Climate classification of *Abies pinsapo* Boiss. forests in Southern Spain

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Abstract

Understanding the current distribution of vegetation and its interaction with climate regularity is important for predicting its future change. 35 weather stations with monthly resolutions have been reconstructed using GENPT software to study the pinsapo fir forest climate types. Ten climate variables have been used to describe the particular climate of *A. pinsapo* forests following the Climatic System of Allué (1990). A climate examination suggests that pinsapo fir forests might be established in a particular climate, which seems to be unique in the Iberian Peninsula, though the species also grows under other climates. A multivariable analysis has been done, providing five classes of pinsapo fir forests sharing some climate features: Atlantic, Mediterranean, warm, continental and cold. Results are biogeographically consistent and may help to explain plant biogeography in this region. Preservation efforts in pinsapo fir forests should be concentrated on the distribution areas with the highest risk of the climate change impact.

Key words: Mediterranean forests, vegetation distribution, Walter-Leich climate systems, *Abies pinsapo*.

Resumen

Clasificación climática de los bosques de *Abies pinsapo* en el sur de España

Los estudios de distribución actual de la vegetación, en un contexto de cambio global, son un elemento importante para predecir los posibles cambios futuros. En este trabajo, a partir de 35 estaciones meteorológicas, se realizó la reconstrucción de los tipos climáticos para el pinsapo, utilizando 10 variables del Sistema Fitoclimatico de Allué (1990). Los resultados sugieren la existencia de un clima específico para la distribución del pinsapo, que parece ser único en la península ibérica, aunque la especie también esta presente en otros fitoclimas. A partir de un análisis multivariable se han identificado cinco clases fitoclimáticas con presencia de pinsapo: atlántico, mediterráneo, templado, continental y frío. Los resultados son biogeográficamente consistentes y pueden ayudar a explicar la biogeografía de su área de distribución. Los programas de conservación del pinsapo deberían utilizar información fitoclimática para definir las zonas prioritarias de protección frente a los posibles efectos del cambio climático.

Palabras clave: bosques mediterráneos, distribución de la vegetación, sistema de Walter-Leich, *Abies pinsapo*.

Introduction

Abies pinsapo Boiss (pinsapo fir) is an endemic fir species native to southern Spain, where it is limited to altitudes of 1,100-2,000 m in the «Sierra de Grazalema» in the province of Cádiz and the «Sierra de las Nieves», and «Sierra Bermeja» in the province of Málaga. It is an evergreen tree growing to 20-30 m in height, with a conic crown, sometimes becoming irregular with age. The leaves are 1.5-2 cm long, arranged radially all round the shoots, and are strongly glaucous pale blue-green, with broad bands of whitish wax on both sides. The cones are cylindrical, 9-18 cm long, greenish-pink to

purple before maturity, and smooth with short and not exerted bract scales. One variety, the Moroccan Fir *Abies marocana* Trabut, occurs immediately across the Straits of Gibraltar in the Rif mountains of northern Morocco, where it is confined to altitudes of 1,400-2,100 m on «Jebel Tissouka» and «Jebel Tazaot». It is differentiated by the leaves being less strongly glaucous and the cones slightly longer, i.e. 11-20 cm long (Farjon & Rushforth, 1989). Several authors treat the African populations *A. tazaotana* and *A. marocana* as varieties or subspecies (Quezel & Barbero, 1990).

Prior to the eighteenth century, *A. pinsapo* was widely distributed on the higher mountains of southern Spain, but it has declined in the last 200 years, mainly due to human activities (Ceballos & Ruiz de la Torre, 1979). At the beginning of the last century, due to extensive cultivation, pinsapo fir numbers began to dwindle. In 1964 only 700 hectares of pinsapo fir forests remained but now, as a result of careful forestry management, there are 5,000 hectares.

The pinsapo fir is thus the sole species that grows in a strictly Mediterranean environment within the Iberian peninsula, which endows it with a great geobotanical and ecological value (Aussenac, 2002). The pinsapo fir occurs in hyper wet Mediterranean climates (annual precipitation 2,000-3,000 mm) featuring a dry summer season (June to September) that it avoids by sheltering in shaded orientations at heights between 1,000-1,800 m, where the temperatures and water stress are moderate. This species does not exhibit any edaphic preferences, so it is encountered on very steep slopes featuring litho soils. The best stands, however, grow on southern brown soils (on peridotites) and forest brown soils (on limestone).

These forest communities are distributed in three different populations in Andalusia; two are found in Málaga (viz. in the «Sierra de las Nieves Natural Park» and the «Reales de Sierra Bermeja Natural Area») and the other in Cádiz (viz. in the «Sierra de Grazalema Natural Park»). In the first, pinsapo fir stands are established on limestone, preferably on north-western slopes. In these areas, the pinsapo fir coexists in close proximity with *Pinus pinaster* Aiton*., Quercus suber* L*., Q. faginea* Lam. and *Q. ilex* L. subsp. *ballota* (Desf.) Samp., as well as a thick coppice consisting of a variety of shrubs and bushes. In «Sierra Bermeja», the peridotite lithology has encouraged the presence of a varied flora, including *Saxifraga* spp., *Arenaria* spp., *Cistus populifolius* L., *Daphne laureola* L., *Rhamnus myrtifolius* Willk., *Ulex baeticus* Boiss. and *Erinacea anthyllis*

Link., in contact with *Pinus pinaster*. In Grazalema, pinsapo fir form young stands and are especially abundant on the northern slope, on calcareous substrates, with inclusions of *Quercus suber, Q. faginea* and *Q. ilex* subsp. *ballota*, *Juniperus phoenicea* L*., J. sabina* L*., Paeonia broteroi* Boiss. & Reut.*„ P. coriacea* Boiss*., Ruscus aculeatus* L*., Rubia peregrina* L*., Hyacinthoides hispanica* (Miller) Rothm*.,* and *Daphne laureola* (Blanco *et al.,* 1997).

Characterizing occupied habitats is a primary step for the conservation of endangered species. The Allué (1990) Climate Classification System is the most widely used for classifying the Spanish's climates. Allué elaborated a climatic system by relating the meteorological courses of a site (climate) and the phytological aspects deriving from them (phytologies) (García y Allué, 2001). This classification system has been used to describe Mediterranean vegetation in Spain (Gil *et al.,* 2001), and also in fir ecosystems (García, 2001).

The aim of this research is to examine the vegetation distribution of *Abies pinsapo* Boiss forests based on the bioclimate classification of Allué (1990) (following the Walter and Lieth typology) and the geographical information system (GIS). The results would be useful for (1) research of plant biogeography and biodiversity conservation; (2) ecological restoration in ecosystems in this region; and (3) an assessment of the impact of the global climate change on vegetation dynamics in this area.

Material and Methods

Study area

The region of Andalusia is located between latitude 36° N and 38° 42' N and longitude 7° 20' W and 1° 39' W in the southern part of Spain. The study site is located at the south eastern tip of Andalusia (Fig. 1) spanning the natural distribution of pinsapo fir in the Iberian peninsula according to the Spanish Forest Map (Ruiz de la Torre, 1990). The total area is about 5,033 has [see Blanco *et al.* (1997) for detailed description of vegetation communities]. The landscape is mantled by surficial deposits of the Quaternary age from Precambrian to Tertiary. Three rugged mountain ranges dominate the area including continuous, unbroken forested stands and stands comprising several forest patches. The climate in the mountain region of Southern Spain is characterized as being a Mediterranean complex
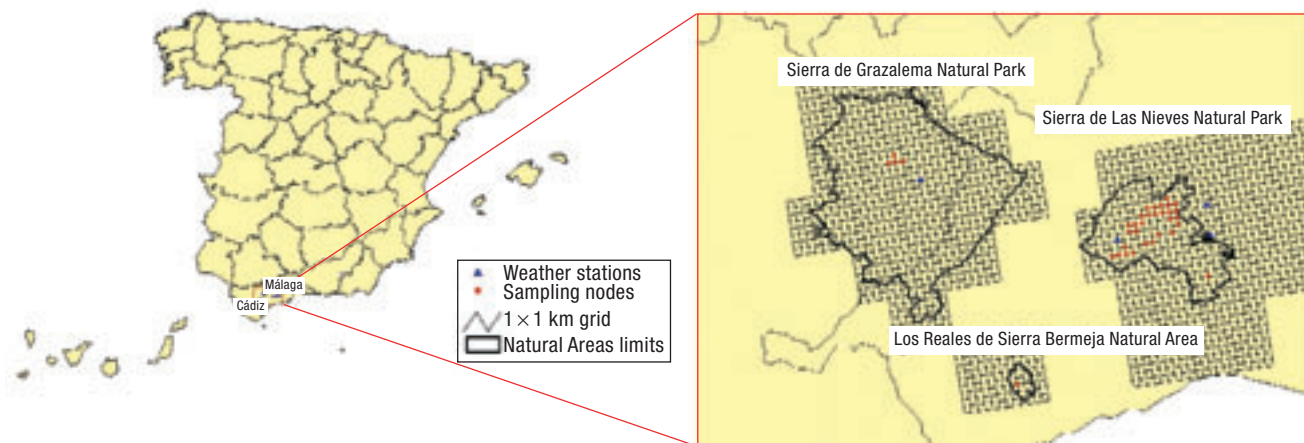
Figure 1. Study area. Distribution of sampling nodes across the pinsapo fir forests network (Navarro y Calzado, 2004).

exhibiting a great diversity over horizontal distances of only a few kilometres (Allué, 1990). The average rainfall in Grazalema (mean for 1987-1998) is 2,563 mm, with January (225 mm) and July (3.5 mm) being the wettest and driest months, respectively. Monthly mean air temperature ranges from 25.8 to 27.1°C, with a minimum air temperature of 21.4°C during September and a maximum of 34.7°C during July. The pinsapo fir occurs in the hyper wet Mediterranean climate (annual precipitation 2,000-3,000 mm) featuring a dry summer season (June to September) that it avoids by sheltering in shaded orientations at heights of 1,000-1,800 m, where temperatures are moderate and low-water effects are weaker. It shows no preference as regards soils, so it is encountered on very steep slopes featuring lithosoils. The best stands, however, develop on southern brown soils (on peridotites) and forest brown soils (on limestone).

Bioclimatic study

The bioclimatic system of Allué (Allué, 1990; see also http//www.fitoclimoal.com/Model.html) was used in this study. Five weather stations from the Spanish Meteorological Network (http://www.inm.es/) were selected as references to collect the climate data (Table 1). The climate data were simulated to a 1×1 km square sampling grid (Fig. 1) (Navarro & Calzado, 2004) defining 35 nodes which cover the current distribution of *A. pinsapo* by using the GENPT®) software (Fernández Cancio & Manrique, 2001). The software algorithms used 6,130 real meteorological stations all over Spain for local approximations at each problem point of the grid by using combined linear gradient

methods based on means, regressions and variance stabilization, with mean square errors of under 0.5°C in temperature and 5-10% in precipitation in comparison with the reference stations (*viz.* those used to calibrate, verify and measure the quality of data, Table 1).

Ten climate variables (Table 2) were selected for analyzing those specific aspects of precipitation, temperature, seasonality and aridity (estival ombrothermic indexes). Selection was based on their usefulness for a climatic classification assessment and their potential relevance to fir distribution. These parameters are discussed in detail elsewhere (Allue, 1990).

Data analysis

Climate variables were analyzed to produce descriptive statistics and existence limits (e.g. mean and standard errors) within the pinsapo fir distribution according to Allué System (1990). Then, the climate data were ordered using a multivariate analysis (Gil *et al.*, 2001) in three steps: the first, a hierarchical classification using the Ward method and normalized Eucli-

Table 1. Weather stations used in the in the *Abies pinsapo* climatic classification

Code	Station name	Altitude (m)	Period of recurrence
5911	Grazalema	823	1921-1999
6031	Ronda «Los Quejigales»	1,180	1983-1994
5107	Dolar «Casa Forestal»	1,550	1971-1976
6138	Yunquera	681	1981-1986
6137	Tolox	620	1966-1976

Table 2. Phytoclimate variables used in the *Abies pinsapo* climatic classification

Abbreviation	Definition	Unit	Reference
A	Duration of aridity, in the sense of GAUSSEN (No. of months in which curve Ti is situated above the Pi curve, i.e., when 2Ti > Pi.)		Allué-Andrade, 1990
K	Intensity of aridity (As/Ah, where Ah is the humid area of the climodiagram (Pi curve above the Ti curve, i.e., 2Ti < Pi) and As is the dry area of the climodiagram (Pi curve below the Ti curve, i.e. 2Ti > Pi)	months	Allué-Andrade, 1990
P	Total annual precipitation	mm	Allué-Andrade, 1990
PE	Minimum summer precipitation (June, July, August or September)	mm	Allué-Andrade, 1990
HS	Freezing certain (No. of months in which TMMF < 0)	months	Allué-Andrade, 1990
TMF	Lowest monthly mean temperature	°C	Allué-Andrade, 1990
T	Annual mean temperature	°C	Allué-Andrade, 1990
TMC	Highest monthly mean temperature	°C	Allué-Andrade, 1990
TMMF	Average of the minimum temperatures in the month with the lowest mean temperature	°C	Allué-Andrade, 1990
F	Absolute minimum	°C	Allué-Andrade, 1990
OSC	Thermal oscillation (TMC-TMF)	°C	Allué-Andrade, 1990
TMMC	Average of the maximum temperatures in the month with the highest mean temperature	°C	Allué-Andrade, 1990
C	Absolute maximum	°C	Allué-Andrade, 1990
HP	Freezing probable (No. of months in which F < 0) with TMMF > 0	months	Allué-Andrade, 1990
M	Average of the maximum temperatures in the month with the lowest mean temperature	°C	Gil *et al.,* 2001
TMI	Mean winter (December-February) temperature	°C	Gil *et al.,* 2001
IFOR1	Ratio of precipitation during the first six months (December-may) to that during the rest of the year		Gil *et al.,* 2001
IIEST	Ratio of ombric index [(P/T)/10] during the first six months (December-May) to that during the rest of the year		Gil *et al.,* 2001
IOIF	Ratio of the winter ombric index with TMMF (extreme winter stress xeric)		Gil *et al.,* 2001
IOPF	Ratio of the spring ombric index with TMMF (extreme stress from spring cold).		Gil *et al.,* 2001

dean distances, the second, a discriminant analysis and the third a correlation-based principal components analysis (PCA).

A discriminant analysis was used for evaluating the relative contributions of each parameter for the discrimination between climate types. These types represent different bioclimatic pinsapo fir forests, and were selected because of their direct implications in the climate change impact and the persistence of the species. The significance of the Mahalanobis distance was tested using the Hottrelin T^2-test and transformed to an F-test. F-values and standardized differences were computed to assess the significance of metric discrimination. The following two assumptions were made about the nature of the data:

1. The metrics were normally distributed within each group.

2. The variance-covariance matrices of the groups were equal in size.

The discriminant function is not seriously affected by limited departures from normality or by the limited inequality of variances (Davis, 1973). All computations involved were done with the software Statgraphics 5.0 (Manugistics, Inc., Rockville, Maryland,. USA).

Results

Bioclimatic characteristics

Table 3 shows the climatic limits of *Abies pinsapo* according to the climate variables included in this study by the Allué system (1990). The values of the Gaussen aridity index over three months suggest a Mediterranean climate type, with a thermal feature and very low summer precipitation. Gaussen aridity in pinsapo fir forests appears to be restricted to 3-4.17 months; these values are typical of Mediterranean sclerophylly. On the other hand, the NPRV (normalized values of summer precipitation) (0.21) exceeds the estimated maximum (0.16), so water stress in the summer must be lower than estimated.

The presence of negative TMMF values, freezes and low mean temperatures additionally indicates a trend to steepness. However, some of the climate features (*viz.* high precipitation and thermal behaviour) are typically nemoral. The seasonal precipitation regime suggests a marked Atlantic influence, with a high IFOR1 (the ratio of precipitation during the first six months —December-May— to that during the rest of the year).

Table 3. Statistical values of the phytoclimatic variables of in the *Abies pinsapo* distribution associated with each network node. For phytoclimate variables see Table 2

Phytoclimatic variable	K	A	P	PE	HS	TMF	T	TMC	TMMF	F	OSC	TMMC	C	HP	M	TMI	IFOR1	IIEST	IOIF	[IOPF
Count	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Average	0.2	3.6	892.0	2.6	0.4	3.7	13.2	24.5	0.6	–14.7	11.0	31.6	39.9	9.8	10.9	5.3	2.2	4.9	1.2	0.2
Standard deviation	0.03	0.2	88.1	0.81	0.6	1.8	1.3	1.1	2	2.9	1.4	1.3	1.7	1.9	3.8	1.6	0.2	1.4	13.0	2.3
Percentile of 5%	0.1	3.1	742	1	0	1.3	9.4	21	–2.4	–17.9	8.2	27.9	37.5	4	5.5	2.4	1.9	3.4	–17.8	–5.0
Percentile of 95%	0.2	3.9	1,066	4	2	7.2	15.1	25.5	4.1	-6	12.8	32.9	41.7	12	15.9	8.0	2.7	8.6	20.3	6.0

Bioclimate types

The multivariate analysis classification techniques provided five classes of pinsapo fir forests according to climate variables (date no included). Table 4 shows the results of the descriptive statistical data of each centroid. The principal component analysis helped us to determine the climatic significance of each class (Fig. 2). Three components accounted for 81.5% of that variation. Component 1 represents the transition from the thermic variables to the ombric ones, from the positive values in the former to negative ones in the latter. Component 2 reflects the extreme effects of M and TMMC with respect to IOIF and IOPF also has height loadings.

The accuracy of the selection was confirmed by discriminant analysis, which revealed that the climate data were correctly classified in 100% of cases (date no included). The five pinsapo fir forest classes can be ranked in terms of the thermal variables TMMF, TMF and TMMC,TMI; TMF, F and M which allow their unambiguous resolution. These analyses confirm that the thermal variables are practically sufficient to classify the different types of pinsapo fir forests. The measu-

rement of the differences between the multivariate means, Mahalanobis distance (157.58), and its associated F statistic (29.22, $P < 0.001$) indicates a significant difference between contiguous and fragmented groups. The group centroids on the dicriminant axis were 11.29 (contiguous) and –146.28 (fragmented). The group means were well-separated, indicating that there was discrimination between the two pattern groups. A cartographic representation of the five pinsapo fir bioclimate classes is presented in Figure 3, which can be described as follows:

— **Class 1**, with an Atlantic-dominant climate. It occupies the western area of «Sierra de la Nieves» and «Sierra del Pinar», as well as the «Reales de Sierra Bermeja». It features high IOIF, IOPF and IFOR1 values, and also a high IIEST. This indicates that pinsapo fir forests in the western areas are subjected to winter and spring precipitations substantially exceeding those of the summer and autumn. Also, this constitutes the coldest group after class 5 and, in fact, it departs from the variables defining thermicity.

— **Class 2** is exclusive of «Sierra del Pinar». It is a warmer area in winter and features the highest TMF,

Table 4. Descriptive statistical data of phytoclimate variables for each climate class. Class 1: Atlantic-dominant climate. Class 2: «Sierra del Pinar» climate. Class 3: Mediterranean climate. Class 4: Continental climate. Class 5: highest climate

Types	Class 1	Class 2	Class 3	Class 4	Class 5
N	14	3	6	8	4
TMF	3.45 (1.85)	7.36 (2.71)	5.23 (2.28)	3.11 (1.76)	1.10 (1.04)
TMMF	1.27 (1.13)	4.40 (2.09)	1.18 (1.08)	–1.05 (–1.05)	–1.85 (–1.85)
F	–16.75 (–16.75)	–9.23 (–9.23)	–11.73 (–11.73)	–15.08 (–15.08)	–15.20 (–15.20)
TMMC	31.14 (5.58)	30.80 (5.54)	32.46 (5.69)	32.83 (5.73)	30.12 (5.48)
M	8.35 (2.88)	11.03 (3.32)	13.98 (3.73)	15.80 (3.97)	5.67 (2.38)
TMI	4.75 (2.17)	7.83 (2.79)	6.85 (2.61)	5.45 (2.33)	2.70 (1.64)
IFOR1	2.19 (1.48)	2.59 (1.61)	1.95 (1.39)	2.17 (1.47)	2.27 (1.50)
IIEST	5.20 (2.28)	4.52 (2.12)	3.47 (1.86)	4.25 (2.06)	7.94 (2.81)
IOIF	7.97 (2.82)	0.38 (0.62)	4.27 (2.06)	–5.16 (–5.16)	–14.18 (–14.18)
IOPF	1.33 (1.15)	0.13 (0.36)	1.43 (1.19)	–1.46 (–1.46)	–1.86 (–1.86)
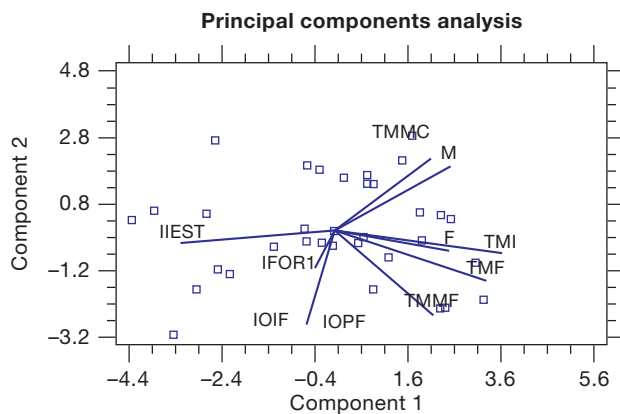
Figure 2. Relationship between the linearly independent phytoclimate variables and the different classes defined by the ranking analysis. Representation in a principal component analysis. Class 1: Atlantic-dominant climate. Class 2: «Sierra del Pinar» climate. Class 3: Mediterranean climate. Class 4: Continental climate. Class 5: highest climate (WGS 82, Huso 29N).

TMMF and TMI values. As implied by its low IIEST, water stress is high in winter and spring compared to summer and autumn.

— **Class 3** has the most Mediterranean climate including «Sierra de las Nieves» pinsapo fir forests, and is similar to class 1, but warmer. However, it features high spring precipitation, lower IFOR1 and IIEST, and

a higher IOPF. This confirms its decreased Atlanticness together with the lowest spring water stress.

— **Class 4** with the most continental climate characterized by cold winters (negative TMMF values) and hot summers showing the highest TMMC. It occupies intermediate zones in «Sierra de las Nieves» and possesses the highest M values, which confirms —by comparison with TMMF— its continental character.

— **Class 5**, occupying the highest altitude, this class being the coldest with the lowest M and TMF values among all the classes. Its location in the western part of «Sierra de las Nieves» reduces the Atlantic influence, as reflected in its IIEST values and its low TMMF. This class is qualitatively rather different from the others and exhibits the most marked differences from the pinsapo fir forest located in the «Sierra del Pinar».

Discussion

The bioclimate types of pinsapo fir forests have been described in this study. A precise climatic examination suggests that pinsapo fir forests might be established in particular physiognomic climate features compatible with those such as nemorality, steppiness and marcescent sclerophylly.
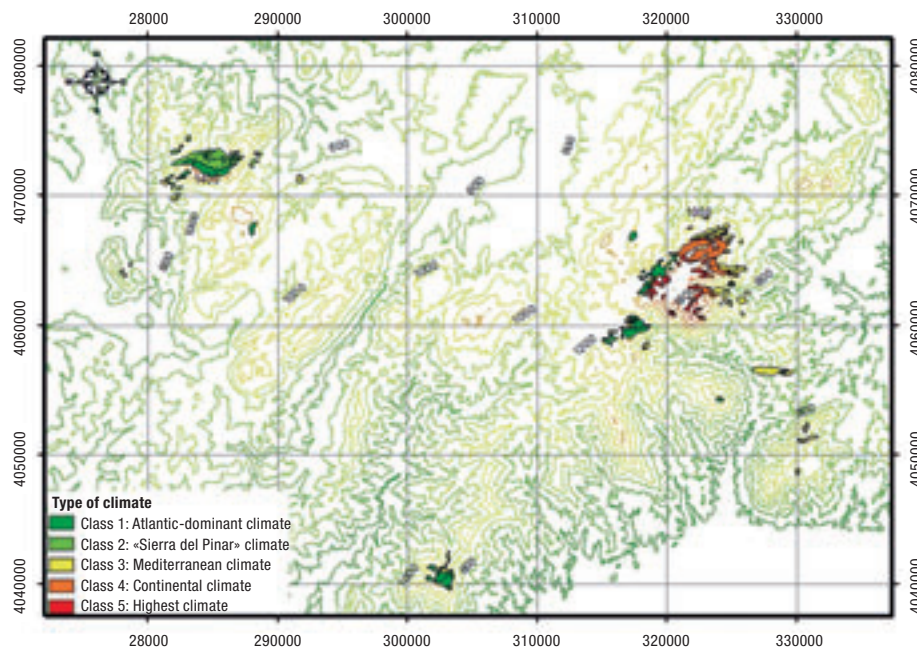
Figure 3. Biogeographic representation of the five pinsapo fir wood classes established from phytoclimatic criteria. Class 1: Atlantic-dominant climate. Class 2: «Sierra del Pinar» climate. Class 3: Mediterranean climate. Class 4: Continental climate. Class 5: highest climate (WGS 82, Huso 29N).

The hierarchical classification proposed in this study adopted five bioclimate classes for pinsapo fir forests in the Iberian Peninsula with a clear discrimination between them: Atlantic type (class 1), Mediterranean type (class 3), warm type (class 2), Continental type (class 4) and cold type (class 5). While this classification cannot be held as being definitive, its discriminant analysis is fairly accurate and the results are biogeographically consistent (Ceballos & Martín Bolaños, 1930). The «Sierra Bermeja» pinsapo fir forest exhibits features that allow its inclusion in class 1, even though some reference climate stations depart from the rest (for example Grazalema, 5911). The analysis of this type can therefore be deemed to be correct and endows these forests with a specific phytoclimatic character.

The climate variables that define these formations are essentially related to thermal and seasonal precipitation factors, so they should be regarded as providers of gradient information about the altitudinal impact of climate on the associated vegetation. The distribution of pinsapo fir forests seems to be determined by the orography and this fact means that the current requirements of pinsapo fir can only be determined by using simulated stations within the network nodes. The estimated precipitation value excludes crypto precipitation, which may account for up to 1,000 mm or more in Grazalema (the reference station). This may substantially alter the response to autumn and spring precipitations. However, crypto precipitation never exceeds the levels reached in «Sierra de Grazalema» and may be insubstantial in many places, so calculated occurrence limits might provide better estimates of the minimum requirements for this species. While certain freezes appear to be accurately estimated, probable freezes do not. The latter may be restricted to 8-9 months at the most and never occur in summer. Again, data for points inside the woods would be required to solve the problem.

Based on the boundaries of climate subtypes defined by Allué in 1990, this climate appears to be unique in the Iberian Peninsula. However, fir forests may also develop under other bioclimate subtypes; these are slightly thermal nemoro-Mediterranean type arboreous exclusively true ilici forests transitional towards decidous broad-leafed trees (VI(IV)$_2$), Mediterranean type arboreous typical sclerophyll, drier (A > 3) than the previous climate (IV$_4$), and nemoro-mediterranean with marcescent broad-leafed cold deciduous trees sub-sclerophyll (IV(VI)$_1$) or Mediterranean type arboreous exclusively true ilici forests transitional towards cold steppe (IV(VII)), their absence from these locations being indicative of their fragility in competing with better adapted vegetation. Studying TMMF values lower than 2°C; their steppiness would result from a (VII) type of Walter. These climate conditions may promote the appearance of a new bioclimate subtype exclusive of pinsapo fir forests. According to the major features related to the presence of summer aridity exceeding 3 months, a high rainfall and relatively low temperatures for the surrounding environment, a suitable climate designation essentially encompassing the Mediterraneity and steppiness features could be designated as Mediterranean type arboreous exclusively true ilici forests transitional towards cold steppe (IV(VII)$_1$). The geographic distribution of this new bioclimate is included in Figure 3. The associated vegetation to this bioclimate possesses some nemoral elements such as *Helleborus foetidus* L., *Berberis hispanica* Boiss & Reuter, *Sorbus aria* (L.) Crantz. and *Taxus baccata* L., which make it difficult to designate the new subtype as an additional nemoro-mediterranean with marcescent broad leafed cold deciduous trees (VI(IV)$_i$) as it consists largely of sclerophyllous or marcescent plants and grasses in open formations. A more detailed study of these plant structures is required in order to adopt a reliable criterion for naming the subtype.

Vegetation observations performed on the ecotones examined have revealed the presence of degradation stages of shrubs (e.g. *Cistus* sp. *Bupleurum spinosum* Gouan, *Ulex baeticus* and *Echinospartum boissieri* (Spach). Rothm.), among other thorny species. The presence of —especially— *Quercus faginea* within the pinsapo fir forests, and also of *Q. ilex*, *Juniperus phoenicea* and thermophilic plants such as *Hyparrhenia hirta* (L.) Stapf. and *Phlomis purpurea* L. in their vicinity, are consistent with a typical ecotone with a wet Mediterranean type arboreous typical less dry (IV$_4$).

Pinsapo fir forests on the upper Mediterranean thermotype appear to be highly jeopardized in relation to the Climate Change and are affected by water stress processes; those definitely within or in the vicinity of Mediterranean type arboreous typical less dry type (IV$_4$) are bound to yield to the pressure of other physiognomic strategies.

Conclusion

Pinsapo fir grow in forest formations phytoclimatically grouped in five well-defined classes, funda-

mentally separated by thermal criteria. Their existence boundaries with respect to the Allue (1990) system are defined and fairly significant with regard to their variables as to be considered to be good parameters for describing a biogeographical area which is compatible with their existence. This gives rise to a possible phytyoclimate subtype IV (VII)$_1$ of a Mediterranean character tending towards cold steppe, exclusive of these forests, which would make it difficult for them to spread to other places. They would also be highly vulnerable to any climate change which, with the increase in temperature, would place them in a critical situation if faced with the disappearance of the climate subtype or environment sustaining them.

Acknowledgements

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