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Alternative tree species under climate warming in managed European forests

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ABSTRACT

This study estimates the present and future distribution potential of 12 thermophilic and rare tree species for Europe based on climate-soil sensitive species distribution models (SDMs), and compares them to the two major temperate and boreal tree species (*Fagus sylvatica* and *Picea abies*).

We used European national forest inventory data with 1.3 million plots to predict the distribution of the 12 + 2 tree species in Europe today and under future warming scenarios of +2.9 and +4.5 °C. The SDMs that were used to calculate the distributions were in a first step only given climate variables for explanation. In a second step, deviations which could not be explained by the climate models were tested in an additional soil variable-based model. Site-index models were applied to the found species distribution to estimate the growth performance (site index) under the given climate.

We find a northward shift of 461 km and 697 km for the thermophilic species over the regarded time period from 2060 to 2080 under a warming scenario of 2.9 °C and 4.5 °C, respectively. Potential winners of climatic warming have their distribution centroid below 48°N. *Fagus sylvatica and Picea abies* will lose great parts of their potential distribution range (approx. 55 and 60%, respectively). An index of area gain and growth performance revealed *Ulmus laevis*, *Quercus rubra, Quercus cerris* and *Robinia pseudoacacia* as interesting alternatives in managed temperate forests currently dominated by *F. sylvatica* and *P. abies*.

The 12 investigated species are already in focus in forestry and it has been shown that the changing climate creates conditions for a targeted promotion in European forests. Nevertheless, area winners exhibited lower growth performances. So, forest conversion with these warm-adapted species goes hand in hand with loss of overall growth performance compared to current species composition. So, the results are a premise for a further discussion on the ecological consequences and the consistency with forest socio-economic goals and conservation policies.

1. Introduction

Forests cover 33% of the European land area and 96% of this area is managed and contributes to the supply of the resource wood (Forest Europe, 2015). *Fagus sylvatica* L. and *Picea abies* (L.) Karst. are two of the most common tree species in boreal and temperate European forests (Köble and Seufert, 2001) with high economic relevance especially for the timber industry (Eurostat, 2018). Nevertheless, several studies

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predict that their proportion will decrease under climate change in European forests (e.g. Hanewinkel et al., 2013; Kellomaki et al., 2001; Ruiz-Labourdette et al., 2013) and they will be replaced by species with a more thermophilic character (Kullman, 2008). Since timber producing tree species typically have rotation periods of 60 years and more, forest managers must know already today which and where such thermophilic species can replace or enrich the current tree species compositions.

Hanewinkel et al. (2013) forecasted a shift in wood assortment in Central Europe from productive species, mainly *P. abies* and *Pinus sylvestris* L., to slow-growing species like Mediterranean oaks. This transformation led to lower productivity and land expectation values. However, adaptive forest management provides strategies to mitigate such impacts. Over the last two decades the research on adaption to climate change has greatly increased. Some measures aim at increasing forest stability based on the current tree species spectrum, for instance by decreasing the forest stand density (Aussenac and Granier, 1988; Kohler et al., 2010; Rais et al., 2014). Also, the shortening of the rotation period reduces the risk of unexpected mortality (Seidl et al., 2011). Another strategy is to regenerate or foster suitable tree species mixtures. Several studies have shown that compensatory and facilitative effects between species are able to improve the stability of tree growth (del Río et al., 2017; Lebourgeois et al., 2013; Pretzsch et al., 2013; Thurm et al., 2016) and also the water status of the trees (Schäfer et al., 2018; Schume et al., 2004) by reducing drought stress. A next step would be to use genetic adaptability of species and to promote drought stress tolerant characteristics or choose drought tolerant populations for planting (Chakraborty et al., 2015; Fady et al., 2016; Montwé et al., 2016).

Nonetheless, the mentioned strategies can only mitigate the risk to a certain degree, and in many regions of Europe the increasing temperatures will force a change of tree species composition (Bonan, 2008; Hanewinkel et al., 2013). In order to prevent a successional-driven permanence of the currently dominant forests species and to ensure the social and economic benefits of this sector, it is important to formulate recommendations for the introduction of alternative tree species. Therefore the question arises which species are able to form the next generation of high-resistance forest and can comply with the qualitative and quantitative demands of the wood market.

Traditionally, large cultivation trials generated recommendations for new non-native or rare species (a detailed description for several species can be found in Pâques, 2013). However, the long time span of these trials is contrasted by the rapidity of climatic change, and forces us to seek faster methodical ways to recommend species ad hoc. Species distribution models (SDMs) are able to generate such information (Elith and Leathwick, 2009). Modern computation and high quality occurrence data sets make it relatively easy to generate such models. They have therefore become a popular tool in macroecology over the last decades to understand global distribution patterns of species. However, SDMs have scarcely been used as a tool in the forest sector or for

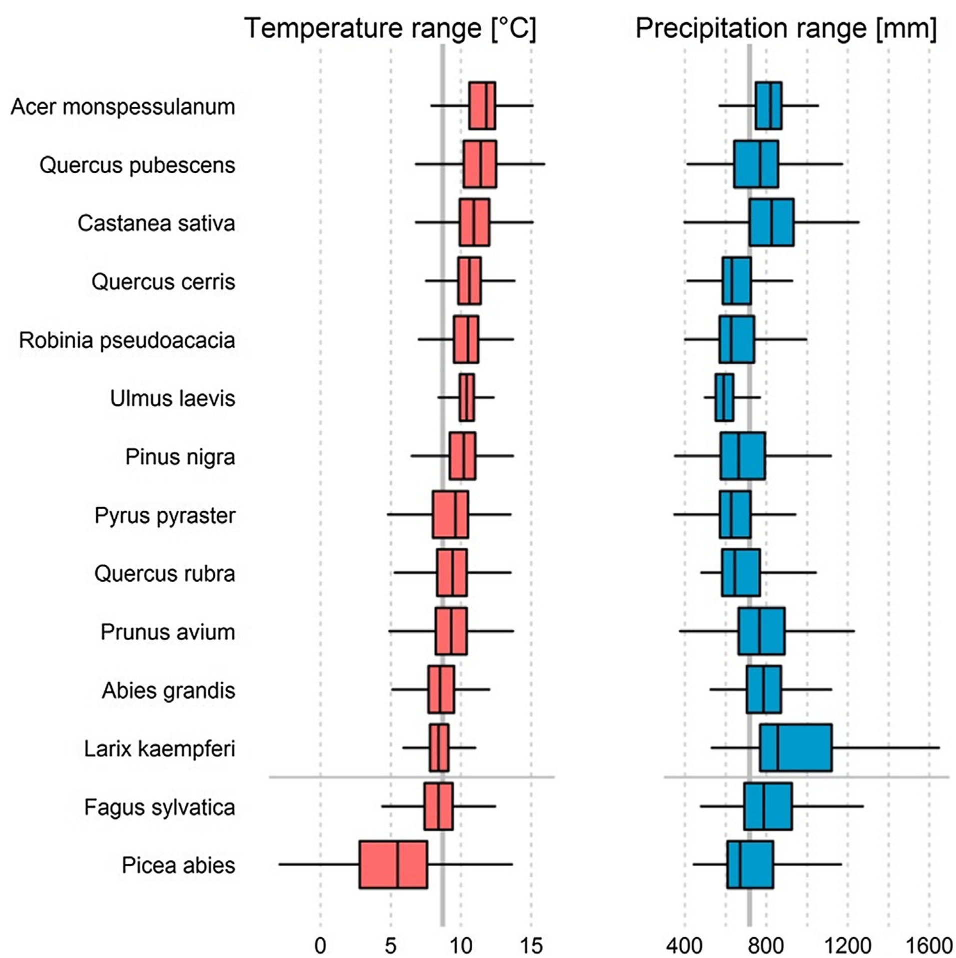

Fig. 1. Annual temperature and precipitation range of the 12 investigated species plus the two comparative species *Fagus sylvatica* and *Picea abies*. The data represents the occurrences of the species in the inventory data in Europe. Climate data derives from WorldClim 1.4 dataset (Hijmans et al., 2005). The species are ranked by their median temperature.