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Elevation and exposition rather than soil types determine communities and site suitability in Mediterranean mountain forests of southern Anatolia, Turkey

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Abstract

The forest resources of south Anatolia (Turkey) are characterized by historical degradation due to wood extraction, overgrazing and fire. In a context of forest restoration, natural vegetation distribution patterns and plant community compositions need to be known and integrated in a framework for site classification. Accordingly, we sampled 153 plots at random along 20 transects perpendicular to the contour lines. In every plot we recorded biotic variables (plant species covers) to describe the vegetation composition; abiotic variables (encompassing landscape and soil characteristics) to assess the site quality; and tree population characteristics to define site index of *Pinus brutia* and *Pinus nigra*. Five communities were identified using MRPP and indicator species analysis. Indirect gradients were analysed with non-metric multidimensional scaling (NMDS). In the ordination, the first NMDS axis (explaining 27% of the variation) separated three groups along an elevation gradient and the second axis (23%) two groups with contrasting exposition at the highest altitudes. Litter characteristics were the main environmental gradient according to PCA, but were only relevant to discriminate between two communities at intermediate altitude. *P. brutia* performed best below 800 m in a Eu-Mediterranean climate. Sites above 1000 m were more suitable for *P. nigra*. *Abies cilicica* and *Cedrus libani* were identified as potential climax species of mountainous Mediterranean communities at the highest elevations, more specifically at the colder, wetter expositions and at the dryer, warmer expositions, respectively. Threats to the survival of *A. cilicica*, caused by clear cutting in the present silvicultural system, may be alleviated by adopting a shelterwood system in the higher altitudinal range.

Keywords: *Abies cilicica*; Indicator species; Local extinction; *Pinus brutia*; *Pinus nigra*; Site classification

1. Introduction

The Taurus mountains in southern Anatolia, Turkey, and in particular the area surrounding the ancient city of Sagalassos have been the theatre of intense human activity for thousands of years, with both early and recent civilizations embracing a continuous quest for fuel wood, timber and livestock grazing areas (Vanhaverbeke and Waelkens, 2003). This long lasting human interference with the natural ecosystem has led to a significant reduction of forest cover while about one third of the remaining forest can be considered degraded and unproductive.

In southwestern Turkey, mixed forests comprising oak, pine and juniper developed from an open landscape around 6700 BC and persisted until ~1240 BC when human occupation started to show significant impact on the natural vegetation due to forest clearance (Eastwood et al., 1999). The area occupied by *Cedrus libani* A. Rich. (Lebanon cedar), once the engine of civilization development, has shrunk to merely 600,000 ha in Turkey and is largely restricted to topographically inaccessible areas (Boydak, 2003). Already since AD ~700 pines have become the dominant forest trees (Eastwood et al., 1999) and nowadays *Pinus brutia* Ten. (Calabrian pine) and *Pinus nigra* ssp. *pallasiana* (Arnold) K. Richt (Crimean pine) are the main

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timber species of the Mediterranean mountain forests in Turkey, accounting for 3.7 and 2.5 million hectares, respectively (Boydak, 2004). However, up to 40% of the total area covered by *P. brutia* is highly degraded and therefore ecologically unstable and economically unproductive (Boydak, 2004). Recently efforts have been made to restore degraded forest areas, and the need for species-specific site selection criteria has been recognized. This paper refines the existing knowledge on site suitability of Mediterranean mountain forest in southern Anatolia in order to make rehabilitation efforts in degraded stands more successful.

An accurate but cost-effective method of site classification is required to predict the suitability of an area for silvicultural activities with certain given tree species. The site index (SI_a) is a species-specific measure of site productivity and is defined as the mean height in meters of a predefined number of dominant trees at reference age *a* (Clutter et al., 1992). Several studies have tried to model site index by coupling age and height measurements to abiotic site properties but with alternating success (see e.g. Corona et al., 1998; Chen et al., 2002; Bergès et al., 2005). Many yielded low accuracy and a high degree of variation (Kayahara et al., 1998; Curt et al., 2001). Moreover the variables needed for such modeling studies are often rather expensive and difficult to assess, especially when long time series are required to compensate for climatologic variation. Alternatively, the use of natural vegetation as an indicator for site quality has provided good results, due to the close relationship it has with abiotic site characteristics (Wang, 2000; Bergès et al., 2006; Waring et al., 2006). On the other hand, it is known that tree species and management can profoundly affect the site characteristics and the vegetation in a given area (Rescia et al., 1994; Augusto et al., 2002; Lenière and Houle, 2006; Tarrega et al., 2006) and potentially smoothen the variation in natural habitats. This often leads to a reduced biotic diversity and a homogenization of the ecosystem, especially in plantations (Larsen, 1995; Uuttera et al., 1997; Maestre and Cortina, 2004; Chirino et al., 2006).

Forest ecosystem types are defined by geomorphology, soil and vegetation (Barnes et al., 1982). Although a particular forest ecosystem may contain multiple species compositions during different time periods (Abella et al., 2003), for instance due to human-induced stress or management, spontaneous vegetation still has a high potential for site quality assessment since floral responses to natural abiotic gradients, being the climate, the soil and the geomorphology, have often proved to persist (see e.g. Abella and Covington, 2006).

Therefore, we explored the community structure of the semi-natural forests in southern Anatolia, identified communities and linked these to existing phytosociological vegetation types (Quézel, 1980). We hypothesized that the different communities are characterized by distinct indicator species which show unique responses to the present environmental gradients despite the long history of human interference and silvicultural management. We also hypothesized that these indicator species can be used to predict differences in site index and thus site suitability for *P. brutia* and *P. nigra* and can therefore support decision making in forest restoration management planning.

2. Materials and methods

2.1. Study site

The study area (55,000 ha) was the Ağlasun forest district (37°33′N, 30°32′E, 350–2200 m above sea level) in southern Anatolia. A cold and sub-humid Mediterranean climate with pronounced winter precipitation and summer drought predominates (Paulissen et al., 1993). From 1963 to 1990 the mean monthly temperature at Ağlasun (1100 m above sea level) ranged from −2.1 °C (January) to 28.7 °C (August) and the mean annual precipitation approximates 990 mm $year^{-1}$ (Librecht et al., 2000). Above 1400 m above sea level a mountainous Mediterranean climate with a higher precipitation prevails.

Limestone is the predominating parent material. Locally also conglomerates and sandstones are present. Soil depth, moisture content and stoniness vary with topography. Most soils can be classified as leptosols, regosols or cambisols (FAO et al., 1998), depending on shallowness and stoniness.

The study area is covered for 53% by Mediterranean mountain forests mainly composed of *Quercus coccifera* (Kermes oak) (11,000 ha), *P. brutia* (Calabrian pine) (10,500 ha), *Juniperus* spp. (6000 ha) and *P. nigra* (Crimean pine) (2500 ha). Some relic stands of *C. libani* (Lebanon cedar) (about 900 ha) forest occur as well. The remainder of the area consists of agricultural land or bare rock. The area has a long history of human settlement and forest utilization, including a high livestock grazing pressure.

2.2. Species selected for site suitability assessment

As opposed to *C. libani*, *P. brutia* and *P. nigra* are widespread tree species occurring on a variety of sites. This enables the study of the factors that determine the site quality and site suitability for these species.

P. brutia is closely related to *Pinus halepensis* Mill. (Aleppo pine) and occupies the eastern part of the Mediterranean basin (Boydak, 2004; Tapias et al., 2004). Its elevation range varies between 0 and 1500 m above sea level with an optimum at intermediate altitudes. The species is known to be a light and heath demanding pioneer tree which is clearly adapted to a Mediterranean climate and its recurrent fires. A high degree of serotinity (sensu Tapias et al., 2004) and massive juvenile regeneration after fire are its main adaptations to survive severe forest fires (Arbez, 1974; Boydak, 2004). It can form pure as well as mixed stands with *P. nigra*.

P. nigra subsp. *pallasiana* also occupies the eastern part of the Mediterranean basin but is typical for higher altitudes. Its optimum is located between 1000 and 1200 m. The species occurs in humid conditions in Greece and in drier environments in Turkey (Quézel, 1980), illustrating its ecological flexibility.

2.3. Data collection

Data were collected in July–September 2005. To maximize spatial variation in the dataset, 20 transects were laid out throughout the study area, principally oriented from valley to