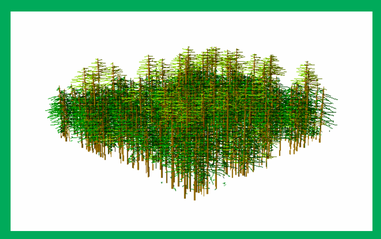
Can mixing of oak and pine compensate for productivity losses due to climate change?



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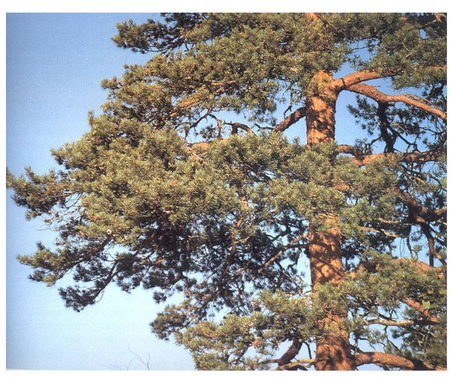
HIGHLIGHTS

- **Productivity decreases with increasing severity of climatic scenario and decreasing latitude**
- **Growth decreases by 7.7 % and 11.6 % for oak and pine for RCP 8.5 shifting the competitive advantage from pine to oak**
- **Mixture cannot compensate for decreases due to climate change**

Introduction

Forests cover about one-third of Europe's surface and their growth is essential for productivity and ecosystem services [1]. Climate change affects forests by modified growth rates, changes in site productivity, altered species composition and increased tree mortality [2]. Adaption of forests to climate change on the one hand side and estimating their mitigation potential on the other hand side are key challenges. Oak *(Quercus robur* and *Quercus petraea)* and pine (*Pinus sylvestris)* grow in pure and mixed stands on xeric sites, where their growth is expected to decrease with climatic warming despite the fact that both tree species are adapted to drought. Tree species mixture decreases risk and is benefical for productivity.



In this research we quantify (i) productivity changes across Europe for different climate scenarios (ii) analyse productivity losses for different latitudes (ii) investigate if the different ecophysiological behaviour results in tree species shifts (ii) evaluate compensating mixture effects.

Material and Methods

The initial data for the simulation consists of 23 triplets. By design, each triplet contains two pure and a mixed plot of oak and pine. Historical temperature and precipitation range from 5.5°C-11.4°C and 586-929 mm (Fig 1.); the scenarios RCP 4.5 and RCP 8.5 showed an increase in temperature up to 12.5 and 14°C, respectively (https://chelsea-climate.org).

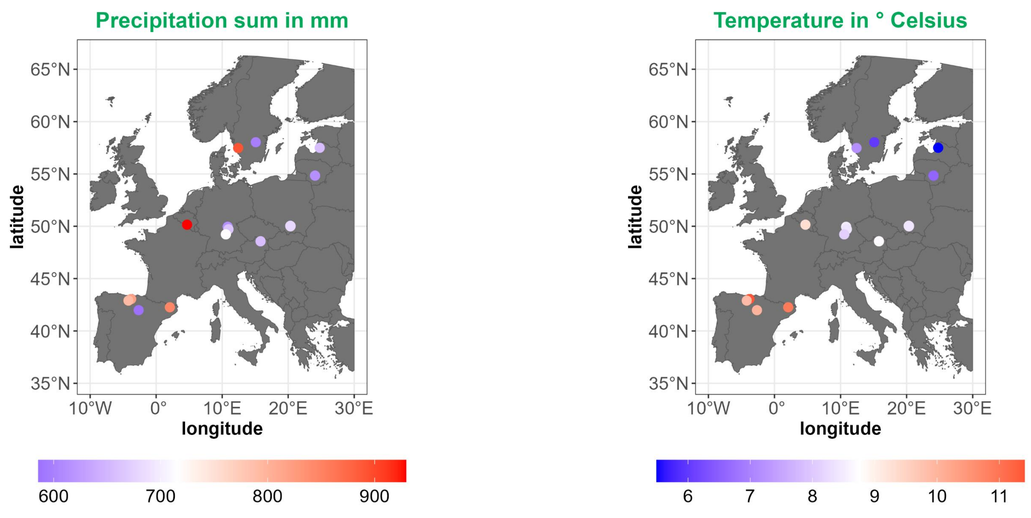


Fig 1 Mean annual temperature and precipitation sum for 23 plots under current climate

Tree growth simulations were done with PrognAus, an individual tree growth model, consisting of a basal area increment, a height increment, a mortality and an ingrowth model. Models were fit from the data of the Austrian National Forest Inventory, which covers a large environmental gradient. Simulations were done at a yearly time step from 2017 to 2100 (Fig. 2). Raw simulations were generalized using a linear mixed effects model.

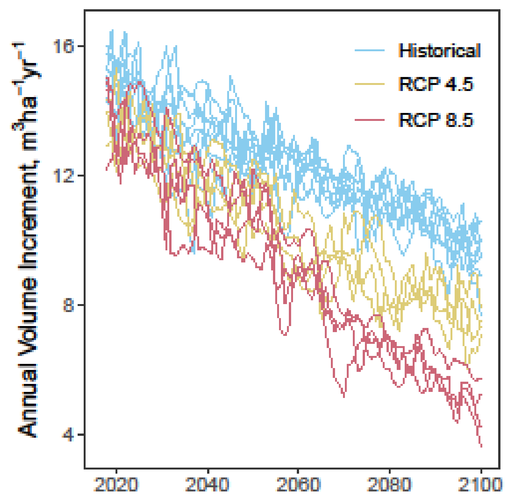


Fig 2 . Simulation with PrognAus for an individual plot

Results

At the end of the simulation period standing volume was highest in the historic scenario. Both species showed a stronger decrease in volume from the historical scenario to RCP 4.5 than a subsequent shift to RCP 8.5. Pure pine plots show the strongest decrease in volume while oak proves to be considerably more resilient. Mixture shows an intermediate response to increased scenario severity. Productivity losses are more pronounced for the lower latitude. (Fig. 3).

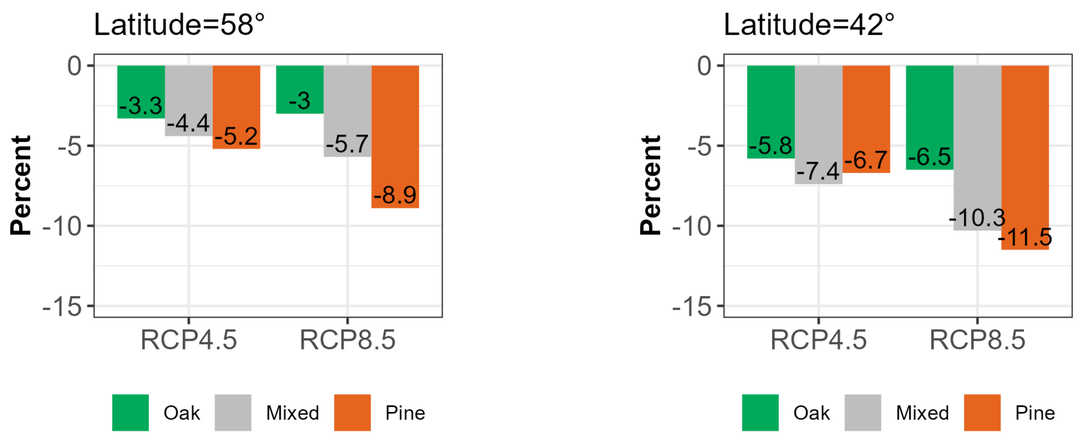


Fig 3 Decrease in volumen increment for different latitudes, climate scenarios and stand type

Discussion and Conclusions

Climate warming will result in severe productivity losses at dry sites. The study suggests a competitive advantage and higher productivity of pine under the current climate, for RCP 4.5 a mixture of oak and pine can be recommended, while for the RCP 8.5 scenario there may be considerable loss in productivity for pine and only oak can be recommended. These differences in growth response are related to the differing physiology of the species: While pine quickly uses favourable time spans in drought periods, oak can endure extremely negative water potentials and keeps sequestering carbon in drought periods [3]. Tree species mixing can only partly compensate for productivity losses due to climate change since gains in productivity reported for these species range between 6-9 % [4]. This may however be possible in combination with other silvicultural adaption strategies.

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