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Site properties for Crimean juniper (*Juniperus excelsa*) in semi-natural forests of south western Anatolia, Turkey

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Abstract: *We explored the semi-natural forests in south western Anatolia along a gradient between Mediterranean and continental climates to determine the site requirements of Juniperus excelsa in Turkey. We hypothesized that environmental variables and indicator species can be used to predict differences in occurrence and cover of J. excelsa and can therefore support decision making in reforestation management planning. Plant species composition and environmental variables were assessed in 153 plots. Association between J. excelsa and other plant species and environmental variables were analyzed using Fisher exact probability tests and stepwise discriminant analysis. High altitude (> 1000 m) as a proxy for an Oromediterranean climate, and high surface stoniness as a proxy for low competition by other tree species, are positive site properties for J. excelsa. The tree species avoids Eumediterranean and Supramediterranean plant communities. Twelve plant species, including the herbs Dianthus zonatus, Ajuga chamaepitys and Paronchia carica and the shrub Cotoneaster nummularia may be used as site indicators for J. excelsa restoration. Platanus orientalis, with similar site requirements but at present negatively associated to J. excelsa due to competitive effects, may be considered an additional indicator if stand conversion (harvesting and replacing P. orientalis) is part of the management plan.*

Key words: *Indicator species, Site classification, Site requirements, Land suitability, Mediterranean, Plant distribution, Reforestation, Discriminant analysis*
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Introduction

In Turkey, juniper forests cover over 1.2 million ha throughout the country, the genus *Juniperus* is represented by six species – *J. oxycedrus* L. (Prickly cedar), *J. phoenicea* L. (Phoenicean juniper), *J. sabina* L. (Savin juniper), *J. communis* L. (Common juniper), *J. foetidissima* Willd. (Stinking juniper) and *J. excelsa* M. Bieb. (Crimean or Greek juniper) (Elicin, 1977; Davis, 1965), the latter comprises the largest stands. However, due to prolonged resource mismanagement, silvicultural problems and a long history of overgrazing by domestic livestock, most natural *J. excelsa* stands are highly degraded (Carus, 2004). Natural regeneration has become scarce and artificial regeneration slow, even under nursery conditions (Avsar and Tonguc, 2003). In addtition, throughout its range, remnant *J. excelsa* stands are suffering from drought, mistletoe, fungal infections and the effects of climatic change (Gardner and Fisher, 1996; Dogan and Karadelev, 2006).

Recent developments in seed viability and germination research (Al-Refai *et al.,* 2003; Gültekin *et al.,* 2003; Gültekin and Oztürk, 2003; Gülcü and Gültekin, 2005) and clonal propagation (Shanjani, 2003; Esmaeelnia *et al.,* 2006) have yielded increased success in ex-situ propagation of *J. excelsa.* Raising planting stock and even direct sowing for reforestation with *J. excelsa* have become feasible (Gültekin and Gültekin, 2005). However, as in other efforts to restore degraded forest areas, species-specific site selection criteria for such activities are needed (Fontaine *et al.,* 2007).

Therefore, the aim of this paper is to determine the site requirements of *J. excelsa* in Turkey. We explored the semi-natural forests in south western Anatolia along a gradient between Mediterranean and continental (Anatolian) climates. We hypothesized that environmental (site) variables and indicator plant species can be used to predict differences in occurrence and cover of *J. excelsa* and can therefore support decision making in forest restoration management planning.

Materials and Methods

Studied species: *Juniperus excelsa* M. Bieb. ssp. *excelsa* is a juniper found throughout the eastern Mediterranean, from northeastern Greece and southern Bulgaria across Turkey to Syria, Lebanon and the Caucasus, generally at an elevation between 100 and 2300 m (Earle, 2007). It is gradually replaced by *J. excelsa* subsp. *polycarpos* (Persian juniper) eastward around the Caspian Sea into Afghanistan, Kirgizstan, Pakistan and Himachal Pradesh (India), along the mountain chains west of the great desert plateaus in Iran and on Jabal-al-Akhdar in Oman. *J. excelsa* subsp. *excelsa* is especially widespread in the hills and mountains of Anatolia and on the Crimea, where the annual precipitation reaches between 500 and 1000 mm. There it forms a large shrub or tree attaining a

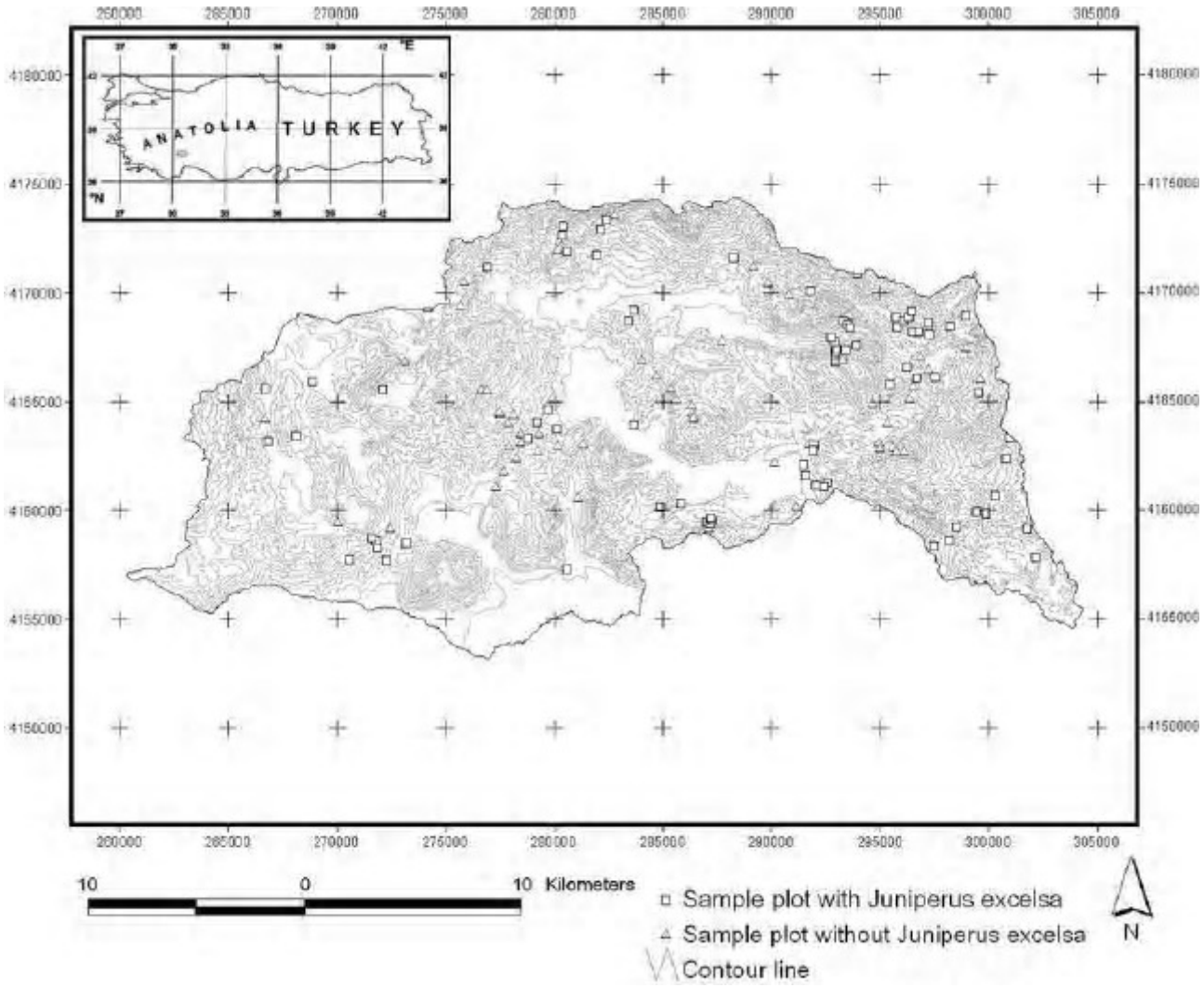

Fig. 1: Distribution of *Juniperus excelsa* in plots in semi-natural forests in south western Anatolia, Turkey, in relation to elevation

height of 6-20 m, with a trunk up to 2 m in diameter and a broadly conical to rounded or irregular crown (Farjon, 1992). In several mountain ranges it is a tree line species where it adopts a crooked form. It is resistant to summer drought and warmth and grows mainly on stony, rocky slopes. It may form pure, open forests, grow mixed with *J. foetidissima* or with other conifers such as *Cedrus libani* A. Rich. (Lebanon cedar), *Cupressus sempervirens* L. (Mediterranean cypress), *Pinus brutia* Ten. (Calabrian pine) and *Pinus nigra* ssp. *pallasiana* (Arnold) K. Richt (Crimean pine), or it may be part of oak-scrub communities in secondary vegetation, but not in Mediterranean maquis (Evrendilek *et al.,* 2004; Farjon, 2005). The sturdy and fragrant timber has been used extensively for carving and indoor wood work including furniture and roof beams (Bektas *et al.,* 2004).

Study site: The study area (55,000 ha) was the Aglasun (Isparta) forest district (37° 33' N, 30° 32' E, 350-2200 m above sea level) in south western 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 Aglasun (1,100 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. The Mediterranean climate with a long summer drought is dominant in the south of the study area, in the surroundings of Aglasun a transitional climate prevails and in the north and northeastern part of the study area the climate is more continental and less Mediterranean.

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. Generally, soils derived from limestone are very shallow and those developed from sandy or clayey deposits deep.

About 53% of the study area is covered by Mediterranean mountain forests mainly composed of *Quercus coccifera* L. (Kermes oak) (11,000 ha), *Pinus brutia* (10,500 ha), *Juniperus spp.* (6,000 ha) and *Pinus nigra* subsp. *pallasiana* (2,500 ha). Some relic stands of *Cedrus libani* (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.

Data were collected in July-September 2005. Twenty transects were laid out throughout the study area, principally oriented from valley to ridge, perpendicular to the contour lines. Along those transects, 153 plots of 20x20 m size were selected at random intervals. The species composition of each plot (woody and herbaceous) was recorded as presence/absence data. The position of the plot in the landscape along the vertical gradient, the soil surface roughness, landform, surface stoniness, slope, aspect and depth of the ectorganic horizon were recorded. To quantify nutrient availability, five topsoil samples (0-10 cm) were randomly collected inside each plot and soil texture, total inorganic carbonate $_{caco_3}$ and total soil organic matter (SOM) were determined. Detailed methods and a map of the study area are given in Fontaine *et al.* (2007).

To determine indicator species for *J. excelsa*, measures of association between *J. excelsa* and other species were determined using Fisher exact probability tests on 2 × 2 contingency tables (Siegel and Castellan, 1988). Stepwise Discriminant Analysis (SDA) was applied to compare environmental characteristics between sample plots with and without *J. excelsa*. Analyses were carried out using SPSS 12.0 for Windows (SPSS Inc., Chicago, IL).

Table - 1: Indicator species for *Juniperus excelsa* in semi-natural forests in south western Anatolia, Turkey, determined by Fisher exact probability tests

Indicator species	c^2	*P*
Positive association		
Dianthus zonatus Fenzl[H]	13.910	<0.001
Ajuga chamaepitys (L.) Schreb.[H]	10.047	0.002
Paronychia carica Chaudhri[H]	10.021	0.002
Cotoneaster nummularia Fisch & Mey[S]	9.233	0.002
Daphne oleoides Schreb.[S]	8.934	0.003
Melica ciliata L.[H]	7.883	0.005
Sanguisorba minor Scop.[H]	6.676	0.010
Poa trivialis L.[G]	6.171	0.013
Piptatherum coerulescens P. Beauv.[G]	5.748	0.017
Dryopteris pallida Fomin[H]	5.185	0.023
Juniperus oxycedrus L.[ST]	4.563	0.033
Telephium imperati L.[H]	3.968	0.046
Negative association		
Styrax officinalis L.[S]	11.811	<0.001
Pinus brutia Ten.[1T]	9.870	0.002
Bromus sp.[G]	8.837	0.003
Arbutus andrachne L.[T]	8.837	0.003
Fontanesia phillyreoides Labill[T]	8.308	0.004
Platanus orientalis L.[T]	8.500	0.004
Quercus ithaburensis Decne.[T]	7.666	0.006
Cerasus prostrata Ser.[H]	7.546	0.006
Eryngium campestre L.[H]	7.666	0.006
Coronilla emerus L.[S]	5.560	0.018
Clinopodium vulgare L.[H]	5.616	0.018
Crataegus monogyna Jacq.[T]	4.702	0.030
Cephalanthera rubra (L.) Rich.[H]	4.047	0.044
Fumana thymifolia Spach[G]	4.047	0.044

[1] Its use as an indicator is limited. G = Grass, H = Herb, S = Shrub, T = Tree

Results and Discussion

A total of 276 species were observed, but only 99 species had a frequency of more than 5%. Among those, 12 species were positively associated to *J. excelsa* and 14 negatively. The most significant occurring species were the shrub *Cotoneaster nummularia* Fisch & Mey. and the herbs *Dianthus zonatus* Fenzl, *Ajuga chamaepitys* (L.) Schreb. and *Paronychia carica* Chaudhri. The Storax tree *Styrax officinalis* L., Oriental plane *Platanus orientalis* L., Grecian strawberry tree *Arbutus andrachne* L. and *Fontanesia phillyreoides* Labill were the strongest antagonist tree species (Table 1).

Juniperus excelsa occurred in 72 of the 153 sample plots (47%) (Fig. 1). The effectiveness of SDA to predict the presence of *J. excelsa* was 74%. Altitude (SDA coefficient = 0.498) and surface stoniness (0.722) were the most significant variables determining the distribution of *J. excelsa*.

As hypothesized, several plant species and environmental variables could be used to predict the occurrence of *J. excelsa* in semi-natural forests in south western Anatolia. Altitude, as a proxy for climate, was the most important environmental factor explaining the distribution of *J. excelsa*. The species strongly preferred sites above 1000 m where the mountainous Mediterranean climate arises (Fontaine *et al.,* 2007). Indeed, its negative indicators *A. andrachne* (L.), *E. campestre* (L.) and *F. thymifolia (L.)* Verlorare indicative of the Eumediterranean plant communities below 800 m and *C. rubra* (L.) and L.C.M. Richard and *S. officinalis* (L.) are representatives of the Supramediterranean plant communities in the region (Fontaine *et al.,* 2007). *J. excelsa* itself, along with its co-occurring species *C. nummularia* and *D. zonatus*, are species of humid mountainous Mediterranean plant communities (Fontaine *et al.,* 2007). *J. excelsa* is cold resistant and requires a high degree of humidity (Aussenac, 2002). Because in south facing valleys the Supramediterranean climate reaches higher elevations the species preferentially occupies northern and western expositions, or sites with very high surface stoniness, where hardly any other tree species can establish.

The negative indicator value of *Platanus orientalis* for *J. excelsa* is probably related to competition rather than climate. *P. orientalis*, fast growing and preferring humid sites, has established fairly dense canopy stands in valley bottoms, where in absence of *P. orientalis J. excelsa* could occur. But slow growing and light-

demanding, *J. excelsa* is outcompeted and replaced by *P. orientalis*. Thus, if stand conversion is part of forest restoration management plans, *P. orientalis* could be a positive rather than a negative indicator for *J. excelsa* after all.

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