Potential impacts of climate change on the distribution of seven dominant tree species in Greece

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Climate change is expected to affect species distribution and ecosystem form and function. Forests provide a range of ecosystem services including the regulation of local and global climate through carbon accumulation, and thus understanding how they will respond to projected climatic shifts is important for biodiversity conservation and climate adaptation purposes (Canadell and Raupach, 2008). In Greece, a detailed evaluation of how forest will respond to climate change is only available for a limited number of sites (Fyllas *et al.* 2007, 2009, 2017). Although local simulations from detailed process-based models are important to understand the mechanisms of shifts in ecosystems function, regional-scale projections under climatic change scenarios are also useful, as they provide an overview of the expected changes. This paper uses empirical species distribution models, to simulate the current and the future distribution of seven dominant tree species in Greece.

Species distribution models (SDMs) have been extensively used to model the potential distribution of both species and ecosystem types (Elith and Leathwick 2009). SDMs simulate species occurrence (or abundance) as a function of several environmental predictor variables, such as climatic and edaphic parameters. After fitting an adequate model, the "function" describing species occurrence is used to simulate species distribution across a range of environmental conditions. SDMs present several advantages such as the quick and spatially explicit simulation of species niche. SDMs on the other hand have several disadvantages as they are empirical and have no mechanistic basis, and that they simulate the realised and not the fundamental species niche. As in most scientific models the principle "garbage in garbage out" also applies in SDMs, and thus appropriate data input are required for adequate model performance and prediction. These include accurate environmental data and species occurrence data that extend as much as possible across the range of species ecophysiological limits.

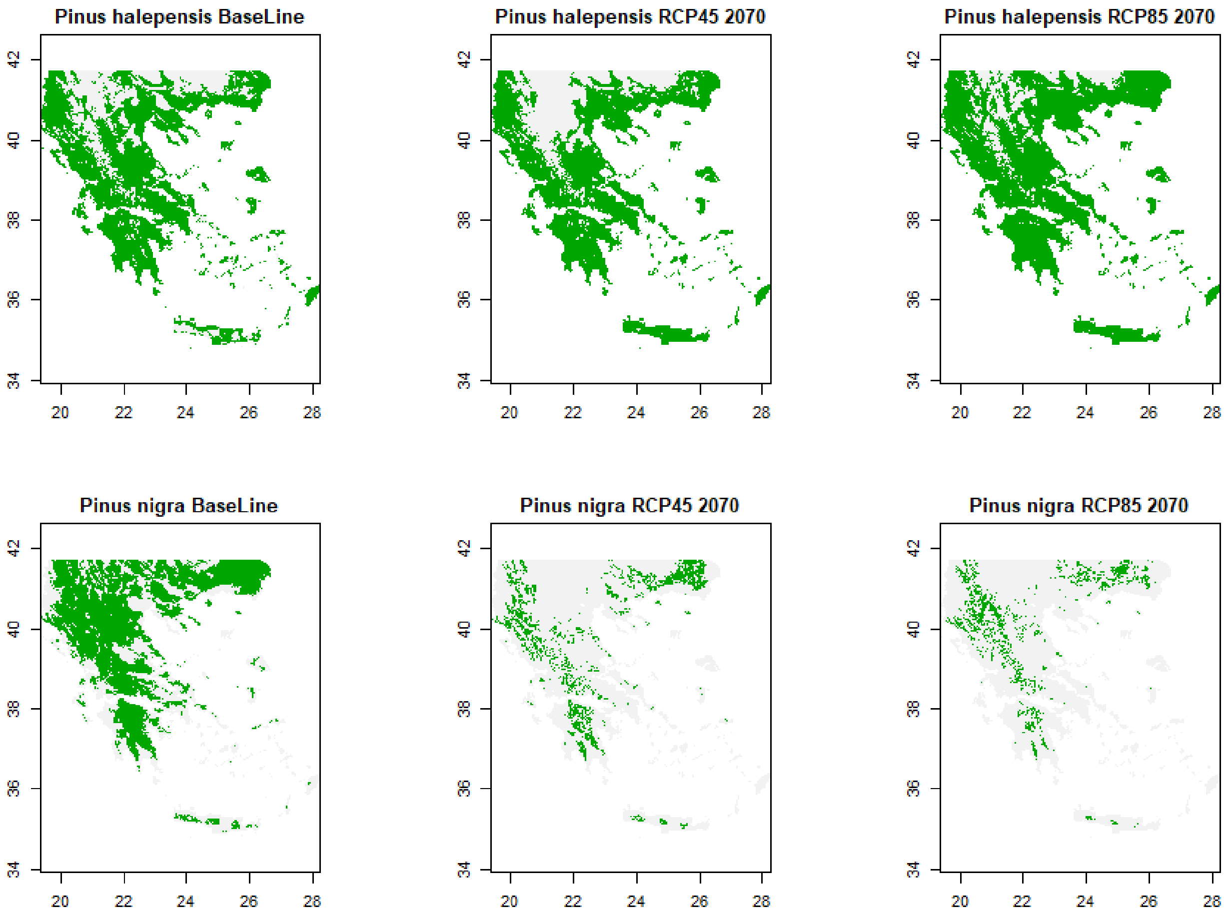
In this study we simulated the distribution of seven dominant tree species in Greece, i.e. *Abies cephalonica, Pinus halepensis, Pinus brutia, Pinus nigra, Quercus pubescens, Quercus frainetto and Fagus sylvatica sl*. Forests stands dominated by these species cover more than 30% of the total forested area. As detailed species distribution maps are lacking in Greece, we used the database from the European Atlas of Forest Tree Species (San-Miguel-Ayanz *et al.* 2016) and extend it with our own observations and data from forest stewardship plans. We increased the poor representation of only 117 datapoints to 601 datapoints for Greece in the the European Atlas of Forest Tree Species. We added 49 sites with *Abies cephalonica* occurrence, 42 sites with *Pinus halepensis*, 51 sites with *Pinus nigra*, *39* sites with *Quercus frainetto*, 27 sites with *Quercus pubescens* and 64 sites with *Fagus sylvatica.*

Climate data for both current and future conditions were taken from the CHELSA Project (Karger *et al.* 2017) with a spatial resolution around 1km^2. The climate variables used were: the mean annual temperature, the mean diurnal range, the maximum temperature of the warmest month, the minimum temperature of the coldest month, the annual precipitation, the precipitation of the driest month and the precipitation of the driest quarter. Climate projections from the Max Planck Institute Earth System Model (MPI-ESM-LR) for two emission scenarios (RCP45 & RCP85) and the 2061-2080 period were used to simulate species future distribution. Edaphic data were taken from the European Soil Data Centre (Panagos et al. 2006). In this analysis we used available water capacity (awc), cation exchange capacity (cec) and depth to rock (dr) as the key soil variables expressing water and nutrients availability.

The same modelling technique was applied for each species. We initially divided the species occurrence data points into two groups; one (80% of data points) used for training purposes and another one (20%) for validation. We fitted a maximum entropy model (Phillips et al. 2006) and evaluated its performance using standard methods. We then used the optimum SDM for each species to simulate species distribution across Greece, under current and future climate conditions. We additionally estimated the ratio of future to current area of potential species occurrence as a metric of change in the available area, and the ratio of overlapping future to current potential species occurrence as a metric of the ability of species to migrate to new favourable areas. Dispersal limitations due to anthropogenic activities such as barriers or land use changes were not considered. All analyses and maps were made with the R programming language (R Core Team 2019) and the *dismo* and *rJava* packages.

Under current conditions the models simulated adequately the distribution of all species, with an AUC higher than 0.80 in all cases. When applied under future climate, significant decrease of areas with favourable conditions were simulated for all species apart from the two drought-tolerant low elevation pines, i.e. *Pinus halepensis & Pinus brutia*. For example, the area of *Pinus halepensis* potential distribution decreased by only 3% under RCP45 and increased by 15% under RCP85 at the 2061-2080 period. On the other hand, a strong decrease of approximately 76% and 82% of the potential distribution area of *Pinus nigra* was simulated for RCP45 and RCP85 respectively. Overall our findings suggest that climate change might lead to significant shifts in species composition, particularly at forests at higher elevations.

Figure 1. Potential distribution of *Pinus halepensis* & *Pinus brutia* (upper panel) and *Pinus nigra* (lower panel) under current (BaseLine) climate and under a RCP45 and a RCP85 scenario at year 2070. Green pixels indicate areas with favourable environmental conditions (probability of occurrence >0.2)



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