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Ecological traits of Mediterranean tree species as a basis for modelling forest dynamics in the Taurus mountains, Turkey

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ABSTRACT

To investigate the past forest–society interactions in the territory of the ancient city of Sagalassos, situated in the Taurus Mountains in Southwest Turkey, it is necessary to reconstruct forest composition and biomass through time. This paper focuses on modelling the natural vegetation dynamics in the area over the occurring gradient of biophysical site conditions under today's climate, as a first and essential stepping-stone towards this goal. GREFOS, a forest gap dynamics model developed for the North-Eastern Mediterranean Basin, was adapted to the bioclimatic conditions of the Taurus Mountains, adding effects of late frost on species regeneration and adjusting the fire module. The model was parameterized based on an extensive literature review and additional field measurements for the seven most important tree species in the study area (*Pinus brutia*, *Pinus nigra*, *Cedrus libani*, *Abies cilicica*, *Quercus cerris*, *Quercus coccifera* and *Juniperus excelsa*) resulting in the most complete and documented ecological traits matrix presently available for the studied species. Qualitative and semi-quantitative model validation indicates that simulated species presence, altitude ranges and basal area estimates correspond reasonably well to field observations or expected values based on literature and expert knowledge. Yet validation results also indicate some inaccuracies for simulation of *P. nigra* and *J. excelsa* at higher altitudes. Simulations are summarized in a conceptual model with four vegetation zones, which reflects literature and expert opinion, and is interpretable in terms of ecological processes and succession dynamics in the study area. It is concluded that the resulting model is able to realistically predict effects of fire and abiotic site conditions on natural vegetation development in different climate zones in the Taurus mountains. Further model development steps should aim to include important additional drivers of vegetation composition, such as climate change and land use.

1. Introduction

The ancient city of Sagalassos, situated in the Taurus Mountains in Southern Anatolia, Turkey, has been subjected to archeological research for a number of decades, with a focus on nature–society interactions through interdisciplinary research. The area has known a long history of intense human activity (Vermeersch et al., 2000; Vanhaverbeke and Waelkens, 2003) that has had a strong impact on the surrounding forests through the harvesting of wood and livestock grazing (Vanhaverbeke and Waelkens, 2003; Akkemik et al., 2012).

To investigate these past forest–society interactions, we aim to reconstruct forest composition and biomass through time. This can be done with forest dynamics models that include effects of (1) site (soil, climate, topography), (2) tree species traits and species interactions and (3) disturbances (fires, grazing, logging). This paper focuses on modelling the natural vegetation dynamics under current climate over a wide range of biophysical conditions using a forest gap model, as a first and essential stepping-stone towards a model that is able to explore past forest–society interactions in the Sagalassos region. Future steps towards this aim will include adding land use (grazing, logging) to the model, exploring the effects of long-term historical climate change, and

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incorporating the simulated fine-scale local forest dynamics in a broader geographic context (Busing and Mailly, 2004; Perry and Enright, 2006).

The GREFOS (GREek FOrest Species) model (Fyllas et al., 2007; Fyllas and Troumbis, 2009) was chosen as the most appropriate model to build on. GREFOS is a mechanistic forest gap model which has been developed for the mountains of the North-Eastern Mediterranean Basin and is thus rather well adapted to the abiotic site conditions and climate circumstances of the Taurus Mountains. Moreover, the model includes a site–climate–vegetation driven fire module, essential for simulating vegetation dynamics in the study area.

In this study the GREFOS model was adapted to the species and specific environmental conditions of the Taurus Mountains. Data from recent field campaigns and previously undisclosed expert- and literature-based information are used to construct and incorporate a species ecological traits matrix for seven main productive tree species and shrubs of the region. Furthermore, the model was improved by adding the effect of late frost on species regeneration and by fine-tuning the fire module to local observations of fire return. Model results were validated using qualitative and semi-quantitative methods based on current vegetation observations, literature and expert knowledge. Model results were summarized into a conceptual model of vegetation zones and succession dynamics for the Sagalassos area.

2. Materials and methods

2.1. Study area

The study area (55.000 ha) covers the Ağlasun forest district (37°33′N, 30°32′E, 350–2200 m above sea level), located in the Mediterranean Transitional Region of Turkey which is situated between the Mediterranean and the Inner Anatolian regions (Atalay and Efe, 2007). The region is characterized by a cold and sub-humid Mediterranean climate with pronounced winter precipitation and summer drought. Local fires can occur every 3–29 (on average 9) years up to 1100 m (Neyisci, 1985, 1993) and occasionally up to 1400 m (Kaniewski et al., 2008). Limestone is the predominating parent material. Locally also conglomerates and sandstones are present. Soil depth, moisture regime and stoniness vary with topography. Most soils can be classified as leptosols, regosols or cambisols (FAO classification), depending on shallowness and stoniness (Fontaine et al., 2007).

About 55% of the study area is covered by Mediterranean mountain forests mainly composed of even and uneven-aged stands of *Quercus coccifera* L. (Kermes oak) (11.000 ha), *Pinus brutia* Ten. (Brutia pine) (10.500 ha), *Juniperus excelsa* M. Bieb. sp. *excelsa* (Juniper) (6000 ha) and *Pinus nigra* Arn. sp. *pallasiana* (Lamb) Holmboe (Black pine) (2500 ha). Some relic stands of *Cedrus libani* A. Rich. (Lebanon cedar), *Quercus cerris* L. (Turkey oak) and *Abies cilicica* de Lannoy (Taurus fir) forest occur as well. The area has a long history of human settlement and forest utilization, including individual tree harvest and grazing (Vermoere et al., 2003).

Data were collected in the summers of 2005–2007 (Fontaine et al., 2007; Aertsen et al., 2010). To maximize spatial and topographic variation in the dataset, transects were established throughout the study area, principally oriented from valley to ridge, perpendicular to the contour lines. Due to the limited number of cedar forests in the Ağlasun forest district, additional cedar forests in neighbouring districts were selected, i.e. Kasnak National Forest (37°44′N, 30°49′E), Prof. Dr. Bekir Sıtkı Evcimen Taurus Cedar Protection Forest at Senirkent (38°05′N, 30°41′E) and Gölishar forest (36°53′N, 29°27′E). Along those transects, 330 plots (20 m × 20 m) were established at random intervals (Fig. 1). Plot locations were mapped using altimeter and GPS.

Environmental variables collected in the plots included topographical, soil and vegetation variables. Slope (%) was measured using a clinometer. Aspect was recorded as the azimuth (θ) measured from true north. Soil depth was assessed using the rod

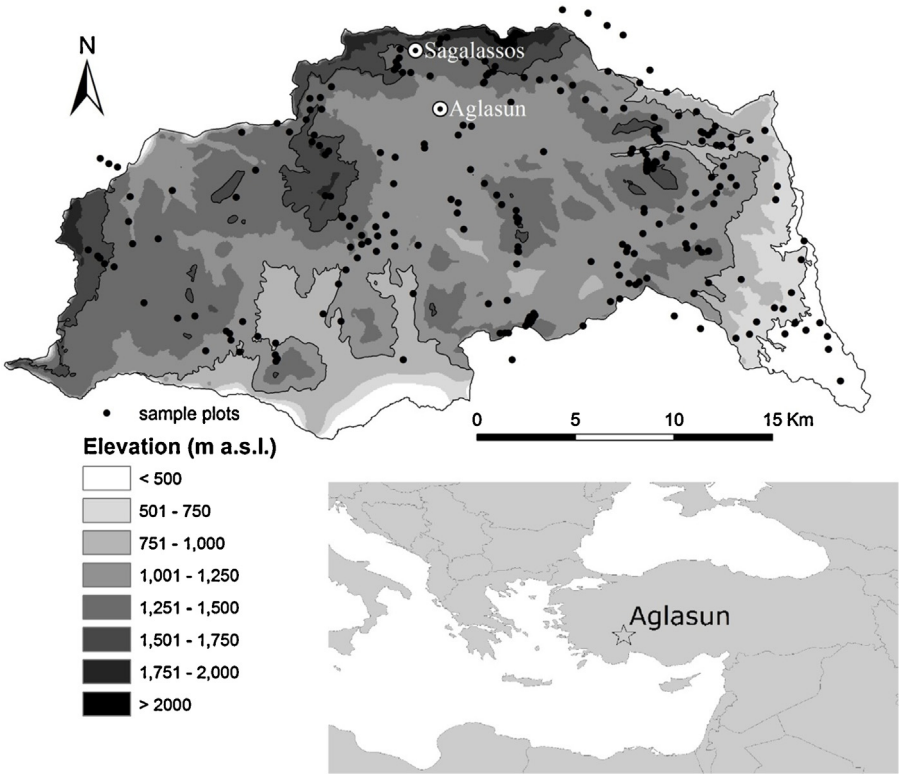

Fig. 1. Location of sample plots in the Mediterranean mountain forest in the Ağlasun forest district of Southern Anatolia, Turkey (bottom inset).