# Previous experiences and divergent political views drive perceptions on climate change impacts in the Canadian forest sector​

Assessing the differences in perception among the main stakeholders of the forest

sector is critical to evaluate their readiness to engage in the adaptation process to

climate change. Here, we present the results of a survey of 1158 individuals,

representing a wide range of stakeholders involved in the management of forest

ecosystems in Canada. The respondents answered questions about climate change,

its impacts on forest ecosystems, and the suitability of current forest management to

address these impacts. As compared to the general population, we found that forest

stakeholders were more concerned about the impacts of climate change. More than

90% of respondents agreed with the anthropogenic origin of climate change, and >

50% considered it as a direct threat to them. Exposure to extreme climatic and

disturbance events drive individual views about current climate change and perceived

threats, whereas political views drive beliefs about the causes and the future

consequences of climate change. Stakeholders from the industrial sector were the

most skeptical about the anthropogenic cause of climate change, its impacts on forest

ecosystems, and the need for new management practices to deal with the associated

impacts. Nevertheless, the degree of awareness and the willingness to implement

adaptive practices were high even for the most skeptical groups, indicating a high

readiness for adaptation within the Canadian forest sector.

# Knowledge gaps about mixed forests: what do European forest managers want to know and what answers can science provide?

Research into mixed-forests has increased substantially in the last decades but the extent to which the new knowledge generated meets practitioners’ concerns and is adequately transmitted to them is unknown. Here we provide the current state of knowledge and future research directions with regards to 10 questions about mixed-forest functioning and management identified and selected by a range of European forest managers during an extensive participatory process. The set of 10 questions were the highest ranked questions from an online prioritization exercise involving 168

managers from 22 different European countries. In general, the topics of major concern for forest managers coincided with the ones that are at the heart of most research projects. They covered important issues related to the management of mixed forests and the role of mixtures for the stability of forests faced with environmental changes and the provision of ecosystem services to society. Our analysis showed that the current scientific knowledge about these questions was rather variable and particularly low for those related to the management of mixed forests over time and the associated costs. We also found that whereas most research projects have sought to evaluate whether mixed forests are more stable or provide more goods and services than monocultures, there is still little information on the underlying mechanisms and trade-offs behind these effects. Similarly, we identified a lack of knowledge on the spatiotemporal scales at which the effects of mixtures on the resistance and adaptability to environmental changes are operating. Our analysis may help researchers to identify what knowledge needs to be better transferred and to better design future research initiatives meeting practitioner’s concerns.

# Bird community response to shelterwood regeneration system in mountain pine forests of the Pyrenees.

Understanding the effects of forest management on biodiversity is a vital challenge given the current regime of largescale socio-ecological drivers affecting forest ecosystems and their multifunctionality. Here we assessed how forest management affects abundances of common breeding birds in mountain pine (Pinus uncinata Ram. ex DC) stands in the Pyrenees. We assessed, at guild level, avian response to changes in stand structure across different management stages in forests managed under a shelterwood system, as well as in unmanaged forests. Bird guilds were based on habitat breadth, nesting habitat, and foraging habitat. Bird abundance was modelled separately for each guild as a function of stand variables known to be good surrogates of stand density (stand density, quadratic mean diameter, shrub cover) and maturity (dominant height, cavities). For this purpose, we used likelihood methods, which provided flexibility in the shape of the expected responses. For most bird guilds, unmanaged forests showed similar bird abundance to managed forests. Total bird abundance was maximum after regeneration cuts, due to the positive response of canopy nesters and canopy foragers. The typical open stand structure after removal cuts negatively impacted forest specialists, cavity nesters and trunk foragers, but the impact was offset by the higher number of generalists, ubiquitous, ground nesters and ground foragers. General stand descriptors such as stand density, quadratic mean diameter and dominant height were the most influential variables, whereas the association of bird abundance with shrub cover and cavities was less influential and guild-specific. We show that a shelterwood system can be a suitable management tool to promote the abundance of most common bird guilds in dense, omogeneous stands, given that some key structural legacies are retained throughout the rotation and stand structure heterogeneity is promoted. By obtaining quantitative relationships between the main structural features affected by harvests and the abundance of birds, we formulate management recommendations that are valid for forests managed not only under shelterwood systems but also under other silvicultural methods.

# Managing stand density to enhance the adaptability of Scots pine stands to climate change: a modelling approach

In the Mediterranean region most climatic forecasts predict longer and more intense drought periodsthat can affect tree growth and mortality over broad geographic regions. One of the silvicultural treat-ments that has gained currency to lessen the impacts of climatic change is the reduction of stand densityby thinning. However, we lack information on how the response of forest stands to different thinningtreatments will be affected by climate change, and on the post-thinning temporal dynamics of waterbalance, specifically blue and green water. We adopted a modelling approach to explore the long-termeffects of different thinning intensities on forest dynamics and water balance under climate change sce-narios, coupling an individual-based model of forest dynamics (SORTIE-ND) with a mechanistic modelof soil moisture dynamics and plant drought stress. We used as a case study three Scots pine plots acrossa gradient of climatic conditions, and we assessed the effect of site, three climatic scenarios and eightthinning intensities on tree growth, stand productivity, tree drought stress and blue water. The bestthinning intensity in terms of stand productivity was obtained when between 20 and 40% of the basalarea was removed, whereas the final stand stock rapidly decreased at higher thinning intensities. More-over, the decrease in final basal area occurred at lower thinning intensities the drier the site conditions.Moderate and heavy thinnings (>30%) doubled basal area increment (BAI) of the following years in allthe plots, although the effect vanished after 30–40 years, independently of the site and climate scenario.As expected, thinning was simulated to have an overall positive effect on the blue water yield and treewater status, which increased and also tended to last longer for higher thinning intensities. However,the magnitude of this effect on tree water status was most dependent on the site and climatic scenario,as drier conditions generally raised stronger and longer lasting reductions in drought stress for a giventhinning intensity. Furthermore, our results highlight the existence of a site- and climate-dependenttrade-off between the gain in stand productivity and the improvement in tree water status obtained bythinning, particularly for moderate or heavy thinning intensities. Our simulations suggest that thinningis a useful management tool to mitigate climate change but strongly argue against the application ofgeneral recipes across sites and appeals for carefully taking into consideration local climatic trajectoriesfor management planning.

# Shade tolerance mediates the functional trait – demography relationship in temperate and boreal forest

1. The multiple dimensions of plant functional trait structure are often represented as axes called trait spectra, and the distribution of species along those axes is assumed to be indicative of their main ecological or life-history strategies.
2. However, the link between trait spectra and plant demographic performance (growth, mortality, reproduction) is not consistent across ecosystems, and the role that integrative variables such as shade tolerance can play in the trait – demography relationship remains unclear.
3. Here, we hypothesize that shade tolerance can be achieved by alternative combinations of traits depending on the species’ functional group (evergreen gymnosperms vs. deciduous angiosperms), and that its ability to explain the array of traits involved in demography in low light environments will also vary across these groups.
4. We used dimension reduction to identify the main trait spectra for 41 tree species – 23 evergreen and 18 deciduous – dispersed across 19 genera and 13 families, and assessed the relationship between functional traits, shade tolerance and demographic performance at high and low light.
5. *Synthesis*. The dimensions found corresponded to the trait spectra previously observed in the literature and were significantly related to measures of demographic performance. However, our results support the existence of a divergence between evergreen gymnosperms and deciduous angiosperms in the way shade tolerance relates to the demography of species along light gradients. We suggest that shade tolerance should be considered a trait syndrome that can be attained through different combination of traits depending on the context, and thus its utilization as a predictor of forest dynamics and species coexistence requires previous knowledge on the role it plays in the demographic performance of the species under study.

# Tree light capture and spatial variability of understory light increase with species mixing and tree size heterogeneity

Mixed and multi-layered forest ecosystems are sometimes more productive than monospecific and single-layered ones. It has been suggested that trees of different species and sizes occupy complementary positions in space which would act as a mechanism to increase canopy light interception and wood production. However, greater canopy light interception reduces the average amount and variability of transmitted radiation offering fewer opportunities for all species to regenerate and to maintain forest heterogeneity in the long-run. We investigated whether increasing overstory heterogeneity indeed results in greater canopy light interception and lower variability in transmittance. We modeled the three-dimensional structure of forest stands with 3 typical forest structures, 10 mixtures of four tree species, and 3 different basal areas. We used the forest light interception model SamsaraLight and performed three-way analyses of covariance to analyze the effects of the three varied components of forest heterogeneity. We found no evidence that increasing structural heterogeneity increases canopy light interception. However, the light interception by mixed canopies was greater than the weighted average of light interception by the corresponding pure canopies. Variability in transmittance increased in some cases with compositional heterogeneity and, to a lesser extent, with tree size inequalities. The advantage of heterogeneous forest is in opportunities for natural regeneration as well as in opportunities to enhance canopy light interception.

# Assessing tree germination resilience to global warming: A manipulative experiment using sugar maple (Acer saccharum)

**A climate warming of 2-5°C by the end of the century will likely impact the likelihood of**

**germination of sugar maple (Acer saccharum), a dominant tree species which possess**

**a restricted temperature range to ensure successful reproduction. We hypothesize that**

**seed origin affects germination rates due to the species' local adaptation to**

**temperature. We tested this by experimentally investigating the effect of stratification**

**temperature and temperature fluctuations on sugar maple seed germination from 7**

**different seed sources representing the current species range. Survival analysis**

**showed that seeds from the northern range had the highest germination rate, while the**

**southern range had the lowest. Mean germination rate under constant temperatures**

**was best when temperatures were ≤5°C, whereas germination rates plummet at**

**temperatures ≥11°C (5.8%). Cool fluctuations increased germination by 19.1% over**

**constant temperature treatments and 29.3% over warm fluctuations treatments. Both**

**fluctuation treatments caused earlier germination relative to the constant temperature**

**treatments. A climate warming of up to +5°C severely reduced the germination rates of**

**seeds from the southern range. However, under a more pronounced warming of 7°C,**

**seed germination at the northern range become more affected and now comparable to**

**those found from the southern range. This study. It also suggests that the high seed**

**germination rate found in sugar maple at the northern range makes it fairly resilient to**

**the warmest projected temperature increase for the next century. These findings**

**provide forest managers the necessary information required to make more accurate**

**projections when considering climate change impacts on regeneration**

# Diversifying sub-Mediterranean pinewoods with oak species in a context of assisted migration: responses to cold and microsite conditions

**Questions**: How do thermal migration distance and extreme cold events affect seedling emergence and survival in assisted migration schemes in the Sub-Mediterranean context? What role does plant provenance play? Can biotic interactions such as nurse effect of the overstory and shrub layer buffer the negative responses to plant translocation? Are any of these effects species-specific?

**Location**: Three pinewoods in the Catalan Pre-Pyrenees, northeastern Iberian Peninsula.

**Methods**: We used a replicated field trial to test the early-years establishment of two contrasted provenances of four Quercus species (Q. coccifera, Q. ilex, Q. faginea and Q. pubescens) that were sown and planted along gradients of elevation and understory microsite conditions in sub-Mediterranean pine forest. Seedling responses to translocation were evaluated by assessing seedling  emergence, seedling survival, and re-sprouting after dieback events according to seedling  provenance, thermal migration distance, extreme cold events and microenvironment.

**Results**: The study reports high success of both the planting (with an overall 76.3% of initial 3-year  survival) and sowing (with an overall 50% of seedling emergence) experiments. The results show  that: i) both thermal distance and extreme cold events have strong effects on the responses of the  translocated populations; ii) the forest overstory plays an important role in attenuating the negative  effects of thermal distance and extreme cold events on seedling survival; and iii) these responses are  species-specific. The evergreen Quercus species and to a lesser extent the marcescent Q. pubescens  showed quite clear signs of high ecotypic differentiation in terms of cold tolerance, enabling local  provenances to respond better to translocation. In contrast, marcescent species, especially Q. faginea,  showed high phenotypic plasticity that led to a better overall establishment success.

**Conclusion**: The implementation of assisted migration is a feasible option to increase the diversity  and resilience of the sub-Mediterranean pinewoods. Assisted migration programs should manage risks by thoroughly considering thermal migration distances and the occurrence of extreme cold  events when selecting species and seed sources, since Mediterranean tree species show different  strategies regarding adaptation to cold. Program managers should also consider the advantage of  planting/sowing under relatively closed canopy to buffer some of the negative responses associated  with translocation.

# Species-specific and generic biomass equations for seedlings and saplings of European tree species

Biomass equations are a helpful tool to estimate the tree and stand biomass production and standing stock. Such estimations are of great interest for science but also of great importance for global reports on the carbon cycle and the global climate system. Even though there are various collections and generic meta-analyses available with biomass equations for mature trees, reports on biomass equations for juvenile trees (seedlings and saplings) are mainly missing. Against the background of an increasing amount of reforestation and afforestation projects and forest in young successional stages, such equations are required. In this study we have collected data from various studies on the aboveground woody biomass of 19 common tree species growing in Europe. The aim of this paper was to calculate species-specific biomass equations for the aboveground woody biomass of single trees in dependence of root-collar-diameter (RCD), height (H) and the combination of the two (RCD2 H). Next to calculating species-specific biomass equations for the species available in the dataset, we also calculated generic biomass equations for all broadleaved species and all conifer species. The biomass equations should be a contribution to the pool of published biomass equations, whereas the novelty is here that the equations were exclusively derived for young trees.

# Land-use legacies rather than climate change are driving the recent upward shift of the mountain treeline in the Pyrenees

**Aim** To assess the effects of physiography, change in climate and past land-use on current treeline position and its dynamics between 1956 and 2006.

**Location** More than 1,000 linear kilometers of subalpine treeline in the Catalan Pyrenees (NE Spain)

**Methods** We determined the change in treeline position between 1956 and 2006 based on change in forest cover, using aerial photographs and supervised classification. We used the distance from the treeline position in 1956 to the theoretical potential treeline as a surrogate of intensity of past land-use.

**Results** Our analyses showed that the Pyrenean treeline has moved upwards on average almost 40 m (mean advance ± SE: 35.3 ± 0.5 m; *P* < 0.001), although in most cases has remained unchanged (61.8 %) or advanced moderately, i.e. less than 100 m (23.7%). Treeline upward shifts were larger in locations heavily modified in the past by anthropic disturbance (mean advance: 50.8 ± 1.1 m) compared to near natural treeline locations (19.7 ± 0.8 m).

**Main Conclusions** In most European mountain areas, forest has expanded during the last decades due to the joint effect of climate warming and change in land-use. Our results stress the impact of past land-use in driving forest dynamics in high mountain areas, and reveal a very low or even negligible climatic signal in the study area.

# Assessing the adaptive capacity of communities to natural disturbances on the basis of species response traits

Adequately assessing the ecosystem resilience and resistance is a challenging and essential question in the current context of widespread environmental change. Here we suggest assessing the capacity of ecosystems to maintain their functions and services after disturbances through a quantitative measure we call Persistence Index (PI). The formulation of PI is based on the diversity, abundance, and redundancy of disturbance- and species-specific response traits. We illustrate our approach by studying the adaptive capacity of forest ecosystems in Peninsular Spain and the Balearic Islands in response to fire, drought and windstorm events. In this application, PI was found to vary within and among different forest types, being particularly high in stands dominated by non-native species (e.g. Eucalyptus sp.) or stands composed of species belonging to several functional groups (e.g. mixed evergreen-deciduous broadleaf forest). PI values increased with the number of tree species present in the stand, although this relationship saturated at a given richness value due to overlap in species response traits.

This index is complementary to other approaches developed to study the functional structure of communities through the distribution of species in a functional space. The PI metric can be applied to a broad spectrum of ecosystems subjected to different types of stressors, making it a useful tool to guide ecosystem management decisions in the present context of changing climate and uncertain disturbance regimes.

# Birch and conifer deadwood favour early establishment and shade tolerance in yellow birch juveniles growing in sugar maple dominated stands

Small-seeded tree species such as Yellow birch (YB: *Betula alleghaniensis* Britt*.*) require deadwood or mineral soil for their establishment. However, little is known about how different seedbeds favour early growth and survival of YB in hardwood deciduous forest. We examine how three common seedbeds (deadwood, DW; moss cover on deadwood, MDW and mineral soil, MS) affected the demography and some traits important for survival of YB juveniles growing in the understory of sugar maple dominated stands. A total of 274 YB were sampled in four stands of the temperate deciduous forest of Southern Quebec where selective-cuts had been applied 6 and 15 years prior to sampling. Establishment and growth, biomass partitioning and morphological traits were measured and compared among the three seedbeds. Over 75% of the YB found on deadwood were on material of birch and conifer origin, although these species made less than 40% of the basal area, whereas almost all YB juveniles found on MS were restricted to skid trails. Deadwood seedbeds favoured traits that improve survival in shade of YB juveniles. Our results demonstrate the importance of deadwood of birch and conifer origin in maintaining an abundant, natural, spatially well-distributed, and multi-storied regeneration of YB.

# Cross-scale integration of knowledge for predicting species ranges: a metamodeling framework.

Aim Current interest in forecasting change to species ranges have resulted in a great diversity  of approaches to species distribution models (SDMs). However, most approaches include only   a small subset of the available information, and many ignore smaller-scale processes such as   growth, fecundity, and dispersal. Furthermore, different approaches often produce divergent  predictions, with no simple method to reconcile them. Here, we present a flexible framework  for integrating models at multiple scales using hierarchical Bayesian methods.

Location Eastern North America (as an example).

Methods Our framework builds a metamodel that is constrained by the results of multiple sub-models and results in probabilistic estimates of species presence. We applied our approach to a simulated dataset to demonstrate the integration of a correlative SDM with a theoretical model. In a second example, we built an integrated model combining the results of a physiological model  with presence-absence data for sugar maple Acer saccharum, an abundant tree native to eastern North America.

Results For both examples, the integrated models included information from all data sources  and substantially improved uncertainty when making projections. For the second example, we  found that the integrated model outperformed the source models with respect to uncertainty  when modelling the present range of the species. When projecting into the future, the model  provided a consensus view of two models that differed substantially in their predictions. Uncertainty was reduced where the models agreed and was greater where they diverged, providing a  more realistic view of the state of knowledge than either source model.

Main conclusions We conclude by discussing the application of our method and its accessibility to applied ecologists. In ideal cases, our framework can be easily implemented using off the  shelf software. The framework has wide potential for use in species distribution modelling, and  can drive better integration of multi-source and multi-scale data into ecological decision-making.

# Modelling the effect of climate-induced change in recruitment and juvenile growth on mixed-forest dynamics: The case of montane–subalpine Pyrenean ecotones

Most predictive models forecast significant upward displacement of forest species due to increases in temperatures, but not all the species respond in the same way to change in climate. In temperate or mountain systems, biotic competitive interactions drive species distributions, and responses to climate change will ultimately depend upon productive and demographic processes such as growth, recruitment and mortality. We parameterized and used an individual-based, spatially explicit model of forest dynam- ics (SORTIE-ND) to investigate the role of species-specific differences in juvenile performance induced by climate change (juvenile growth and recruitment ability) in the dynamics of mixed forest located in the montane–subalpine ecotone of the Pyrenees. We assessed this role for two types of forest composed of three species with differing light requirements and sensitivity to climate change: (1) a mixed forest with two shade-intolerant pines (Pinus uncinata and Pinus sylvestris) and (2) a mixed forest composed by a shade-intolerant pine and a shade-tolerant fir (Abies alba). Our results show that for species with similar light requirements (i.e., both pines), small differences in sapling growth response to climate change can lead to significant differences in future species composition (an increase in P. sylvestris growth of 10% leads to an increase in its abundance from 42% to 50.3%). Conversely, in pine-fir forest, shade-tolerance results more decisive than climate-induced changes in growth in driving the future forest composition.

# Herbivory and seedling establishment in Pyrenean forest: Influence of micro- and meso-habitat factors on browsing pressure

Browsing damage is among the most determinant factors that limit the establishment of tree seedlings in forest. In some areas, this process leads to massive mortalities that can reduce or even completely pre- vent the regeneration of some tree species. Mediterranean mountain forest have undergone during the last decades important change in land-use that have significantly altered the type and abundance of herbivore populations. In this study we assessed the impact of current grazing conditions in forest regen- eration using a set of experimental plantations established in the Eastern Pyrenees in areas visited by domestic livestock (cattle and horses) and wild ungulates (mainly roe deer and chamois). We analyzed during 4 years the role of seedling species and size, mesohabitat (elevation and type of forest cover) and microhabitat (herbaceous cover, distance to shrub, and light availability) on the browsing-induced mortality of more than 500 seedlings of Pinus sylvestris, Pinus uncinata, Betula pendula and Abies alba, the most common tree species in the study area. Browsing-induced mortality for the three conifer species was much lower (<15%) than the one observed for B. pendula (>40%) and depended on both microhabitat – mainly on the distance to protective elements such as shrubs; and mesohabitat, with an interaction between the elevational belt (site) and the type of forest cover (gaps vs. understory). In the subalpine belt, browsing on A. alba and P. uncinata was higher during summer at plots located in the forest understory whereas, during winter, it was higher at plots located in gaps. The study shows that both mesohabitat and microhabitat can exert an effect on the patterns of plant damage by herbivores, providing useful informa- tion to adapt forest management in areas particularly exposed to them.

# [Unraveling the role of light and biotic interactions on seedling performance of four Pyrenean species along environmental gradients.](http://www.sciencedirect.com/science/article/pii/S037811271300217X)

The predicted upward displacement of forest species due to climate warming is expected to be modulated by a medley of abiotic and biotic factors acting at microsite level. Species-specific differences in plant responses to this set of environmental factors can thus have strong implications in the future dynamics of forest ecosystems. To gain a better understanding of the main fine-scale factors and processes driving present and future species performance in the montane and subalpine belt of the Eastern Pyrenees (NE Spain), we established a set of experimental mixed plantations along elevational and environmental gradients using the four tree species dominating these areas (*Pinus sylvestris*, *Pinus uncinata*, *Abies alba* and *Betula pendula*). Once the plantations had been established, the performance and growth of 72 seedlings of each species was monitored and linear and non-linear models were fitted to identify the main factors controlling their survival and growth.

We found most of the mortality to occur during the third growing season, following a harsh winter and a drought period during summer. Mortality patterns were highly species- and site-specific. At the subalpine belt, shrubs were found to have a facilitative effect on winter survival of *P. sylvestris* (mortality < 10%) but not on the other species. At the montane belt, *A. alba* mortality during the summer increased in areas with high light exposure and herbaceous cover (mortality > 30%). All species except *P. uncinata* showed lower height growth at high elevation, with differences between sites matching differences in growing season duration (20%).

Our results underline the strong impact that short periods of extreme climate can have in the performance of plants developing in mountainous areas far from their optimal elevational range. However, they also underline a potentially critical role played by biotic and abiotic microsite factors in mediating species responses to these climatic events.

# [Understory light predictions in conifer-mixed forest: the role of aspect-induced variation in crown geometry and openness.](http://www.sciencedirect.com/science/article/pii/S0378112712001867)

Predicting light availability in forest understory is a key step in the modeling of forest dynamics. Aspect is often the main source of environmental variation in mountain forest, and so aspect-induced differences in crown geometry and transparency can be expected to affect light transmission through the canopy and modify understory light predictions. To gain a better understanding of the effects of aspect on the light interception capacity of forest trees, we determined crown allometry and crown openness (CO) in 120 adult trees of three common conifer species in the Pyrenees (mountain pine, Scots pine and silver fir), sampled in eight montane-subalpine forest that each included two contrasting aspects. CO was calculated from digital photographs and several crown outlines were automatically determined to prevent user bias. We also calculated crown irregularity as the difference between crown surface area for the tightest and loosest outlines. Predictions of understory light availability obtained from a forest dynamics model were compared with actual values obtained from 115 hemispherical photographs. Crown length and CO varied across species following previous rankings of shade tolerance. Both pines had longer and wider crowns in the north aspect, whereas fir crown geometry was not affected by aspect. CO depended largely on the method chosen for determining crown outline, ranging from 0.10 to 0.56, and the tightest outline provided the best predictions of understory light (slope = 0.89, *R*2 = 0.46). CO was also significantly affected by tree size and plot aspect (*p* < 0.001): crowns in southern-oriented plots were more open for mountain pine and silver fir, whereas Scots pine showed the opposite trend. Predictions of understory light were significantly improved when crown geometry and openness were allowed to vary according to plot aspect (slope of the regression: 0.95, *R*2 = 0.50). Our results suggest that aspect should be explicitly considered when modeling ecological processes and dynamics in mixed mountain forest given its influence on both abiotic conditions and crown responses to them.

# [Tree dynamics and coexistence in the montane-subalpine ecotone: the role of different light-induced strategies](http://onlinelibrary.wiley.com/doi/10.1111/j.1654-1103.2011.01316.x/abstract).

**Questions:** Is light availability the main factor driving forest dynamics in the Pyrenean subalpine forest? Do pines and firs differ in their growth, mortality and morphological response to low light availability? Can differences in shade tolerance affect the predictions of future biome change in the Pyrenean subalpine forest in the absence of thermal limitation?

**Location**: Montane-subalpine ecotones of the Eastern Pyrenees (NE Spain)

**Methods**: We evaluated the morphological plasticity, survival and growth response of saplings of Scots pine, mountain pine and silver fir to light availability in a mixed-forest ecotone. For each species, we selected 100 living and 50 dead saplings and measured their size, crown morphology and light availability. A wood disk at root collar was then removed for every sapling, and models relating growth and mortality to light were obtained.

**Results**: Fir showed the lowest mortality rate (< 0.1) at any given light condition. Pines showed comparable responses to light availability although in deep shade Scots pine faced a higher risk of mortality (0.35) than mountain pine (0.19). Pines and fir developed opposing strategies to face light deprivation: fir employed a conservative strategy based on sacrificing height growth, whereas pines enhanced height growth to escape from shade, but at the expense of higher mortality risk. Scots pine showed higher plasticity than mountain pine on all architectural and morphological traits analyzed, showing a higher adaptive capacity to a changing environment.

**Conclusions**: Our results support the prediction of future biome change in the Pyrenean subalpine forest as silver fir and Scots pine may find appropriate conditions for colonizing mountain pine dominated stands due to land-use change-related forest densification and climate warming-related temperature increases, respectively.

# [Land-use change as major drivers of Mountain pine (Pinus uncinata Ram.) expansion in the Pyrenees.](http://www3.interscience.wiley.com/cgi-bin/fulltext/123443673/HTMLSTART)

**Aim** To assess the spatial patterns of forest expansion (encroachment and densification) for Mountain pine (*Pinus uncinata* Ram.) during the last 50 years in a whole mountain-range scale by the study of different topographic and socio-economic potential drivers in the current global-change context.

**Location** The study areaincludes the whole distributional area of Mountain pine in the Catalan Pyrenees (NE Spain). This represents more than 80 municipalities, covering a total area of 6,018 km2.

**Methods** Forest cover was obtained by image reclassification of more than 200 pairs of aerial photographs taken in 1956 and 2006. Encroachment and densification were determined according to change in forest cover, and were expressed as binary variables on a 150x150m cell-size grid. We then used logistic regression to analyze the effects of several topographic and socio-economic variables on forest expansion.

**Results** In the period analyzed, Mountain pine increased its surface coverage by 8,898 hectares (an increase of more than 16%). Mean canopy cover rose from 31.0% in 1956 to 55.6% in 2006. Most of the expansion was found on north-facing slopes and at low altitudes. Socio-economic factors arose as major factors of Mountain pine expansion, as encroachment rates were higher at municipalities with greater population losses or weaker primary sector development.

**Main Conclusions** The spatial patterns of Mountain pine expansion highly matched the main patterns of land-use change in the Pyrenees, suggesting that land-use change have played a more determinant role than climate in driving forest dynamics at landscape scale over the period studied. Further studies on forest expansion at regional scale should incorporate patterns of land-use change to correctly interpret drivers of forest encroachment and densification