem for Brutian pine. The derived volume from the taper equation was also compared to existing total tree volume equation for Brutian pine. The error analyses showed the segmented taper equations provided an accurate and precise alternative total tree volume tables. Based on the results obtained, it is recommended that segmented taper models be considered operationally for practical forestry in these regions point of view estimate volume.

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Influence of vegetation control and fertilization on *Pinus pinaster* timber production and on understory vegetation

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To study the influence of controlling understory vegetation and N, P and K addition on pine growth and competing vegetation, a field trial was established in a 6-year old pine forest. Five treatments were tested: control (T), vegetation cutting and removal (CR), vegetation cutting, removal and fertilization (CRF), vegetation cutting and chipping (CD), vegetation cutting, chipping and fertilization (CDF). Treatments were replicated three times and arranged in completely randomized blocks. The average plot size was 782 m² and there was, on average, 115 trees per plot. Pine volume was determined between 2002 and 2007 and understory vegetation was surveyed, quantified and analysed in 2002 and 2003. On average, CDF treatment lead to the biggest ($p < 0.05$) increase in volume (9.6 m³ ha⁻¹ year⁻¹) while the lowest increase ($p < 0.05$) occurred in treatment CR (5.1 m³ ha⁻¹ year⁻¹). In Control and CRF and CD treatments, the average increase in volume was similar (6.4 m³ ha⁻¹ year⁻¹). When understory vegetation was removed, CR and CDR treatments, nutrient output was rather large, specially N output since *Ulex minor* was in 2002 the dominant understory species (65 %). From the 162 kg N ha⁻¹ exported, 133 kg were exported by the *Ulex*. CD treatment was the most effective in reducing the understory vegetation (-76%), followed by CR (-65%), CDF (-57%) and CRF (-46%) treatments. In Control, vegetation biomass increased 48%. These results point out that removal of understory vegetation, for instance to be used in biomass centrals, should be considered only if fertilizers were applied in order to avoid negative effects on pine growth. Chipping of vegetation avoids nutrient output, is an effective method in decreasing the amount of fuel, hence in decreasing pine forest flammability, and if used with fertilizers leads to a significant increase in pine growth.

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Seed mass and seedling performance variation according to mother plant age in *Pinus nigra* subsp. *salzmannii*

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Rising temperatures and drought resulting from climate change may negatively affect seed size, thus limiting tree regeneration as it is generally accepted that seedlings which develop from larger seeds are better prepared to withstand stress or perturbation. On the other hand, new silvicultural systems recommend management strategies which favor currently under-represented age classes and older trees. In the case of *Pinus nigra* subsp. *salzmannii*, trees tend to produce seeds with a smaller mean mass as they age. As a result, it can be argued that stand regeneration of *Pinus nigra* subsp. *salzmannii* might be limited in these ways in future scenarios. In this paper, I present results from a preliminary study of seed mass variation and seedling performance in a natural population of that species, located in the Sierra de Cazorla (Southeast of Spain). From each of eight different trees, with ages ranging up to several centuries, at least 30 cones were collected, opened in an oven, and a sample of 100 seeds used to investigate intra- and inter-individual variation in seed mass. These seeds were then sown in pots, and seedling performance (emergence, survival and growth) monitored for one growing season. Seed mass proved to vary between trees and between cones from the same tree, with older trees producing smaller seeds. Seedling emergence and survival were not affected by seed mass, or mother plant age. However, seedling growth was positively correlated with seed mass, though dependent on maternal origin. Integrative measurements, such as overall biomass, were positively related to seed mass, but the importance of this effect varied amongst mother plants. Thus, seed mass alone is not enough to predict the contribution of old trees to stand regeneration or the effects of a hypothetical reduction of seed mass during climatic change.

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Pine-herbaceous layer interaction is decisive for the conservation of biodiversity in semi-arid sandy substrates of central-northern Spain

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Plant - plant interactions are among the most important processes for the structure of communities in arid and semiarid ecosystems. Of especial relevance is the presence of perennial neighbours, which may facilitate the occurrence of many herbaceous species absent from open sites. A few recent works have suggested that the overall outcome of these interactions would be decisively affected by the spatial scale of study. In the particular case of Mediterranean pines a reduction of the understory herbaceous species richness is expected due to a number of negative impacts related to resilient litter fall, acidic organic matter and allelopathic substances. On the other hand, a different pool of species underneath pine canopies is expected to occur in contrast to open areas, which may provide a significant increase of species richness at local scale if climatic/edaphic harshness limits the establishment and growth of herbaceous plants outside the influence of pines. Data on the abundance of herbaceous species were collected in pinelands of central Iberian Peninsula (Spain) following a nested sampling design. Results show a rough taxonomic segregation of herbaceous species associated to the influence of pines at neighbourhood scale. These species of open sites are substituted by few different species exclusive of the understory. The results strengthen the idea of pine - herbaceous layer interaction being scale - dependent, since the overall negative and positive effects on diversity may vary with the spatial scale of study. Additionally, this revealed decisive at the time to evaluate the importance of pine forest management for biodiversity conservation in a Global Change scenario where more arid conditions are predicted for the Mediterranean area of central northern Spain.

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Variation in biochemical stress indicators among *Pinus pinaster* genotypes

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We analysed several biochemical stress indicators: proline ($\mu\text{mol/g PF}$), abscisic acid (ABA), jasmonic acid (JA), indolacetic acid (IAA) and salicylic acid (SA, ng/g PF). Three *Pinus pinaster* populations and several families per population from the French Lands, interior Spain and Morocco were chosen in two provenance-progeny trial sites. The environmental effect was remarkable, as striking differences between sites were obtained for all indicators except for SA. As expected, the production of metabolites increased in the xeric site. Variation was displayed among families ($P < 0.0001$) but not among populations. A genotype by environment interaction was observed in proline and ABA. The French population displayed the higher proline and ABA values in the xeric trial site. The plasticity of these two stress indicators and its genetic variation at the family level would be useful for the selection of resistant genotypes in the framework of global warming.

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Providing silvicultural models to reduce crown fire hazard in *Pinus sylvestris* stands

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In the Mediterranean basin the likelihood and impact of wildfires might increase in the near future due to climate, environmental and social changes leading to drier periods, higher fuel loads and more ignition sources. In a context of global change, active crown fires pose a significant and growing threat to forest managers, who need tools for fuel management. Using an expert opinion approach we have developed a key based on the main structural and silvicultural variables that play a significant role in crown fires. The key has been designed to rank pre-fire stand conditions for the initiation of crown fires in *Pinus sylvestris* stands. The key has led to a total of 24 types of forest structures, ranked as A (high vulnerability to the initiation of active crown fire), B (moderate) and C (low). In addition, silvicultural models have been prepared in order to reduce crown fire hazard for each type of the defined forest structures, taking into account the percentage of surface fuel cover, presence of ladder fuels, height to live crown and percentage of forest cover. We discussed the effectiveness of treatments such as thinning from below, pruning and understory removal to reduce canopy bulk density, increase live to crown base and reduce surface fuel load for each rank.

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Forestry students' attitudes towards forest Biotechnology: a tool to fight global warming

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The common perception of forest biotechnology, giving special thought to forestry education by answering the main issue of this century Forestry, Biotechnology and Climate Change will be highlighted. Also, advances in forest biotechnology, drawing attention to Pine genus, possibly able to shape the new forests of the 21st century will be underlined.

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FREEZING DAMAGE OF SIX *Pinus pinaster* AIT. POPULATIONS MEASURED ON SEVERAL TISSUES (NEEDLES, BUDS AND STEM) USING DIFFERENT SCREENING METHODS

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Abstract: Several screening methods were used to study the genetic variation in freezing damage among six populations of Maritime pine (*Pinus pinaster* Ait.) coming from the whole range of distribution of this species. Three of these populations come from the Atlantic coast, while the other three come from the Mediterranean area. Visual scoring, electrolyte leakage and chlorophyll fluorescence screening methods were compared. Twigs were collected in March from saplings (4-year-old trees) of 54 open-pollinated families from the six populations in a provenance-progeny test and were subjected to artificial freezing. Damage to each twig was assessed on three different tissues: bud, needle and stem using visual scoring and electrolyte leakage, while the chlorophyll fluorescence method was only employed on needle tissue. Population differences were significant ($p < 0.05$) no matter which tissue or screening method was used. As regards the several tissues assessed, there is a lack of correlation between the damage measured on the different tissues, especially between the damage measured on the needles and the damage assessed on the other two tissues. Hence at least two damage traits (one in needles and one in any other tissue) should be evaluated when freezing testing is done during spring for predicting the actual damage. As regards the several screening methods used, any of the three assessing methods can be used when evaluating needles, since the correlation between the different methods is significant in all cases. For this tissue, the chlorophyll fluorescence was found to be an easy and quick method for assessing freezing damage in needles. However, no correlation was found between visual scoring and electrolyte leakage when working with the other tissues.

Keywords: Maritime pine, freezing resistance, visual method, electrolyte leakage, chlorophyll fluorescence.

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Implementing the OSU vigour test for early assessment of drought tolerance in Maritime pine.

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Searching a reliable method to assess tolerance to water stress in forest species in the nursery or the greenhouse has become a puzzling issue in the last decades. Especially, genetic improvement programs typically work with many genetic units (from dozens to hundreds), but at the same time searching for enhanced drought tolerance has become increasingly common in programs carried out in southern Europe, such as the Maritime pine program in Spain. In fact, the problem has two main faces: firstly, defining clearly the levels of water stress that maximize differences among genotypes, and second, quantifying the response. Polietilenglicol-induced drought stress in hydroponic solutions combined to isotope discrimination techniques has been recently postulated as a promising tool, but still important drawbacks need to be solved. The vigour test was firstly implemented at the Oregon State University and was initially thought for comparing planting stock quality of bare-root seedlings. Further modifications were introduced and published to adequate the initial protocol to containerised seedlings. Basically, this test consists of extracting a plant from the rooting media, drying the whole plant in a chamber with controlled temperature and humidity, replanting it and quantifying survival after a given time lapse. If it cannot be considered a fast or cheap method, its main goal is its simplicity and repeatability, once the protocol parameters have been adjusted for a given plant material. We used seedlings of different provenances of Maritime pine, chosen to represent contrasting adaptive behaviour facing drought, to obtain a protocol that maximised responsiveness and genetic differences. We checked different temperatures and duration of the desiccation period, quantifying the effect of seedling size and water loss during the experiment. In this communication we will present the results of three sequential experiments, and discuss the applicability of the method as a phenotypic evaluation tool.

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Basal area increment models in *Pinus nigra* Arn incorporating climate variability.

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Tree diameter growth depends on stand characteristics, inter-tree competition, and climate. Forest tree growth rates have been generally modelled using the first two components, leaving out the high frequency variation caused by climate variability. Therefore, the differences between actual and predicted growth could be explained as a function of climate. In this study, annual basal area increment (BAI) of *Pinus nigra* Arn. was modelled as a function of stand characteristics, tree size, and climate variables using linear mixed effects models. A multilevel approach was used because of the hierarchical structure of the tree-ring data set from permanent sample plots from three different regions in Eastern Spain. The effect of competition on BAI was analysed by means of different distance independent competition indices. Climatic data specific for each region was considered. Our results showed that tree growth strongly depends on autumn to spring precipitation and spring temperature, although some differences between regions on the climate forcing of growth were observed. Including these climate variables improved the models and reduced their residuals, capturing as well growth variability at the inter-annual scale. These new models improve the descriptive and predictive power of former models, and might appear especially useful to assess growth under different climate change scenarios.

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Spatial patterns of Scots pine post-harvest regeneration at different scales in a Mediterranean forest

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Silvicultural treatments are known to condition natural regeneration distribution patterns by altering both forest canopy structure and soil characteristics, and thus influencing microenvironmental conditions. However, scarce information is available on the critical factors that affect regeneration success in Mediterranean managed forests and on the different scales at which these factors operate. We studied Scots pine (*Pinus sylvestris* L.) regeneration patterns in Navafria forest, on the Mediterranean mountains of central Spain, where an intensive thinning and pruning regime is applied throughout the life of the stand and where mechanical soil tilling is often required to enhance regeneration. We recorded regeneration, forest structure and environmental data at the plot scale (0.5 ha), the stand scale (with a grid covering a regeneration cutblock of ca. 40 ha) and the forest scale (with transects covering several cutblocks across the forest). Our results emphasize the importance of considering different spatial scales when we aim to determine the influence of management practices and the factors responsible of regeneration patterns. In the light of our results, several management strategies to enhance regeneration success at different spatial scales and under current and future scenarios with more frequent droughts can be proposed.

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Fuel management to fire prevention by silvicultural treatments. An approach to *Pinus pinea* sustainability

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Pinus pinea forests are found in sustainable management approach due to their tangible assets such as timber, pine nut and hunting activity, environmental services such as carbon storage and soil erosion and landscape goods. Generally, *P.pinea* landscape encompasses a range of socio-economic activities that aim to improve the livelihoods of people living in rural communities. In Mediterranean areas, fire suppression activities can be placed on the stand because of its importance on rural development. Climate change will increase the fire risk and socio-economic vulnerability associated to forest fires. In conifer stands with a continuous crown cover, crown fires are the most dangerous events causing high ecological and socio-economic losses. Fires burning in the crown layer are difficult to control and spread quite rapidly. One principle that forest managers must never forget is that the main purpose of the fire budget is to minimize the damages caused by forest fires. Silvicultural treatments such as thinning, brush out and pruning, are extremely effective tools for fire control, particularly in dense stands with height understory. As an example, we have characterized six stands of *P. pinea* in polewood stage showing the effects of different silvicultural treatments in fire spread. Forest characterization includes traditional parameters and fire behavior variables such as crown height, canopy base height, canopy bulk density and fuel moisture content. The integration among the above stand characterization, weather and topography determines the main parameters in fire behavior: probability of crown fire initiation, critical spotting distance, likelihood of crown fire and potential danger index. This technical information can be used in making decisions about the forest management and rural development. The economy efficiency of fire management can be obtained through the minimization of the probability of crown fire initiation, the crown fire rate of spread and fire impacts. Silvicultural treatments are evaluated based on potential fire behavior for reducing fire hazard.

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Satellite remote sensing helps in the sustainable management of Mediterranean pines.

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In this study case remote sensing and GIS tools are applied showing some of their strengths and capabilities for forestry. An automated method for delineation of management units is performed in Pinar de Valsain (Segovia), a Scots pine (*Pinus sylvestris* L.) forest in the Central Mountain Range of Spain. In this Mediterranean pine a strong linear relation (R^2 0.9/0.8) exists between inventoried wood volumes at the stand level and vegetation indices evaluated through reflectance data of medium and high spatial resolution images. Volume surface units (VSU) i.e. areas with user defined wood volume can be defined, considering at the same time topographic limitations for access and transit. This approach represents a flexible alternative to the traditional definition of forest stands, sometimes conditioned by ancient restrictions. The method requires knowledge of landscape breaking lines, such as rivers and ridges and an image segmentation algorithm.

Key words: Remote sensing, segmentation, VSU

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Change in area and distribution of Central Spain Mediterranean pines over two decades captured with a time-series of Landsat imagery

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Mediterranean pines are subject to continuous change under the influence of natural and human factors. Remote sensing provides a means to detect and characterize this modification of forestry resources. Utilizing medium spatial resolution images from the Landsat series of satellites we investigate the alteration of pines in the Central Mountain Range of Spain that occurred during the last two decades (beginning in 1984), with attention to their area and distribution. Per pixel analysis is applied to locate and assess variations in the forest area and to spot disturbed zones. An object oriented approach is also carried out for the assessment of more subtle changes occurred in stand-like areas due to their natural evolution during this period. Reflectance indices such as NDVI (Normalized Difference Vegetation Index) TCT (Tasseled Cap Transformation) NDMI (Normalized Difference Moisture Index) or NBR (Normalized Burn Ratio) are used to identify the location and nature of changes with the assistance of ancillary data. Our findings show that alterations in the treed area occurred during this time had mainly been caused by disturbances such as fire or wind throw events, leaving detectable scars on the landscape. NDVI and NBR were the best indices for identification of these affected areas, which recovery was sometimes also identified. Limitations exist to detect subtle changes such as natural growth or light silvicultural treatments when they do not induce a noticeable modification in the spectral response of the forest. The periodicity of available imagery is a key factor in the kind of changes detectable. Our results indicate that multispectral imagery is a reliable source of information for forest change detection at the scale of this study.

Key words: Mediterranean pines, change, Landsat, reflectance indices, object oriented

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Structural and climatic determinants of demographic rates of Scots pine forests in the Iberian Peninsula

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Type of submission: poster Abstract Forests are under strong pressure from human-induced climate warming and changes in land uses. Recent observations of forest dieback, with corresponding changes in forest structure, composition and functional processes, have been documented in many regions of the World. Scots pine (*Pinus sylvestris* L.) covers large areas of the Northern Hemisphere, being the Iberian Peninsula its south-western distribution limit. In recent decades, an increase of severe droughts and an intense densification of forests as a result of changes in forest uses have occurred in this region. We used climate and stand structure data to explain mortality and growth patterns of Scots pine forests of the Iberian Peninsula during the last two decades of twentieth century. The information of 2550 plots from the National Forest Inventory of Spain was used to fit linear models to assess the response of mortality and growth rates to the spatial variability of climate and forest structure. Over a period of approximately 10 years between the mid 1990s and the mid 2000s, the amount of standing dead trees increased eightfold. Higher levels of mortality were concentrated in dry and cold sites, while growth declined with increasing dryness and temperature. Forest structure was strongly related with demographic rates, suggesting that competition is the main factor associated with tree mortality and growth decline. A slight negative relationship between mortality and growth rates was observed, indicating that potential stress factors are acting adversely on both survival and growth of Scots pine. Regional increases in water deficit and forest density are likely both contributing to the increased mortality and growth decline of Scots pine. Since the key role that forests play in global hydrologic and carbon cycles, continued forest research and monitoring are needed in face of unavoidable environmental changes.

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Site quality curves for natural Aleppo pine forest (*Pinus halepensis* Mill.) in Ebro Valley (Spain)

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Site quality curves for *Pinus halepensis* Mill. were made in a wide area from the natural range of the species in the Ebro Valley (northeastern Spain). Raw data were obtained from 924 plots in a circa of 40.000 ha area and 111 trees were cut. A total of 11 equations with generalized algebraic difference approach (GADA) were fitted with longitudinal data structure that considers all possible growth intervals. Comparison of the models was conducted by three statistical criteria: root mean square error (RMSE), adjusted coefficient of determination (R^2_{adj}) and Akaike's information criterion (AIC). Graphical validations (observed vs. predicted and residuals vs. predicted values) were used as well. Age evolution vs. root mean square error was evaluated graphically. Moreover, fitted quality curves for different site index were represented overlaying with the real profile plots of the 111 stems analysed. The relative error in dominant height prediction was used in order to select the value of 60 years as the best reference age. According our comparative analysis the Hossfeld IV model were the most suitable for representing the site quality in the study area. Furthermore, only three quality curves (6, 10 and 14 m at 60 years) were enough for classifying all the studied area due to the low production of these woods. Our results were compared with some other curves obtained from Spain and other countries from the natural range of distribution of the species.

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Populations Monitoring of Pine Processionary Moth (*Thaumetopoea pityocampa*) by Pheromone Trapping in Eastern Algeria

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In the Mediterranean, the Pine Processionary Moth (*Thaumetopoea pityocampa*) is known for the breadth of its defoliation on the genus *Pinus* and Cedar and other species but with a relative degree of infestation. In order to determine local population density and the life cycle of this defoliator by highlighting emergence dates of adults to plan a microbiological control. We used 126 synthetic pheromone traps placed randomly on trunk of Aleppo pine (*Pinus halepensis*) located in the major pine forests of the wilaya of Batna (East of Algeria). In our approach, we harvested daily contents of traps installed at an average height of 1.70 ± 0.30 m, where we totaled 19,339 individuals (males) captured during the study period extending from August 20th, 2008 to September 30th, 2008 with an average catch equals 153.5 ± 179.4 per trap. Furthermore, it appears that pheromone traps is an important tool to assess population density and rhythms of flight of *T. pityocampa*. In addition, the results of this study based on the proposed use of mating disruption and mass trapping of adult males to limit reasonably heavy outbreaks of the insect pest by failure of reproductive success on the one hand, and provide data on exact dates of adult emergence to monitor future outbreak and use the appropriate control technique on the other hand. In this study, we will highlight the damage caused by this moth on *Pinus halepensis* forests. This pest insect has caused damage in some stations reaching 80% dieback where different findings are discussed namely, dendrological measurements, infestation levels, correlation of these two parameters with temperatures...

Keywords: Adult flight, Algeria, Batna, infestation level, Pheromone Trapping, *Pinus halepensis*, *Thaumetopoea pityocampa*.

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SCOTS PINE REGENERATION IN OLD POST-LOGGING DEBRIS BONFIRES IN ACIDIC SOILS

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Coarse and fine woody debris generated during logging operations and silvicultural treatments usually have some kind of processing in traditional silviculture. Debris treatments look for reducing the risk of fire or plagues, facilitating the movement of people and machines, decreasing landscape impact, etc. Timber harvesting residues have typically been burned in traditional silviculture in Spain. Still in use, it is being progressively replaced with other methods, like chopping. In this work we analyze the case of the private state 'Cabeza de Hierro' (Rascafría, Madrid, Spain). Natural vegetation is a forest of Scots pine in an uneven-aged structure in most of its management units, located in the upper valley of Lozoya river, in a elevation range between 1260 and 2000 m.a.s.l at the Spanish Central Range. The private ownership has been harvesting pine timber since acquisition in 1840, under technical management plans since 1957. The soils are acidic and derived of gneisses alteration. In the past and almost exclusively, logging residues has been removed by burning in small bonfires at the same forest. The objective of this work is to test the effect of low-intensity burns in bonfires at forest on the natural regeneration of Scots pinewood. Old bonfires were located in the forest, ranging from 1 to 6 years since residues were burnt, with five replications of each 'age'. Around each bonfire, four side control plots (1 m² each) were located and studied. Several variables were registered and analyzed: regeneration density, physiographic parameters, direction and distance to the nearest mature tree, amount of coal peaces, litter fall, bush and herbaceous species were estimated in bonfires and control plots. Density regeneration is significantly higher inside old bonfires than in control plots outside the burns. Influence of the environmental variables on regeneration is also discussed.

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First approaches of the Spanish Carbon Accounting System: Scots pine in Castilla y León

Iñigo Lizarralde*

Spain is starting to develop a national carbon accounting system that could lead both researchers and decision makers to a better understanding of the role of forests regarding carbon issues. On the one hand, a new path for researchers is open since some carbon pool behavior needs more focus on its study. On the other hand, forest owners, managers and decision makers have a new tool to simulate different management options and assess the future results in terms of carbon stocks. The national system development is taking its first steps with a pilot region such as Castilla y León, one of the most relevant regions in Spain regarding forest research and management. In order to show the potential of the system, some example studies using Scots pine (*Pinus sylvestris* L.) are carried out. Although future enhancement of the system is needed, interesting results can be already shown.

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Growth dynamics and responses of intra-annual density fluctuations to climate in Aleppo pine (*Pinus halepensis* Mill.) trees of different crown classes

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Understanding how forest growth responds to climate is a key element for a deeper knowledge of forest dynamics in a new environment. Moreover, Mediterranean regions, as transitional climate zones between arid and humid regions of the world, are areas where climatic changes may have the greatest effects. The objectives of this paper are to analyze radial growth of Aleppo pine (*Pinus halepensis* Mill.) trees of different crown classes, to specify the differences in frequency of intra-annual density fluctuations (IADFs) according to crown class and cambial age and to identify strongly related climatic variables to be integrated in empiric growth models. Eight sampling sites were selected throughout the natural distribution area of *Pinus halepensis* in the Iberian Peninsula. Chronology quality was evaluated using mean sensitivity (MS), standard deviation (SD), signal-to-noise ratio (SNR), expressed population signal (EPS), the percentage of the variance accounted for the first eigenvector and the correlation between individuals. Precipitation and mean monthly temperatures in spring were positively correlated to the occurrence of IADFs. A higher frequency in IADFs occurred in the last fifty years. The increase in drought events in the Iberian Peninsula may explain the higher IADF frequency during this period.

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Spatial structure changes induced by thinning in a Scots pine stand at the Mediterranean rangelands

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Forest cover modifies the prevailing climatic conditions in a certain area, and generates special microclimatic conditions under canopy. This weather transformation is conditioned and partially determined by stand spatial structure. Thinning is the main tool for density and structure handling during stand development, but specific structural criteria are usually not taken into account when tree marking is carried out. Nowadays, climate change is expected to alter global weather, and vegetation patterns would be affected by this alteration. Any management tool that makes possible to deal with the effects of global warming on vegetation, should have to start being studied and considered, especially on limits of species ranges. The present work analyses thinning effects on stand spatial structure in a real example of application within a uneven-aged natural stand of Scots pine (*Pinus sylvestris* L.) located in the southern border area of the species range (Sistema Central Spanish mountains). The studied forest (?Monte Cabeza de Hierro?) has been a fine example of private sustainable management with continuous timber outputting for the last 150 years. Its planning is based on floating periodic block method and shelterwood regeneration system. After tree marking, a single plot of 0,9 ha was sampled within a thinning assigned stand of this forest. X-y coordinates, total height, dbh and species of pertenance were recorded for every tree. The spatial structure of the measured variables in the plot is analyzed by means of the classical spatial point pattern methods ($k(r)$, $L(r)$, O-ring, and F, G, & J functions). Both vertical and horizontal structures are considered. Initial and final state of the stand, and spatial structure before and after thinning are reported. Conclusions about the effects of thinning on final stand spatial structure are provided.

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Site index curves for Aleppo pine (*Pinus halepensis* Mill.)

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Aleppo pine plays an important role in the Mediterranean region of Spain as its stands cover near 1.500.000 ha and are located on poor soils in semi-arid conditions. Aleppo pine stands have two primary objectives: soil protection and biodiversity maintenance although they supply wood for particle board and pallets industries too. Due to the relative importance of this production, the ecological role that developed in the Mediterranean area and the necessity to have a better understanding of its dynamic we have considered the priority to develop a study program about the growth of Aleppo pine into a global change scenario. Firstly, we have elaborated a site index model for *Pinus halepensis*. Data from 213 stem analysis and 72 permanent sample plots were combined and used to develop the model. Plots were installed in even-aged stands in 1965 by the Forest Research Center (CIFOR-INIA) around the natural distribution area of this species in Spain. They are being re-measured every 5 to 10 years to complete eight inventories at this time. To fit the model we tested different equations using generalized algebraic difference approach (GADA). In order to select the best model we have used use root mean residual (MRES), mean square error (RMSE), model efficiency (MEF) and biological behavior. This dominant height growth model will be the basis for a broader study about the trends of height growth in these forests.

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Native Scots pine in Portugal: the ?west end? or just ?the end??

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Abstract: Scots pine (*Pinus sylvestris* L.) is represented in Europe as a large continuous area from northern latitudes till its south eastern dispersion in Iberian Peninsula. Although presenting the widest natural distribution among pine species, the presence of a possible native population in Portugal has long surprised botanists and ecologists. This hypothetical outlier in the species geographical range of distribution is confined to a few riparian areas in Serra do Gerês (NW Portugal), but an attempt to ensure its native origin has never been made. The present study presents preliminary data (location, biometry and dendrochronology) allowing the support for the hypothesis of its autochthonous character. Work in progress is also presented on genetics, population structure and regeneration status. As this population may become extinct in a nearby future, as a consequence of forest fires and grazing, proposals for a conservation strategy of this biogenetic heritage are outlined.

Keywords: *Pinus sylvestris*, remnant populations, nature conservation, dendrochronology, natural regeneration

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A phytoclimatic methodology for the evaluation of the climatic change effects in the dynamics of *Pinus sylvestris* L. stands in the Mediterranean basin

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A phytoclimatic methodology was assayed to evaluate the possible effects of the climatic change in the composition and competition capacity of *Pinus sylvestris* L. forests in the Mediterranean basin. The temporary variation of the phytoclimatic suitability index of the main tree species present in a forest formation, and their relative values are used to indicate the competition hierarchy of *Pinus sylvestris* and other forest tree species, especially *Fagus sylvatica* L. The methodology is applied in a specific location: The station of Canfranc, 1168m above sea level, in the south-facing slopes of the Pyrenees mountain range, in the Iberian Peninsula. We have studied the evolution of the phytoclimatic suitability index within the period 1910-2008. The thermopluviometric values have been calculated by 30 years mobile averages. In the period of observation at Canfranc station the increase in the average temperature has been 1,4°C (from 7,9°C in the period 1910-1939 to 9,3 in the period 1979-2008). The results indicate that the situation of apparent balance between the two species studied seems to have started changing from the average 1951-1980, with a gradual loss of scot pine competition capacity in comparison with beech. This is indicated by the gradual drop of the phytoclimatic suitability index of the pine compared to the regularity of the values of the beech. This integrated phytoclimatic approach proposed offers new methodological horizons for the study of the effects of climate change in stands of *Pinus sylvestris* in the mountains of the Iberian Peninsula before defining different alternatives of forest management.

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Macroremains evidence of the anthropogenic recession of *Pinus nigra* Aiton in Northern Spain

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Macroremains and travertine molds were studied to assess past distribution of pines on the northern Iberian Peninsula. Seventeen fossil trunks and 71 cones were found at Tubilla del Lago (Burgos) mire. The travertines sampled at Tubilla del Agua (Burgos), and Fuentetoba (Soria), contained pine cones impressions which could be identified by their well-preserved morphological characters. Identification of the wood samples was achieved with published descriptions and keys of their anatomical features. Pine cones were identified to the species level by morphological comparison with modern collections and available descriptions. Results indicate local presence of *Pinus nigra* at all sites. Radiocarbon dating performed on wood and CaCO₃ show that the material spanned the time period from 850 to 7450 years BC. This evidence and the analysis of the *P. nigra* phytoclimate type show a wider distribution of this taxon on the northern highplain of the Iberian Peninsula during most of the Holocene period. Palynological evidence points to the anthropogenic pressure on natural resources as principal responsible to *P. nigra* decline. Accordingly, the analysis of the *P. nigra* phytoclimate type distribution shows no significant difference between the present and 4000 B.C., when the anthropogenic impact was very low. In the light of these results, *P. nigra* should be considered as potential specie, at least on the calcareous highplains of the northern Iberian Peninsula. Furthermore, the recovery of their natural populations should be targeted to prevent the negative impact of the predicted climate scenarios on the vegetal landscape. This work was funded by projects MIA and CGL2008-06005.

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Effects of different intensities of overstory thinning on tree growth and understory plant species productivity in a semi-arid *Pinus halepensis* Mill.

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It is becoming more common in the Mediterranean basin to guard against forest fires by creating wooded firebreak areas by reducing the overstory, pruning the remaining trees and slash mulching. Nevertheless, very few attempts have been made to analyse the effect of this practice upon the tree growth and productivity of the understory plant species in semi-arid areas, following a well-defined experimental design along the time. In this way, three different intensities of overstory reduction (~800, 400 and 250 trees per ha) were carried out in winter of 2005 from an initial density of 1,500 trees per ha in a semi-arid Aleppo pine afforestation in SE Spain planted in winter of 1993-1994. Annual growth data of each stand (height, normal diameter and canopy cover) were measured in 4 randomly-situated quadrats of 20 x 20 m where above-ground biomass was also harvested from 5 subplots of 0.5 x 0.5 m from early summers of 2006 to 2009. Our results showed different growth patterns of *Pinus halepensis* and statistical differences in understory biomass production inside the different areas of overstory thinning as response to the new biotic (less competition) and abiotic conditions (more radiation, soil water availability,...). These results could be of great interest because of their management implications under a global change context in an area where reductions and irregularity in precipitation as well as increases in temperature are predicted.

Keywords: above-ground biomass, dasometry, forest management, semi-arid SE Spain.

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THE EFFECTS OF CONTAINERS ON THE AERIAL AND RADICULAR DEVELOPMENT OF *Pinus pinaster* Aiton FROM FOUR ORIGINS

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Due to the concern about stability problems caused by strong winds found in numerous plantations of *Pinus pinaster* in recent years, we analyzed the influence in nursery during the first year of life of four types of containers: big container with wire mesh, small container with wire mesh, big container without wire mesh and small container without wire mesh placed over *P. Pinaster* seedlings from four parts of Spain, that is, Oña, Tietar, Gredos and the Northeastern coastline, showing the ones which are most suited for growing *Pinus pinaster* by means of a study on morphological variables. We emphasized the performance of roots in order to point out differences among origins (genotype-environment interaction), and aerial parts and roots according to crop systems and use of containers. We measured the following variables: height, diameter, dry weight of aerial surface and dry weight of roots and carried out analysis of variance for all the variables and comparisons of mean values by means of Duncan multiple range test, adjustment of the model PROC GLM. The results indicated that the origin that performed best was Tietar, which has significant differences compared to the other three: Northeastern Coastline and Gredos, without differences between them, and Oña, different from the rest. Concerning the containers the best to be used was the big one without wire mesh. Key words: toppling, instability, container, origin, root and aerial development, radical deformation, plant quality.

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RECRUITMENT IN MEDITERRANEAN FORESTS OF *Pinus pinaster* subsp. *mesogeensis* IN THE CENTRAL RANGE, SPAIN

Rodríguez-García, Encarna & Bravo, Felipe*

Mediterranean ecosystems are characterized by the consecutive alternation of two favourable (autumn and spring) and two unfavourable (winter and summer) growth periods for plants through the year. In addition, water availability is quite irregular and abiotic stresses are great. Shrubs act as landscape modellers, affecting microenvironmental conditions, which could enhance natural seedling emergence and survival. Overstory structure control is also very important in natural establishment at early stages. There is not enough knowledge about the effect of shrubs on *P. pinaster* seedling survival in mediterranean forests. The effect of overstory structure is not better known, and there are few studies that focus on this part of the regeneration process. An analysis of seedling emergence and survival through two years was conducted in twenty four 1-m circular plots. The stand is located in the southern part of the Guadarrama Range, in the locality of Las Navas del Marqués (Ávila). Observations were made monthly from March to final August 2008 and from February to final August 2009. Two canopy-cover environments were considered, and stand structure was characterized (N/ha BA, H0, D, Dbh, Canopy %). Understory was almost exclusively formed by rockrose shrubs (*Cistus ladanifer* L) of great size. They were also characterized (H, % cover). Soil characteristics (nutrients, water volumetric content, texture, pH) and microenvironmental variables (soil T^a, air relative humidity, air T^a) during six typical summer days, were measured in both canopy environments in shrub-free and shrub-shade sample points. We investigated 1) the relation between overstory structure, season of germination and seedling survivorship and, 2) tested the hypothesis that seedling survival is enhanced by the presence of shrub cover

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Evaluating distance-dependent competition indices to improve basal area growth models used for two Mediterranean conifer tree species in the Iberian Peninsula

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Interrelation between basal area growth and competition index for different spatial distribution in two widely distributed species from the Iberian Peninsula was studied at this work. Competitor selection method is very important.

Delaunay triangulation was the search radius method whose selected neighbors work better. Height angle gauge (HAG) was also found a very good method for selecting competitors, were neighbors are selected depending on the distance and relative heights to subject tree, and reflects the influence in light interception. Most important index found was crown closure.

Keywords: *Pinus pinaster*, *Pinus sylvestris*, spatial distribution, Delaunay triangulation.

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BIOMASS YIELD AND CARBON SEQUESTRATION: A POTENTIAL FROM SPAIN'S FORESTS (ON CENTRAL AN IBERIAN MOUNTAIN RANGE SYSTEM)

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The interest on the estimation of forest biomass, regulation of carbon sequestration and nutrient cycling has grown dramatically over the past decade. Forests in Spain are important resources of timber and other forest products. The post-Kyoto climate change agreement period from 2013 to 2020 is likely to indicate large amounts of biomass loss, as well as possible prevention of carbon emission. Therefore, it is necessary to estimate and to understand the potential role of forests in the mitigation of global warming effects. However, few studies have been conducted to estimate the biomass carbon accumulation of Spanish forest ecosystems. With current data, we developed a forest growth dynamic model that considered the structure variables of forest growth. The main focus of this study is to provide an estimation framework based on biological principles and forestry evidence of Mediterranean pine (*Pinus pinaster* Aiton) and Scots pine (*Pinus sylvestris* L.) stands. We developed a model to estimate woody biomass and carbon sequestration under different scenarios of forestry. Information available from forest studies, such as stand increment, ingrowth, harvested, disturbed and dead trees were considered. Data were analyzed throughout the last decade. As expected, factors related to density and site productivity interacted on woody biomass production of forest stands. Due to these interactions, managers need more tools for forest management, knowledge of different forest structure and practical silvicultural methods.

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Selection in Italy of *Pinus pinaster* provenances resistant to *Matsucoccus feytaudi*

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The presence of the insect *Matsucoccus feytaudi* Ducasse, specific parasite of *Pinus pinaster* Aiton, was proved massively in Provence (France) in the 1960s and '70s and in pinewood stands of Italy between 1970 (Liguria) and Tuscany (1990-2000).

After promising results obtained in France around 1960s in an experiment aimed at selecting genotypes of *P. pinaster* provenances of Tamjoute (Morocco) and Cuenca (Spain) resistant to *M. feytaudi*, comparative tests were carried out around 1985-86s in Liguria, Latium and Sardinia using 5 provenances from Spain (Arenas de San Pedro-Avila, Coca-Segovia, Cuenca, Gran de Campalbo-Cuenca, Siles-Jaen), 1 from Morocco (Tamjoute), 1 of Corsica (Bastia-Vivario) and one of Italy (Valfreddana-Lucca).

Results: Stem circumference and height inter-site analysis (made in Rome-Latium, Arbus-Sardinia and Domusnovas-Sardinia plantations) at 20 years showed that:

1. VIVARIO (Corsica) and GRANJA CAMPALBO (Cuenca) provenances are the most interesting from the point of view of growth;
2. VAL FREDDANA (Tuscany) and ARENAS DE SAN PEDRO (Avila) provenances were more easily influenced by local factors of the station;
3. CUENCA and TAMJOUTE provenances showed in Liguria good vegetative conditions in area strongly infested by *Matsucoccus feytaudy*. In the same areas an extensive regeneration (probable hybrid of the two provenances resistant to matsucoccus and locally sourced) was observed.

Based on the current environmental emergencies, we suggest the conservation and the valorisation of these genotypes entities, also suitable for the brackish areas restoration.

Currently to ensure the presence of pinewood stands in areas affected by *Matsucoccus* it's important to evaluate the relations between the

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ecological characteristic of primary stands (Tamjoute-Morocco and Cuenca-Spain) and the growth rates in secondary areas.

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GLOBAL CHANGE AND MEDITERRANEAN PINES: ALTERNATIVES FOR MANAGEMENT

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