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Short communication. Soil development mediated by traditional practices shape the stand structure of Spanish juniper woodland

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Abstract

Aim of study: Assessing the effect of soil development on the stand structure of a Spanish juniper forest traditionally shaped by livestock browsing and wood extraction.

Area of study: Berlanga de Duero (Soria, Castilla y León), Spain.

Material and methods: A stand inventory served to record stand structure. Tree age, height, DBH, basal area, and overbark volume were determined in each plot. Results were pooled considering two well-differentiated degrees of soil evolution. One-way ANOVAs (and Tukey's test) and regressions between growth parameters were performed to assess significant differences between growth performances on both types of soils.

Research highlights: Deeper soils yielded significant higher plant density and stand stock figures than stony shallower profiles despite the intense past livestock activity in the area; and single tree-size was also significantly greater. Non-significant differences were found for merchantable junipers age (≈120-160 years). Wood extraction and livestock browsing should be limited on shallower soils to allow soil and forest evolution; as well as to preserve the genetic pool better adapted to hardest growing conditions.

Key words: livestock browsing; forest development; *Juniperus thurifera* L.; soil evolution; stand stock.

Introduction

Spanish juniper (*Juniperus thurifera* L.) is a very resistant species to adverse conditions (Bertaudière *et al*., 2001) that forms one of the most singular forests of continental sub-Mediterranean chalky Spain, as denoted by its inclusion as a priority habitat by the European Directive 92/43/EEC0. Particularly, the strong decline that human and livestock activities have experienced recently, which have been identified as a key factor shaping their structure (Chauchard *et al*., 2007; De Soto *et al*., 2010), is leading to the promotion of junipers natural regeneration all across Europe (Gauquelin *et al*., 1999). Nevertheless, special attention should be paid to limitations imposed by fragmentation and aridity (Pueyo and Alados, 2007), Global Change (Del Río and Peñas, 2006), and the competitive colonization of pines and oaks (De Soto *et al*., 2010; Gauquelin *et al*., 1999).

Juniper wood has not been considered of great interest because it generally shows a high number of defects, so it has been traditionally extracted for firewood and other uses related to its high durability in the open. Nevertheless, few local primary industries have shown its interest on other potential higher-value final products (furniture, rural construction, and flooring) fitting its aesthetic value and dimensional stability (Crespo *et al*., 2006). Considering Global Change, traditional-land-use change has been identified as one of the major drivers for future forest dynamics in Mediterranean regions (Chauchard *et al*., 2007), and a potential wood demand increase may represent an opportunity for further local socioeconomic development (Rudel *et al*. 2005); otherwise, a new potential pressure as well (Olano *et al*., 2008). Considering all together, Spanish juniper wood market might rather positively contribute to its preservation, Carbon sequestration, and global warming attenuation, if proper management policies are implemented (Rice *et al*., 2001).

Forest research records on the field performance of Spanish juniper are limited to specific ecological and

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conservation issues. Particularly, the effect of soil development on the stand structure of Spanish juniper forests has not been reported yet; neither its potential implication on management and conservation policies to be developed.

Material and methods

A post-fire forest inventory was promoted in the Spanish juniper forest located in "*Berlanga de Duero*" (Soria, Spain) in order to record its structure and measure wood physico-mechanical properties aiming to assess potential industrial use. The fire spread out very quickly leaving behind tree trunks of merchantable dimension mainly unaffected, so the designed survey properly recorded the stand structure.

This tree-height Spanish juniper stand, including some scattered Holm oaks, grows on a gently undulating limestone moorland (1,020-1,090 m) broken up by small ravines, which covers ≈70 km^2. Transhumant livestock grazing and wood extraction have been addressed to drive these forests to its actual conformation (Rozas *et al*., 2008), although these activities have greatly and progressively decreased from mid-19th century (Olano *et al*., 2008).

Nine circular 10 m radius plots reflecting the heterogeneity of the area were randomly laid out onsite as designed for its survey. All trees holding merchantable logs (diameter at breast height, DBH > 7.5 cm) were unearth and measured. Seedlings (< 5 years old) and saplings (DBH < 7.5 cm) were just counted. Age (counting growth rings on its basal cross-section), height, DBH, basal area, and overbark volume (Huber's formula) were measured in all trees considering 1-m-long boles.

Results were pooled considering two well-differentiated types of soils regarding its evolution degree. The slope in the sampled plots was always pretty flat (< 5%). Three of the sampled plots laid on very shallow stony profiles (A/C; R) classified as leptic calcaric regosols. Other plots showed a higher degree of soil evolution with clearly differentiated A, B and C horizons: two calcaric cambisols and two haplic calcisols; from which the two deeper profiles (one of each type) were grouped with a chromic luvisol lying on a ravine's floor. One leptic cambisol was also pooled in average results.

One-way ANOVAs were performed to assess significant differences between the results of each type of soil (SigmaStat 2.0, SPSS Inc.). *Post hoc* pairwise comparisons were performed by Tukey's test ($p < 0.05$). Log(x)-Log(y) transformed linear regressions between growth parameters were fitted identifying shifts in slope, elevation, or along the same line, between soil types (SMATR ver2; Falster *et al*., 2006).

Results and discussion

A significant higher junipers density and significant greater stand stock figures were found on deeper soils (≈3-6 times depending on the variable and DBH class; Fig. 1) despite these stands have been shaped by traditional activities, which have surely masked real po-

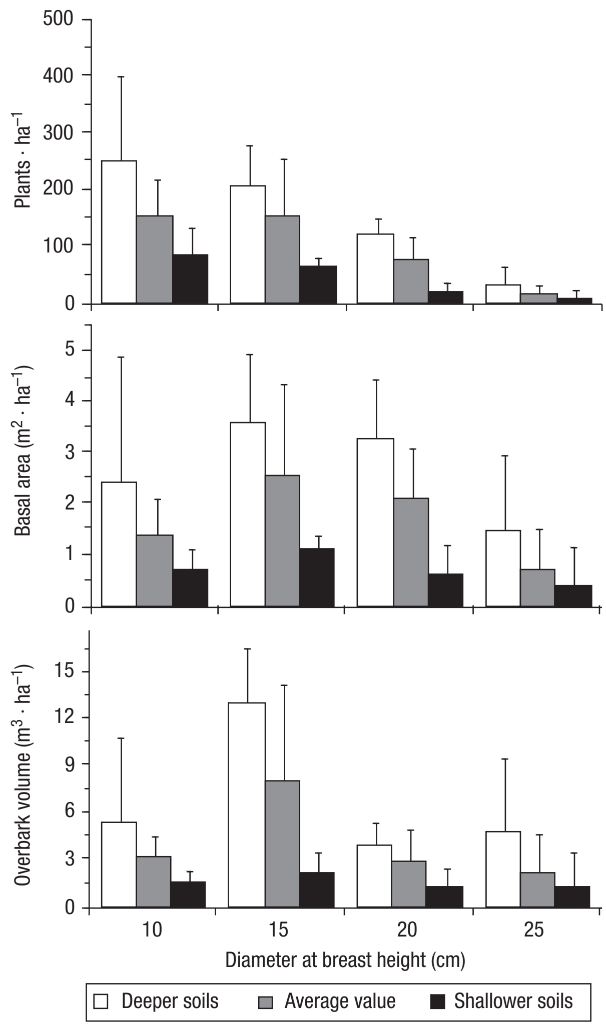

Figure 1. Stand stock structure of the sampled Spanish juniper forest considering soil development. DBH classes of 5 cm are considered. Bar values are means ± sd. Significant differences by Tukey's test ($p < 0.05$) were found between deeper and shallower soils for most levels of the variables.

Table 1. Plant density, stand stock, and growth of a Spanish juniper forest considering soil evolution

Soil type	Plant density (plants · ha^{-1})		Basal area (m^2 · ha^{-1})	Overbarck volume (m^3 · ha^{-1})	Growth	
	Total	Merchantable			Wood-volume (mm · ha^{-1} yr^{-1})	Tree-radial (mm · yr^{-1})
Deeper[a]	1,056 ± 186	615 ± 175	10.7643 ± 1.0551	26.960 ± 0.991	0.198 ± 0.009	0.51 ± 0.16
Shallover[b]	396 ± 134	179 ± 21	2.9077 ± 1.0140	6.391 ± 3.286	0.046 ± 0.024	0.42 ± 0.15
Average[ab]	724 ± 334	346 ± 227	6.7746 ± 3.7281	16.412 ± 9.758	0.120 ± 0.072	0.48 ± 0.18

Plant density includes merchantable logs, seedlings and saplings. Stand stock figures only include merchantable logs. Letters ([a,b]) identify significant differences for all features (Tukey's test, $p < 0.05$).

tential differences under natural conditions. In addition, results denoted an irregular stand structure, where a lower number of individuals is found at greater tree sizes; although central DBH classes (12.5-22.5 cm) accounted for greater values of accumulated biomass (Fig. 1). This irregular stand stock structure resulted very conspicuous on deeper soils, but it was much softened on shallower ones. Considering total values of plant density and stand stock figures (basal area and overbark volume), deeper soils already developed significant 2.5 to 4.5 times higher values than shallower ones (Table 1) without including the biomass of seedlings and saplings, which may even contribute to increase this difference. Average tree-density (346 trees · ha^{-1}) resulted similar to previously reports in a close woodland shaped by livestock browsing (Rozas *et al*., 2008). In addition, seedlings density was also found significantly greater on deeper soils (≈100 *versus* 300 plants · ha^{-1}), even though these figures do not exactly reflect potential figures under natural conditions. Supposing fire might have actually burnt to disappear many small junipers, results denoted an irregular stand structure anyway, accumulating higher tree-densities at lower size classes.

Although correlation coefficients between DBH and height were not very high for every group of soils ($R^2 \approx 0.45$-0.55; Fig. 2), the relationship between both variables resulted significantly positive. In addition, even though relative growth rates on both types of soils were not significantly different, as estimated by the slope of the DBH-height logarithmic regression; significant shifts were identified in both, elevation and along the common slope of the regressions (Fig. 2). Therefore, the positive effect of growing over more evolved and deeper soils was still significantly noticed beyond the resulting wood volume growth of individual trees.

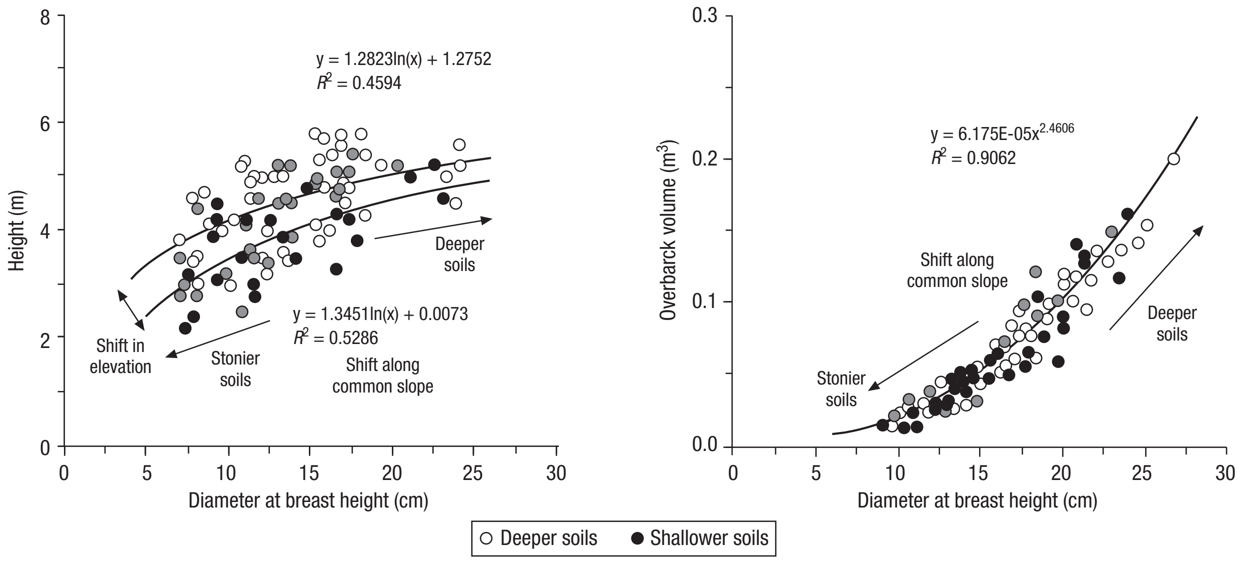

Figure 2. Dendrometric relationships of all sampled junipers considering soil development. Significant ($p < 0.1$) regression shifts are identified (SMATR version 2; Falster *et al.,* 2006).

Non-significant differences between soil groups were found for the age of junipers reaching merchantable dimensions (120-160 years). Average radial growth also resulted significantly higher (≈20%) for deeper soils (Table 1); and very poor relationships ($R^2 < 0.1$) were found between tree dimensions and age. In fact, average tree-radial growth figures (≈0.5 mm · year^{-1}) resulted similar to those previously reported for browsed junipers in a close woodland (Olano *et al*. 2008), whereas it was up to 2-3 times higher for unbrowsed ones. This regular age distribution does not match the irregular stand stock structure, further supporting the relevance of past land-use activities (De Soto *et al*., 2010; Olano *et al*., 2008).

Forest development is strongly related to soil evolution where climate doesn‘t limit forest growth (Bond, 2010), as well as soil properties and forest dynamics are improved back thanks to the forest cover (Callaway, 1997; Gauquelin and Dagnac 1988). Furthermore, the actual mono-specific conformation of juniper woodlands might be explained by an arrested succession process mediated by long-term livestock grazing (De Soto *et al*., 2010), so Spanish junipers would facilitate oaks and pines colonization once livestock pressure is released. Therefore, the removal of Spanish junipers cover will negatively affect further soil and forest evolution (De Soto *et al*., 2010).

In conclusion, despite Spanish juniper mono-specific woodlands are currently in expansion in this area, future management policies should address the clear interplay between livestock browsing intensity and juniper stands growth patterns (Olano *et al*., 2008; Rozas *et al*., 2008), and its evolution towards a mixed stand once livestock and wood extraction pressures are limited (De Soto *et al*., 2010). Particularly, these traditional practices should be much restricted on shallower soil profiles to protect soil and forest cover dynamics and preserve the species genetic pool that is better adapted to the hardest growing conditions. A higher land-use threshold could otherwise be set for deeper soils, even potentially serving to promote forest evolution.

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