Spanish Journal of Rural Development

Volume I, Number 1
January, 2010

SPANISH JOURNAL OF RURAL DEVELOPMENT

Editor: Ignacio Javier Díaz-Maroto Hidalgo
University of Santiago de Compostela, High Polytechnic School, Campus Universitario s/n, E-27002 Lugo, Spain. ignacio.diazmaroto@usc.es

www.sjruraldevelopment.org

Volume I, Number 1
January 2010

Spanish Journal of Rural Development

Editor: Ignacio J. Díaz-Maroto Hidalgo. University of Santiago de Compostela Department of Agroforestry Engineering

Spanish Journal of Rural Development [D.L.: LU 224-2009; ISSN: 2171-1216]. It will be published quarterly for a total of four issues per year. www.sjruraldevelopment.org

Production, Advertising and Subscription Office: Ignacio Javier Díaz-Maroto Hidalgo. Department of Agroforestry Engineering, University of Santiago de Compostela, High Polytechnic School. Campus Universitario s/n, E-27002 Lugo (Spain). Phone: +34 982 285900, Fax: +34 982 285926. ignacio.diazmaroto@usc.es.

Spanish Journal of Rural Development
[Revista Española de Desarrollo Rural]
Volume I, Number 1, January 2010

CONTENTS

Spanish Journal of Rural Development: 60 – 74, 2010

Toward proactive management in relict Mediterranean mountain forest dominated by *Abies pinsapo*

Linares, J.C.[1], Carreira, J.A.[2]

[1] Area of Ecology, Pablo de Olavide University. 41002-Sevilla, Spain. jclincal@upo.es

[2] Area of Ecology. University of Jaén. Campus Las Lagunillas, 23071-Jaén, Spain.

Short title: Land-use and biodiversity of *Abies pinsapo* forests

Abstract

The Spanish and Moroccan Pinsapo-fir forests have been recognized as areas of high biodiversity and endemism. Global Change, mainly throughout Land-use and Climate Changes can endanger this flora. It is necessary to know stand structure and biodiversity of these relict forests in order to apply conservation strategies. Several structural features, biodiversity and environmental variables were assessed in the wider Pinsapo-fir forests. Biodiversity values were higher on Moroccan stands while maximum tree-size class variability and stand structure diversity was yielded in an old-growth Spanish stand. Mean tree-ring width showed a steady pattern on Moroccan stands, while Spanish forests yielded a higher variance and sudden growth decline over the last third of the XX century. Our results suggest that the preservation of minor perturbation regimen by local populations would also help to preserve the whole biodiversity of this relict habitat**.**

Keywords: Proactive planning / *Abies pinsapo* / Biodiversity / Forest structure / Land-use changes

1. Introduction

Abies pinsapo is a relict species of the group of the circun-mediterranean firs. This endemic tree grows in small and isolated populations between 1000 and 1800 meters a.s.l., in N-facing slopes of some coastal mountain ranges of southern Spain, West Betic Range, and northern Morocco, Rif Mountains (Barbero and Quézel, 1975). In SE Spain *A. pinsapo* is currently found only in about 3600 ha while it account for about 4000 ha in northern Morocco (Linares, 2008). These forests were intensely damaged over the centuries through a variety of unsustainable practices such overgrazing, uncontrolled logging and pollarding (Linares *et al.,* 2009). In south Spain fragmented populations of *A. pinsapo* experienced an expansion and densification from scattered remaining stands following the implementation of conservation measures in the middle of the XX century (Ruiz de la Torre *et al.*, 1994; Linares and Carreira, 2009). The Rif mountains of northern Morocco represent a region of international significance from the standpoint of plant biodiversity with *Abies pinsapo* var. *marocana* amongst the endemic species. On this region the forest clearance, soil erosion, high rural population density and population growth are serious threats. Legal and illegal exploitation of the remaining natural forest for fuel, timber, forage and cork, produces some loss of forest but land clearance for extensions of the cultivated area, and other changes in the agricultural system such as the use of herbicides and fertilizers, and increased mechanization, are also resulting in loss of natural vegetation cover (Moore *et al.*, 1998).

The need to conserve and restore these relict and endemic fir forests has been increasingly recognized, being, for instance, a priority habitat under the EU Habitat Directive (9520) and being included in national and regional red list and protection initiatives. Moreover, since 2006 the Pinsapo-fir forests are included in the Mediterranean Intercontinental Biosphere Reserve of Spain and Morocco, established by the UNESCO's Man and the Biosphere Program.

As a result of intense historical and contemporary land-use, many of the forested areas in the Mediterranean basin are concentrated in mountainous areas. Mountain-top areas around the Mediterranean basin are refuges for relict conifer tree species (e.g., circum-Mediterranean fir species) as well as for genetically valuable, isolated populations of tree species whose core distribution is located at higher latitudes. Thus, to some extent, these areas represent temperate-like, conifer biome islands within the Mediterranean climate region (Linares and Carreira, 2009), and are expected to be particularly vulnerable to the effects of ongoing climate change (Boisvenue and Running, 2006).

However, conservation planning has traditionally focused on preserving patterns and has acted reactively, an approach that no longer fits in a changing world (Pressey *et al*,. 2007). A paradigm shift is needed that focuses on processes rather than patterns and that give priority to proactive planning. This requires the development of forecasting tools by scientists, to assist stakeholders in the development of decision tools based on predictions of the response of biodiversity to ongoing land-use and climate change.

The objective of this study was to account structural attributes and the history of the pinsapo fir forests and what are the processes underlying the stand dynamic of a Mediterranean montane old-growth community. For this purpose, we carried out a structural characterization and dendrochronological analyses in the main Spanish and Moroccan pinsapo fir forests, accounting for several sources of variation (elevation, lithology, land-use history, stand structure, and trees biodiversity).

2. Materials and Methods

2.1. Site description

Our study was conducted at the Mediterranean Intercontinental Biosphere Reserve of Spain and Morocco (Figure 1). We summarised several field surveys carried out between 2003 and 2007 on two localities of south Spain: *Yunquera forests* (Y), in the Sierra de las Nieves Natural Park, and *Grazalema forest* (G), in the Sierra de Grazalema Natural Park; and one locality in North Morocco: *Talassemtane forest* (T), in the Talassemtane National Park (Figure 1). We selected stands not disturbed by intense logging or fires during the last 50 years. Basic substrates (limestone and dolomite) are the most abundant bedrock in Sierra de las Nieves, Sierra de Grazalema and Talassemtane (Figure 1).

2.2. Structural analysis

We measured the size of trees (diameter at breast height, DBH) and the density of the stands (basal area and trees per hectare). We sampled 22 *Abies pinsapo* stands in plots of c.a. 0.1 ha (T: n = 5, G: n = 9, and Y: n = 8) to estimate several environmental (elevation, aspect, soil type, topography, structure, overstorey and understorey types) and biotic variables (trees species diversity; density and basal area). We also studied structural variables typically related to the successional stage of the stand (Oliver and Larson, 1990). Shannon's diversity index was calculated as:

$$H = \sum_{i=1}^{S} p_i \ln(p_i)$$

where p_i is the fraction of individuals belonging to the *i-th* species.

2.3. Dendrochronological methods

In each plot 5-10 dominant trees were selected to develop dendrochronological analyses with the consideration of two criteria: (i) achieving a data set covering the mean diameter class of the dominant trees distribution and (ii) selecting trees randomly located. Only alive and apparently healthy trees were sampled to avoid, as much as possible, other factors affecting growth. Two cores per tree were obtained at 1.3m by a borer increment. Samples were studied for age determination at 1.3 m and radial-growth analyses. Cores taken were sanded until tree rings were clearly visible under a binocular microscope. All samples were visually cross-dated. Tree-ring widths were measured to the nearest 0.01 mm on two radii per tree using a LINTAB measuring device (F. Rinntech, Heidelberg, Germany), and cross-dating quality was checked using COFECHA (Holmes, 1983). Long-term trends were estimated by local smoothing technique using polynomial regression and weights computed from the Gaussian density function (LOESS, see Zuur *et al.*, 2007).

2.4. Land-use history reconstruction

The impact of forest-use changes on tree regeneration was deduced by comparing historical records of land-use and canopy disturbance events with the stand structure data. Anthropogenic activities in the forest were compiled from diverse documentary sources. Key events that presumably implied a significant change in the use of the *Abies pinsapo* forests were documented from publications dealing with forest administration and land-use history. Also, a variety of unpublished documents and forest reports from Spain and Morocco were examined.

3. Results

In the studied plots on Sierra de las Nieves, Sierra de Grazalema and Talassemtane the soils were mainly mesic Calcic Haploxerepts in low- and mid-elevation and mesic Calcixerolls in upper elevations. In theses localities *A. pinsapo* appeared frequently mixed with *Pinus halepensis, Quercus ilex* and *Q. faginea* in the lower limit of fir forest; above 1200 meters a.s.l. firs were growing on near mono-specific stands, with the understorey mainly composed by *Helleborus foetidus*, *Hedera helix*, *Rubia peregrina*, *Daphne laureola* subsp. *latifolia* and *Paeonia broteroi*. In gaps and open stands also appeared *Crataegus monogyna* subsp. *brevispina*, *Rubus ulmifolius*, *Prunus spinosa*, *Ulex baeticus* and *Erinacea anthyllis*. In the upper elevations stands (1700-1800 meters a.s.l.) pinsapo fir grows with others relict trees, narrowly distributes in the Mediterranean mountains as *Quercus faginea* subsp. *alpestris*, *Acer opalus* subsp. *granatensis*, *Sorbus aria* and *Taxus baccata*; and exclusively in Morocco, with *Cedrus atlantica* and *Pinus nigra* subsp. *mauretanica.* At the highest elevations of the studied sites in the Rif mountains the vegetation is dominated by *Cedrus atlantica* while below 1600 m, *Quercus spp.* is the dominant tree.

Several of the studied plots were mono-specific stand by *Abies pinsapo* (see Table 1). Trees species diversity was higher for Moroccan stands (T, Figure 2), followed by G stands, and lower in Y. In the T stands this trees diversity was related to the presence of Mediterranean taxa at lower elevation (*Quercus ilex, Q. faginea*) as well as Mediterranean mountain conifer at higher elevation (*Cedrus atlantica*, *Pinus nigra* subsp. *mauretanica*, *Taxus baccata*, etc.). G stands also shown mixed stands with *Quercus ilex* and *Q. faginea*.

The mean TRW over the 1890-1920 span was significantly greater in the G and Y stands than in the Moroccan sites (Figure 3). Radial growth in Y stands declined from the onset of the 1920s to about 1950, but showed a recovering in the mean growth between the 1950s and the 1970s. Thereafter, Y and G showed a converging growth decline trend since the 1980s leading to no significant differences between the two sites, and current growth rates below 1 mm yr-1. Trees from Y produced very narrow rings in 1995 (Figure 3), and such growth reduction was observed on the whole Y dataset. However growth decline in 1995 on G stand were less sudden and a certain recovering trend is observed. By opposite, Moroccan stands yielded low but c.a. steady growth rate over the study period, and since 1990, mean growth is slightly higher on T populations.

Our bibliographical survey yielded that land use changed in Spain between the 1950s and the 1970s decades by the adoption of conservation measures. This conservation effort has resulted in an elimination of traditional uses (e.g., logging) with subsequent increases in tree cover within protected areas. For instance, in the Sierra de las Nieves Natural Park fragmented populations of *Abies pinsapo* experienced an expansion and densification of the scattered, remaining stands following the implementation of conservation measures in the 1950s, such as the cessation of logging and grazing by domestic animals.

In the north of Morocco, forest clearance over many centuries has greatly reduced the areas of natural woodland, particularly at lower elevations. During the colonial period, the Spanish colonial policy (1912-1956) was characterized by an intense forests management with economic goal, leading to the deterioration of some natural ecosystems. However the direct impact on Pinsapo-fir forests is not well documented. Although since the 1970s the Moroccan study area was also protected into the Talassemtane National Park, high rural population density have determined the maintenance of forest clearances, logging, pollarding, grazing and others marginal uses of the remaining natural forest to the present.

4. Discussion

Due to intense historic and contemporary land-use, many of the forested areas in the Mediterranean basin are concentrated in mountainous areas. Top-mountain areas around the Mediterranean basin are refuges for relict conifer tree-species (e.g., circun-mediterranean fir species) as well as for genetically-valuable, isolated populations of tree-species whose core-distribution range is located at higher-latitude, in temperate regions (e.g., *Pinus sylvestris, Taxus baccata*). Thus, to some extent, these areas represent temperate-like biome "islands" within the Mediterranean-type climate region (Linares and Carreira, 2009), and are expected to be particularly vulnerable to the effects of ongoing climate change (Boisvenue and Running, 2006). In addition, the areas supporting endemic mountain conifer forests have experienced major land-use changes during recent decades, with the abandonment of traditional uses along with the adoption of protection measures. These have often been rather intensive, because of the high conservation value of these forests, their limited area of distribution and the low overall economic impact of their traditional uses (Carreira *et al.*, 2009). At first, protection measures were frequently directed towards encouraging natural regeneration and/or towards reforestation tasks focusing on the reconstruction of spatial patterns derived from potential vegetation models. Thereafter, no-management or minimum-management (just when problems arise) options have been commonly applied in the areas occupied by these forests (IPCC, 2007). Consequently, in the absence of a natural minor perturbation regime, it has led to the densification of these forests in recent decades, resulting in the reinforcement of density-dependent factors and low canopy structural diversity at the stand level. The carbon and energy balance of trees can be compromised under such conditions, weakening them. This can diminish the trees' ability to cope with climatic stress, especially drought (Valladares, 2008). Thus, paradoxically, the outcome of severe protection measures may be an increase in the vulnerability of endemic mountain conifer forests to climate change. In these cases, adaptation to climate change requires a shift to proactive management, directed towards the enhancement of canopy structural diversity at both stand and landscape levels (Millar *et al.*, 2007).

Since the onset of the 1950 decade, the traditional use of *Abies pinsapo* forests by local communities (tree pollarding, charcoal production and uncontrolled grazing) was severely restricted in Spain, following the carrying out of state protection measures (Álvarez, 1994). In a first phase, protection measures were frequently addressed to foster natural regeneration and/or to reforestation tasks focused on the reconstruction of spatial patterns derived from potential vegetation models. Thereafter, no-management or minimum management options have been commonly applied in the Spanish territories occupied by these forests. Although overall Spanish Pinsapo-forest were subjected to intense grazing and logging by the local population for centuries (Barbey, 1930; Boissier, 1839; Ceballos and Bolaños, 1928; Ceballos and Vicioso, 1933; Laguna, 1868), remnant old growth stand and less damaged stand (G) contrast to highly overgrazed forests (Y, see Linares and Carreira, 2009). Nowadays the *Abies pinsapo* forests from Y present high density, homogenous stems structure, growth decline, and lower biodiversity (see Table 1 and Figures 2 and 3).

Over the Moroccan populations remain nowadays a natural minor-perturbation regimen by rural inhabitants, which could be related to a lesser densification of these forests during the last decades, higher canopy structural diversity at the stand level (Photo 1), steady mean growth (Figure 3), and higher biodiversity (Table 1, Figure 2). Nonetheless, in the north of Morocco, forest clearance over many centuries has greatly reduced the areas of natural woodland, particularly at lower elevations. During the colonial period, the Spanish extended and intensified logging operations particularly of hardwoods such as oak and cedar, for construction purposes; the process of clearance continues today, and it is estimated that 1000-1500 ha of forest are currently lost to clearance each year. Of particular importance is the dwindling extent of *Abies pinsapo maroccana*, which accounted for 15000ha in 1938, 5500 in 1951, 4000 in 1994, and slightly above 4500 ha nowadays.

The causes of fir-forests degradation in the Rif mountains are set against a background of rapid population growth in the region in the last 40 years (Woodward, 1995). For example, in the central Rif mountains the annual growth in population averaged 1.6% between 1930 and 1950, 2.5% between 1950 and 1960, 2.3% between 1960 and 1982, and maintain rising trends nowadays (Moore *et al.,* 1998). This rapid growth of rural population in the Rif mountains is, to some extend, the result of improvements in infrastructure and the illicit cultivation and trade in cannabis (*Cannabis sativa*) have provided added stimulus. These population changes have helped to place great pressure on the natural landscape of the region (Photo 2).

Traditionally, the natural forests of the Rif have been an important element of the rural economy (Photo 3). Over many centuries, unmanaged exploitation of the forests has largely resulted in their clearance and concomitant loss of biodiversity and land degradation; however a minor perturbation regime by local inhabitant could be a sustainable and beneficial use of the land, providing biodiversity protection and forests adaptive capacity (Millar *et al.,* 2007).

Results obtained in this work could have substantial implications when applied to the restoration and management of *Abies pinsapo* forests. Restoration of native forests and management of forest dynamics in nature areas are increasingly considered as priorities in forestry and environmental policies. However land abandonment has also played a major role in promoting large continuous areas of dense and uniform early-successional vegetation, which could led to low growth rates and some decay symptoms by stand stagnation (Linares and Carreira, 2009). By opposite, successful natural regeneration could be promote by low intensity logging by local inhabitant and low browsing intensity, as we have assessed on Moroccan stands. Theses minor perturbation regime could to generate small gaps and areas with a not very dense overhead cover and higher biodiversity (Figure 2). Meanwhile, strictly protected *A. pinsapo* stands show less structure-diversification and lower biodiversity. On summary, our results suggest that the preservation of minor perturbation regimen by local populations would also help to preserve the whole biodiversity of this relict habitat.

Acknowledgements

This work was financed through the Spanish Ministry of Science and Technology projects PB98-0309 and BOS2000-0897. We wish to thank to Consejeria de Medio Ambiente (Junta de Andalucia) and to Reserva de la Biosfera Intercontinental Andalucía (España)-Marruecos for providing sampling permissions, accommodation, and access in the study plots as well as available information about *A. pinsapo* forests.

References

Álvarez, M., 1994. Los pinsapares malagueños en el recuerdo. (Pinsapares from Malaga in memory). En: Gestión y conservación de los pinsapares andaluces, Asociación forestal andaluza: 77-90.

Barberao, M., Quézel, P., 1975. Les forets de Spain sur le pourtour méditerranéen (Spanish forests around the Mediterranean perimeter). Anal. Inst. Bot. Cabanilles 32: 1245-1289.

Barbey, A., 1930. Descripción de una nueva especie de Pyralidae (*Dioryctria aulloi*, n. sp.) perjudicial a *Abies pinsapo* Boiss (Description of a new harmful species of Pyralidae (*Dioryctria aulloi*, n. sp.) for *Abies pinsapo* Boiss). Revista de Biología Forestal y Limnología II(3): 5-10.

Boissier, C.E., 1839. Voyage botanique dans le midi l´Espagne pendant l´année 1837 (Botanical travel to the South of Spain during 1837). Gide et Cie, Paris.

Boisvenue, C., Running, S.W., 2006. Impacts of climate change on natural forest productivity-evidence since the middle of the 20th century. Glob. Change Biol. 12:1-12.

Carreira, J.A., Quintanilla, J., Linares, J.C. 2009. Conservation and management adaptation options for the in-situ preservation of endemic mountain conifer forests: the *Abies pinsapo* case in Andalusia (Spain). In: Mediterranean mountains in a changing world. Guidelines for developing action plans: 57-61 (Anonymous). Gland, Switzerland and Málaga, Spain: IUCN.

Ceballos, L., Bolaños, M., 1928. Notas sobre el aspecto botánico-forestal de la Serranía de Ronda y Grazalema (Notes about botanical-forest aspect of Serranía de Ronda and Grazalema). IFIE, Madrid.

Ceballos, L., Vicioso, C., 1933. Estudio sobre la vegetación y la flora forestal de Málaga (Study about forest vegetation and flora from Malaga) IFIE, Madrid.

Holmes, R.L., 1983. Computer-assisted quality control in tree-ring dating and measurement. Tree-Ring Bull. 43: 68-78.

IPCC, 2007. Climate change, fourth assessment report. Cambridge University Press, London, UK.

Jalas, J., Suominen, J., Lampinen, R., 1999. Atlas Florae Europaeae. Cambridge University Press, Cambridge.

Laguna, M., 1868. El pinsapar de Ronda. (The pinsapar from Ronda). Revista Forestal.

Linares, J.C., 2008. Efectos del cambio global sobre la dinámica poblacional y la ecofisiología de bosques relictos de *Abies pinsapo* Boiss. (Effects of global change over population dynamic and ecophysiology of *Abies pinsapo* Boiss. relician forests). PhD Thesis. University of Jaén.

Linares, J.C., Camarero, J.J., Carreira, J.A., 2009. Interacting effects of climate and forest-cover changes on mortality and growth of the southernmost European fir forests. Glob. Ecol. Biogeogr. 18: 485-497.

Linares, J.C., Carreira, J.A., 2009. Temperate-like stand dynamics in relict Mediterranean-fir (*Abies pinsapo* Boiss.) forests from Southern Spain. Ann. For. Sci. 66 (610).

Millar, C.I., Stephenson, N.L., Stephens, S.L., 2007. Climate change and forests of the future: managing in the face of uncertainity. Ecol. Appl. 17: 2145-2151.

Moore, H.M., Fox, H.R., Harrouni, M.C., El Alami, A., 1998. Environmental challenges in the Rif mountains, northern Morocco. Environmental Conservation 25: 354-365.

Oliver, C.D., Larson, B.C., 1990. Forest Stand Dynamics. McGraw-Hill, New York.

Pressey, R.L., Cabeza, M., Watts, M.E., Cowling, R.M., Wilson,A. 2007. Conservation planning in a changing world. Trends in Ecology & Evolution 22: 583-592.

Ruiz de la Torre, J., García, J.I., Oria de Rueda, J.A., Cobos, J.M., Neva, J.C., Navarro, R.Mª., Catalina, M.A., López-Quintanilla, J., Álvarez, M., Arista, M., Talavera, S., Herrera, J., 1994. Gestión y conservación de los pinsapares andaluces (Management and conservation of Andalusian pinsapares), Asociación Forestal Andaluza.

Valladares, F., 2008. A mechanistic view of the capacity of forest to cope with climate change. In: Managing Forest Ecosystems: the challenge of climate change: 11-35. (Eds F. Bravo, V. Le May, R. Jandl and K. von Gadow). Springer Verlag. Berlin.

Woodward, J.C., 1995. Patterns of erosion and sediment yield in the Mediterranean river basins. In: Sediment and Water Quality in River Catchments: 365-389. (Eds I. Foster, A. Gurnell and B. Webb). Wiley. Chichester, UK.

Zuur, A.F., Ieno, E.N., Smith, G.M., 2007. Analysing Ecological Data. Ed. Springer.

Table 1. Characteristics of the studied *Abies pinsapo* stands. Number of plots and units are shown between brackets; *H*, Shannon Index.

Country	Morocco	Spain	
Locality	Talassemtane	Grazalema	Yunquera
Plot	T (n = 5)	G (n = 9)	YL (n = 8)
Longitude	35.12	36.77	36.72
Latitude	5.42	5.42	5.37
Elevation (m a.s.l.)	1554	1138	1195
Aspect (6: N, 4: NW, 2: NE)	4	4	6
Slope (%)	27	31	25
H Species	1.34	0.29	0.11
Basal area (cm^2)	55.86	49.01	38.47
Density (trees ha^{-1})	869.02	807.03	1263.37
Mean DBH (cm)	20.11	25.51	17.30
Variance DBH (cm)	389.33	308.71	95.00
Max DBH (cm)	95.60	76.86	62.33

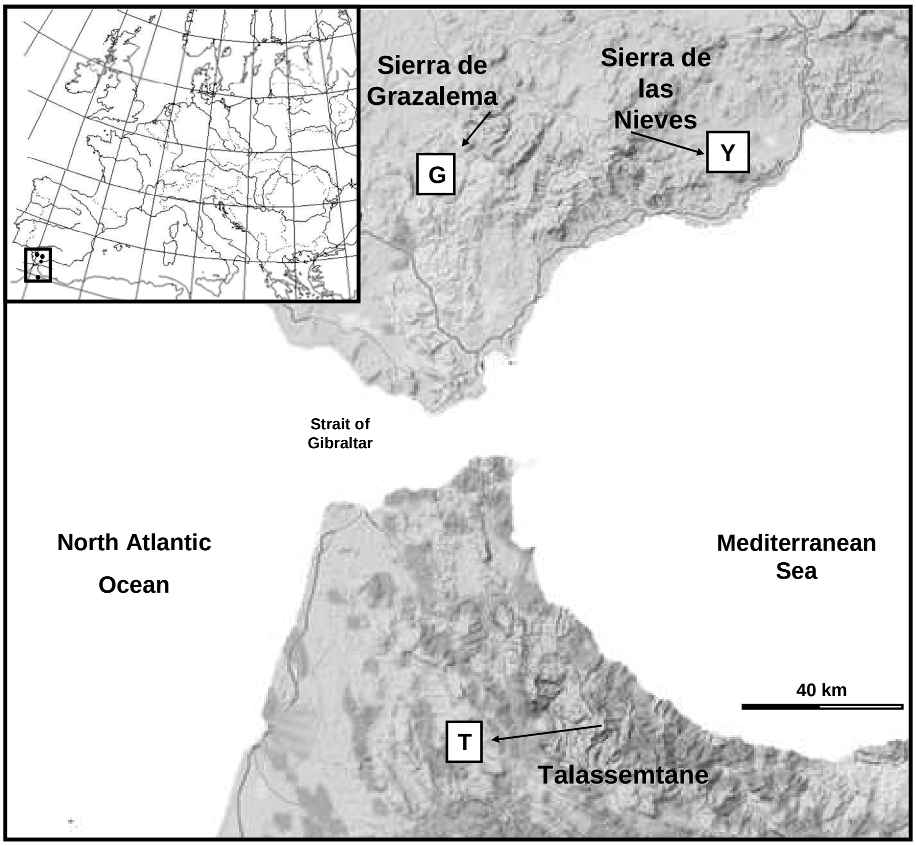

Figure 1. Distribution of *A. pinsapo* forests in South Spain and Northern Morocco (inset redraw based on Jalas *et al.* 1999. Study sites locations: Talassemtane National Park (T), Sierra de Grazalema (G) and Sierra de las Nieves Natural Park, Yunquera forest, (Y)

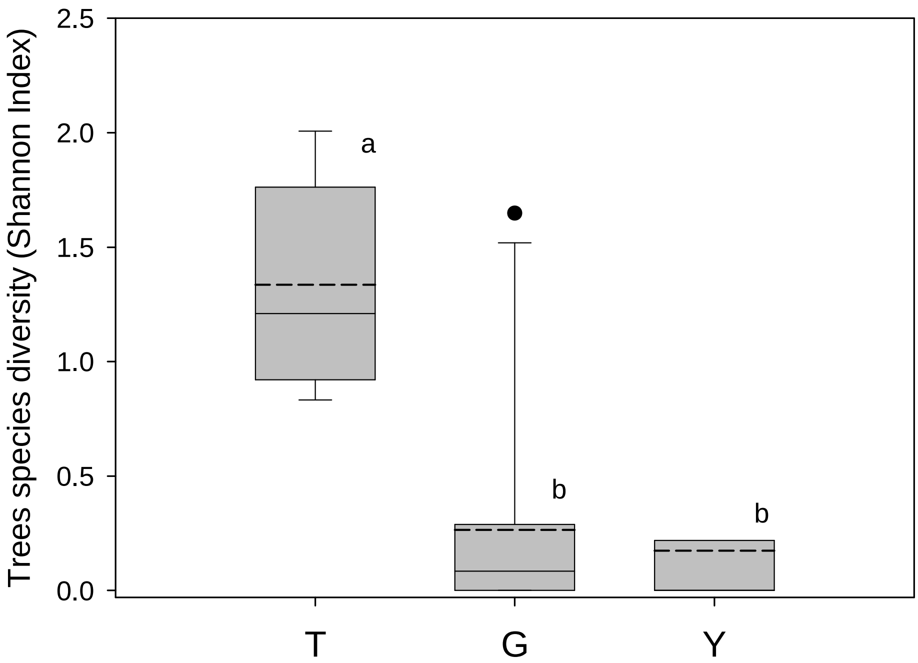

Figure 2. Tree species biodiversity estimated by Shannon Index. In the box-plot figure error bars represent the 5th/95th percentiles; boxes represent the standard errors; solid lines represent the median; dashed lines are mean values; and points are outliers. Differerent letters represent significant deference for ANOVA, P <0.05

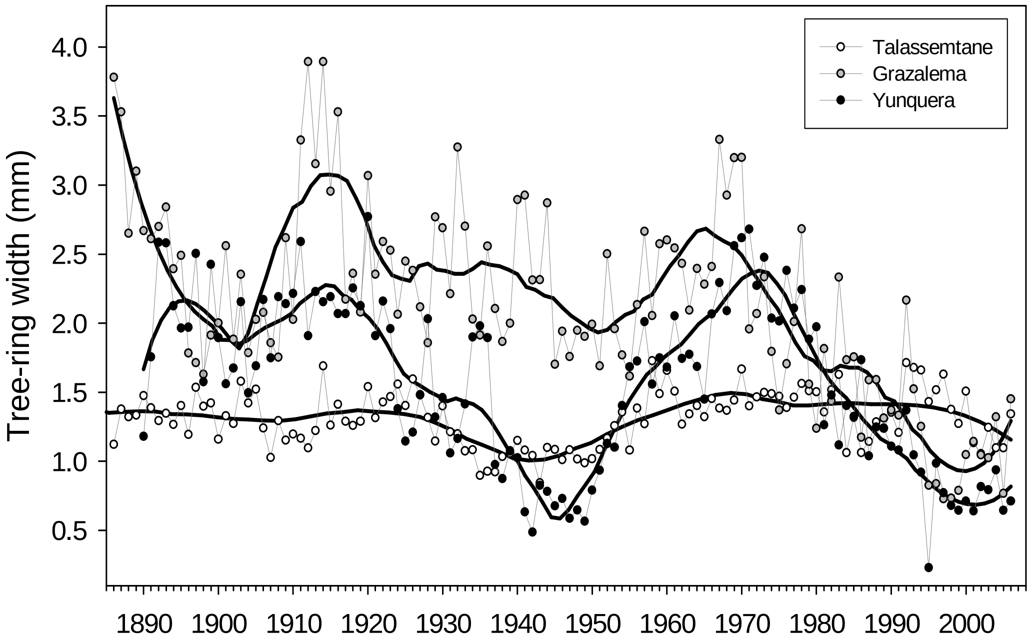

Figure 3. Mean *Abies pinsapo* tree-ring width measured on two localities of south Spain: *Yunquera forests* (Y), in the Sierra de las Nieves Natural Park, and *Grazalema forest* (G), in the Sierra de Grazalema Natural Park; and one locality in North Morocco: *Talassemtane forest* (T), in the Talassemtane National Park. Line represent long-term trends estimated by local smoothing technique using polynomial regression and weights computed from the Gaussian density function (LOESS, see Zuur *et al.* 2007)

Photo 1. High canopy structural complexity and biodiversity at the stand level in the Talassemtane National Park, Rif mountains, North Morocco. Photo from J.C. Linares

Photo 2. Cultivated area of cannabis in the Rif mountains. Much of the recent increase in high elevations cultivated area has taken place away from roads on the more inaccessible slopes of marginal land due to stronger policing and attempts to curb the cultivation. Terracing is used to extend the area of cultivation where slopes are steep but rock picking from mountain slopes to provide materials for terracing may further exacerbate soil erosion through interference with rock fragment covers. Photo from J.C. Linares

Photo 3. Rural inhabitant activities in the Moroccan fir-forests. Low livestock density (a), natural plant collection to traditional uses (b), marginal agriculture (c); Photo from J.C. Linares.