ECOPYREN3

Summary of the project achievements

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Main results since project´s beginning

The two most important European forest species (Scots pine and European beech) cover a large part of continental Europe. When mixed, conifer-hardwood forests can be more productive than pure forests and they are increasingly considered ecosystems providing adaptation measures to be use in a strategy to face global change. However, the combined effect of tree-to-tree competition for nutrients and water, rising atmospheric CO_2 concentrations and climate change on such mixtures remains poorly characterized and understood. Competition between both species for available resources (space, light, water, nutrients) may change as a result of changes in climate and forest management. In this project, such changes have been studied at two research sites in northern Spain: a continental-high elevation forests and a Mediterranean low-elevation forest. Combining field research and mathematical modelling, our project has gone beyond the state-of-the-art on ecology of mixed forests with these main results:

- **The longest time-series of nutrient circulation** for these mixed forests (15 years). These series show that pine, which grows faster than beech, dominates nutrient circulation during the first part of the stand´s life (up to about 40 year-old stand). However, as beech trees begin to reach the co-dominant canopy stratum there is an increase in nutrient circulation through them. Beech trees rapidly monopolize an important part of nutrient it after the stand reaches 50 years and gets older.
- **The first empirical evidence that complementarity in using water resources enhances tree growth** in in mixed Scots pine – European beech forests**.** Growth of both species was reduced when intra-specific competition increased. Species complementarity was linked to improved pine growth in continental sites, whilst competition overrode any complementarity advantage in drought-prone Mediterranean sites. Beech growth did not show any significant response to pine admixture due to its shade tolerance. Increasing inter-specific competition was the main factor on water use efficiency, which increased in pine but decreased in beech over time. Improved water use efficiency did not improve Scots pine growth, but enhanced beech growth in drought-prone sites was found due to an improved water use (Fig. 1A). However, the trade-off between shade and drought tolerance limits the gains in productivity by species complementarity for shade intolerant species (like Scots pine) in dry sites. Therefore, beech could be a better target than pine for adaptive management.
- **The most detailed projections of species complementarity under future changing climate conditions available up to date** (Fig. 1B)**:** Under current climate conditions, in Mediterranean areas beech trees are favored by the presence of an accompanying species, while pine trees are almost indifferent. This result could indicate that beech trees, once they have reached the codominant canopy stratum, benefit from the cover provided by pines, which also maintains the nutrients in the ecosystem in the early stand development stage, before the beech trees need them. At the same time, pine trees have a more superficial and less competitive root system to

Project Objectives

In mixed Scots pine – European beech stands in SW Europe, a change in resource availability (water, nutrients, light) caused by changes in climate or in forest management could change inter-specific competition, potentially displacing these stands towards new ecological sates. Nutrient and water fluxes, together with stand structure, are key features to understand how tree species compete for resources. To explore the long-term consequences of such competition, the ECOPYREN3 had the following objectives:

1. Characterizing nutrient and water cycles in the forest-soil system for the research sites.
2. Identifying the main factors influencing inter-specific competition between species for water and nutrients in mixed stands.
3. Creating mathematical relationships of climate-tree growth and water use efficiency based on historical series of tree rings.
4. Modelling mixed Scots pine – European beech stands with the FORECAST-Climate ecosystem model growing under different climate scenarios.

compete for water. On the other hand, in continental locations where nutrients are more limiting, beech trees lose their competitive advantage and pine trees benefit from a shallow radical system that captures more nutrients. These interactions will change under climate change, which in cool Mediterranean will favor beech growth in the mixed forests areas, but will have little effect on pine trees. However, in continental areas pine trees will be moderately favored while beech will be slightly impaired due to the increase in interspecific competition. At stand level, Mediterranean sites will lose productivity but continental sites may gain (Fig. 1C).

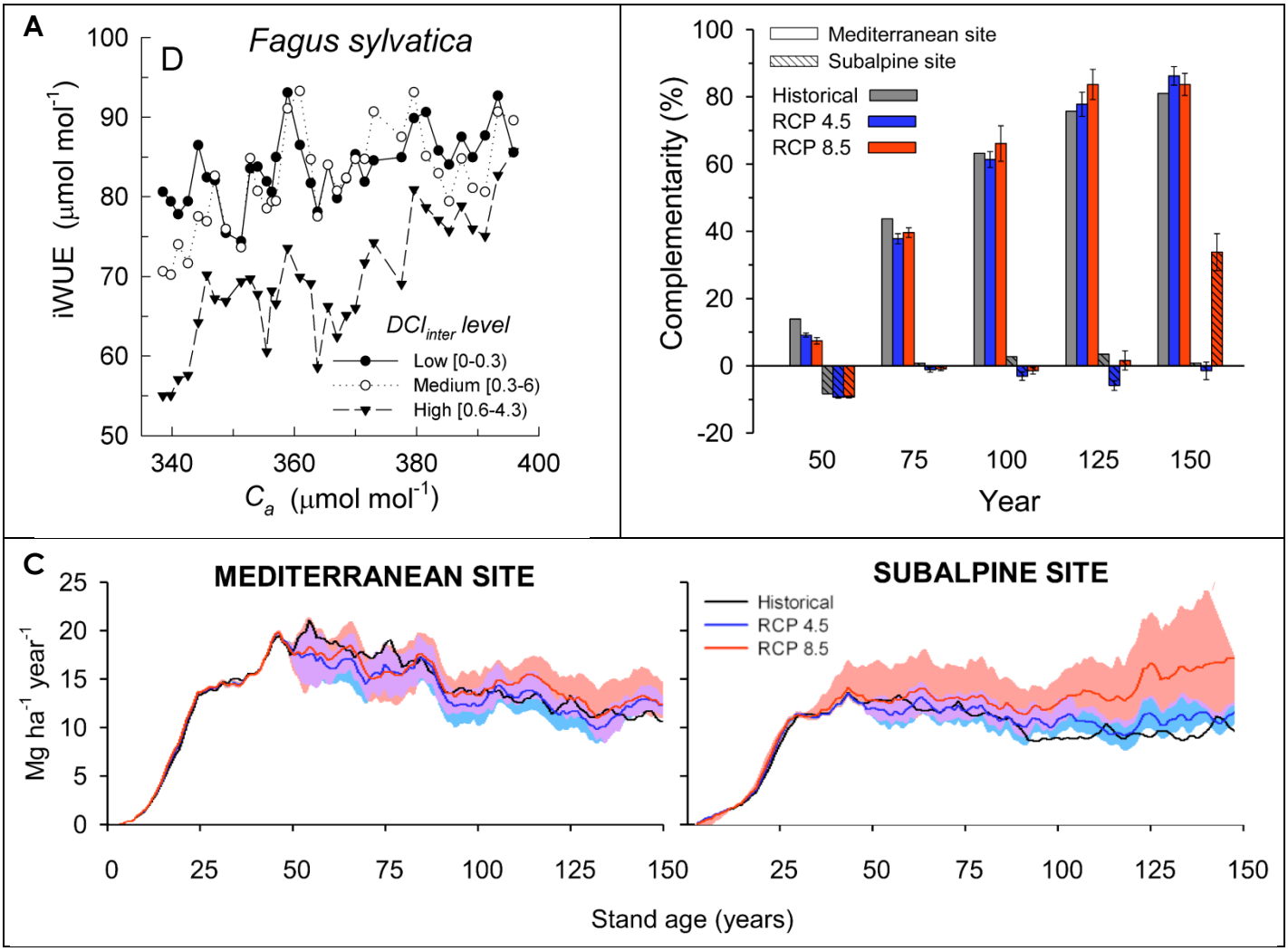

Figure 1. *Main results from ECOPYREN3. A) Recorded increase in water use efficiency (iWUE) in beech under increasing atmospheric CO_2 (C_a) gets higher as competition (DCI_{inter})* also increases. B) Complementarity at stand level grows as the Mediterranean site ages, but not the continental, whereas total productivity, C) follows the opposite pattern.

Socio-economic and academic impacts

1. A finally tuned-up tool for decision-support in forest management operation under current and future conditions (FORECAST-Climate), useful for comparing the consequences of different planning and managing strategies on forest productivity of timber and non-timber values (biomass, water use).
2. A better understanding of the ecological interactions between two major European tree species when growing together. Our results support adaptive forest management in cool Mediterranean sites should focus on promoting beech growth to take advantage of the complementarity in productivity found in mixed stands compared to traditional monospecific conifer stands.
3. Transfer and generation of expertise in using complex ecosystem-level hybrid forest models with socio-economic applications in forest management, and new mathematical techniques forest ecology research.