Factorial Ambits with High Phytoclimatic Viability for Chestnut (*Castanea sativa*) in Spain

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Abstract

Factorial ambits with high viability have been established for chestnut (*Castanea sativa)* formations in Spain. Preliminary phytoclimatic characterization was carried out on the basis of a survey of 898 sampling points from the Second National Forestry Inventory, where chestnut was the dominant species in forest formation. A modified version of the Allué-Andrade phytoclimatic system was used; this was applied to a factorial climatic model of regionalized climatic variables superimposed on a digital model of elevations of all peninsular Spain. This is a quantitative phytoclimatic system, meaning that it does not only allow inclusion of a station in a previously-defined phytoclimatic category in qualitative terms, but it also allows quantification of the extent to which the station fits into such a category or phytoclimatic type—and also into other types in the system—by using coordinates of position and phytoclimatic distances, as related to one another and with reference to factorial phytoclimatic ambits corresponding to the chief plant life strategies of forest covers. By requiring increasing values of the phytoclimatic suitability index, several factorial ambits of increasing phytoclimatic viability were derived for Spanish chestnuts. For the purposes of this research, phytoclimatic suitability means the extent (from 0 to 1) to which a site is suitable as a habitat for chestnut formations, always from the combined standpoints of durability (capacity for self-regeneration), ability to compete with other species and resistance to diseases. The paper stresses that the system of increasing degrees of phytoclimatic suitability is used to select, within the species' own ecological ambit, chestnut stations presenting aridity (preferentially lasting between 1.5 and 3.5 months), higher limits of average annual and summer precipitation, lower and higher temperatures (practically zero duration of frosts and high average temperatures in the coldest month). A (duration of aridity) and T (average annual temperature) were the factors that correlated best with suitability of chestnut; a simple polynomial formula based on these two factors is presented for approximate evaluation of the index.

Resumen

Se establecen ámbitos factoriales de alta viabilidad fitoclimática para los castañares (*Castanea sativa)* en España. La caracterización fitoclimática previa se efectuó a partir del estudio de 898 puntos de muestreo procedentes del II Inventario Forestal Nacional con presencia del castaño como especie dominante de la formación forestal. El sistema fitoclimático utilizado fue el de Allué-Andrade modificado, que se aplicó a un modelo climático factorial de variables climáticas regionalizadas sobre un modelo digital de elevaciones de toda la España peninsular. Mediante la exigencia de valores crecientes del índice de idoneidad fitoclimática se obtuvieron varios ámbitos factoriales de creciente viabilidad fitoclimática para los castañares españoles. Se destaca que las idoneidades fitoclimáticas crecientes van seleccionando, dentro del ámbito autoecológico de la especie, aquellas estaciones de castañar con aridez presente (preferentemente entre 1,5 y 3,5 meses de duración), límites superiores de precipitaciones medias tanto anuales como estivales menores y mayores termicidades (duración de la helada prácticamente inexistente y altos valores de la temperatura media del mes más frío). Los factores A

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(duración de la aridez) y T (temperatura media anual) resultaron ser los más correlacionados con la idoneidad del castañar y se presenta una fórmula polinomial sencilla basada en ambos factores para la evaluación aproximada del índice.

INTRODUCTION

Chestnut woods occur naturally in the northern part of the Mediterranean region, with some minor occurrences in Central Europe, North Africa and the Caucasus. In Spain, there are a total of around 84,000 ha occupied by chestnuts according to the Second National Forestry Inventory. There are four principal nuclei (Ruiz de la Torre, 2006). The first lies in the north-west and the Cantabrian littoral, stretching from Galicia to Navarre; the second is in Catalonia (Barcelona and Gerona); the third is in the centre-west (Tiétar Valley, Gredos, Peña de Francia, South-West Madrid, etc.); and the fourth is in Andalusia (Sierra de Ronda, Sierra de Aracena, Sierra Nevada and Sierra Morena).

Studies which mention ecological aspects relating to *Castanea sativa* are relatively abundant but traditionally very little have been written about the phytoclimatic aspect. The most comprehensive studies existing to date for the entire national territory are those of Gandullo et al. (2004), based on 182 plots. The authors of the present work seek to gain a more complete phytoclimatic knowledge of Spanish chestnut formations by establishing high-viability phytoclimatic ambits.

MATERIAL AND METHODS

From the data base of sampling plots in the Second National Forestry Inventory (DGCONA, 1986−1995) 898 points where *Castanea sativa* is naturally present as the main species of the forest formation were selected. Plots were selected with the BASIFOR IT utility (Del Río et al., 2001); entries where chestnut was present as the first dominant species in the formation were set aside. Figure 1 shows the distribution of the 898 sampling points used.

The phytoclimatic system used is based on the models of Allué-Andrade (1990 and 1997) as modified by García-López and Allué Camacho (2003). This system was chosen for the present study because at present it is a *quantitative* phytoclimatic system—in other words, it not only allows inclusion of a station in a previously-defined phytoclimatic category in simple qualitative terms, but it also allows quantification of the extent to which the station fits into such a category or phytoclimatic type (and also into other types in the system). In contrast with other methodologies (Gavilán et al., 1998; Gavilán, 2005), *"coordinates of position"* and *"phytoclimatic distances"*, as related to one another and with reference to factorial phytoclimatic ambits corresponding to the chief plant life strategies of the dominant forest covers, based on the life types of Walter & Lieth (1960) are pointed out as parametrical references. All this goes to make up an important element of this study, namely the numeric quantification of the degree of a territory's phytoclimatic potential as a habitat for chestnut formations.

The 898 chestnut points were identified by their UTM coordinates (Zone 30) and their altitude and were processed using the FITOCLIMOAL'2000 computer programme (García-López and Allué Camacho, 2000) to derive the gross monthly temperature and rainfall data following the models of Sánchez Palomares et al. (1999). The same programme was then used to find the phytoclimatic factors listed in Table 1.

The methodology followed in this study was based on the selection of maximum and minimum values of the phytoclimatic factors for those of the target stations which satisfied the condition of having a suitability index higher than a given limit. For the purposes of this research, *"phytoclimatic suitability"* (Allué Camacho, 1996) means the extent to which a site is suitable as a habitat for certain taxons or syntaxons, always from the combined standpoints of durability (capacity for self-regeneration), ability to compete with other species and resistance to diseases. We have already used this methodology to determine ambits of high phytoclimatic viability for other forest species such as *Fagus sylvatica* in the Iberian Peninsula (García-López et al., 2005).

RESULTS

Table 3 presents the results after filtering of suitability scores for cut-off points 0.50 and 0.65.

As the table shows, the system of increasing degrees of phytoclimatic suitability is used to select chestnut stations presenting aridity, lower limits of average annual and summer precipitation and higher temperatures (practically zero duration of frosts and high average temperatures in the coldest month).

DISCUSSION

By considering territorialized phytoclimatic factors corresponding to a very large number of chestnut stations and applying an integrated filtering criterion, in this case the Suitability Index, it was possible to establish more comprehensive and nuanced factorial ambits of existence than any defined to date.

Examination of the bivariate correlations of suitability (ID) with the phytoclimatic factors used, quantified by means of Pearson's correlation coefficient, shows that factors A and T correlate the closest with ID. All correlations are significant at a level of 0.01.

The identification of maximum suitabilities of chestnut with the presence of aridity appears to be borne out if we consider the average suitabilities of factor A in amplitude intervals of 0.25 months. As Table 4 and the related graph in Figure 3 show, the phytoclimatic suitability of chestnut gradually increases as the values of A increase from the bottom limits of its ambit of existence (A=0), reaching maximum at values of A between 3 and 3.5 months, with a sharp fall at less than approximately 3.5 months' duration.

In the case of the chestnut formations studied, the Phytoclimatic Suitability Index can be estimated approximately for the factorial limits in Table 2 using the expression:

$$ID= -0,61133+0,08522.A-0,0202.A^2+0,15847.T-0,00532.T^2 \qquad R=0,87$$

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Tables

Table 1. Phytoclimatic factors used.

Abbreviation	Factor	Unit
K	Intensity of aridity. Calculated on the basis of the quotient 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 above the Ti curve, i.e., 2Ti>Pi).	
A	Duration of aridity in the sense of GAUSSEN, that is the number of months in which the Ti curve is above the Pi curve, i.e., 2T1>Pi.	months
P	Total annual precipitation	mm
PE	Minimum summer precipitation (June, July, August or September)	mm
TMF	Lowest monthly mean temperature	ºC
T	Mean annual temperature	ºC
TMC	Highest monthly mean temperature	ºC
TMMF	Average of the minima of the month with the lowest mean temperature.	ºC
TMMC	Average of the maxima of the month with the highest mean temperature.	ºC
HS	Certainty of frost. Calculated as no. of months in which TMMF <=0	months
PV	Free vegetal activity periodo. Calcullated as no. Of months in which Ti>=7,5ºC and A=0	months
OSC	Continentality Index. Calculated as TMC-TMF	ºC

Table 2. High-viability potential phytoclimatic ambits of *Castanea sativa* in Spain as a function of suitability index (ID).

Id	Stations	K	A	P	PE	T	TMF
Total	898	0,254	3,82	2403	111	16,6	10,2
		0	0	632	2	8,8	1,5
Id<=0,50)	244	0,254	3,82	2403	111	16,6	10,2
		0	0	720	2	8,8	1,5
Id>0,50	654	0,244	3,77	2110	106	16,3	9,9
		0	0	632	2	9,3	2,3
>0,65	90	0,212	3,59	1465	44	15,8	9,3
		0	0,14	666	2	11,9	3,8
Id	Stations	TMC	TMMF	TMMC	HS	PV	OSC
Total	898	26,7	6	32,2	3,5	12	20,3
		15,9	-2,1	20,2	0	4,2	8,9
<=0,50	244	26,7	6	32,2	3,5	12	18,7
		15,9	-2,1	20,2	0	4,2	8,9
>0,50	654	25,8	5,8	31,5	2,8	12	20,3
		16,5	-1,4	20,7	0	4,4	9,2
>0,65	90	25,3	5,2	30,8	0,3	11,6	19,2
		18,2	0	22,7	0	5,7	10,9

Table 3. Analysis of bivariate correlations between the Phytoclimatic Suitability Index and the phytoclimatic factors used for the 898 chestnut plots studied. Pearson's correlation coefficient and the corresponding levels of significance are included.

	K	A	P	PE	T	TMF
Pearson	0,462586	0,646350	-0,200827	-0,547594	0,654284	0,500090
Sig.	1,03E-48	4,0E-107	1,32E-09	3,04E-71	9,6E-125	7,15E-58
	TMC	TMMF	TMMC	HS	PV	OSC
Pearson	0,622861	0,498445	0,62709	-0,334887	0,111310	0,390891
Sig.	5,8E-110	1,90E-57	4,2E-99	6,38E-25	0,0008	4,38E-34

Table 4. Average suitability values (ID) of the different value intervals corresponding to factor A for the 898 chestnut points analysed. Dst: Standard deviation of ID.

A (months)	0	0-0,25	0,25-0,50	0,50-0,75	0,75-1	1-1,25	1,25-1,50	1,50-1,75
ID	50,3	52,3	56,1	56,8	55,6	55,9	56,8	59,5
Dst	3,9	4,9	4,7	4,6	4,7	3,7	3,8	2,9
A (months)	1,75-2	2-2,25	2,25-2,5	2,5-2,75	2,75-3	3-3,25	3,25-3,50	>3,50
ID	64,1	65,1	65,3	65,8	62,1	64,9	66,7	56,5
Dst	2,7	1,4	1,3	2,3	3,3	3,6	2,4	8,9

Figures

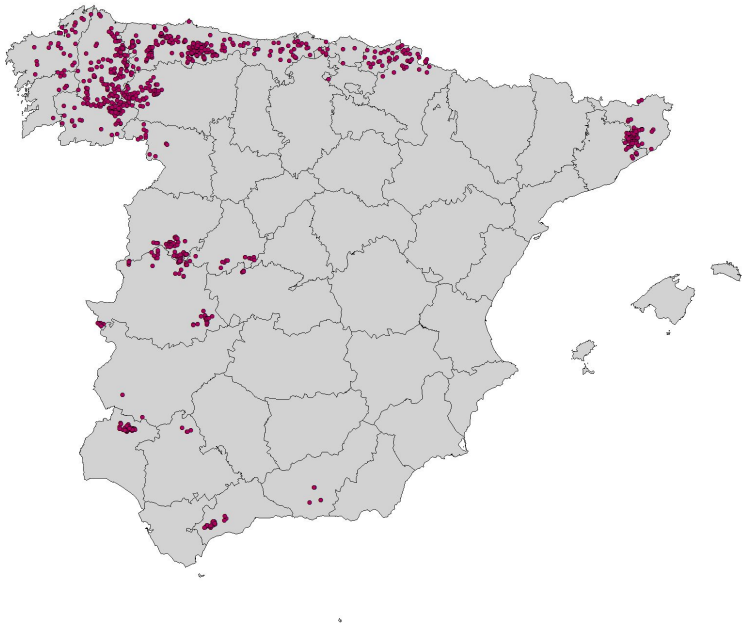

Fig. 1. Situation of the 898 points from the 2nd NFI where *Castanea sativa* occurs as the principal plant formation.

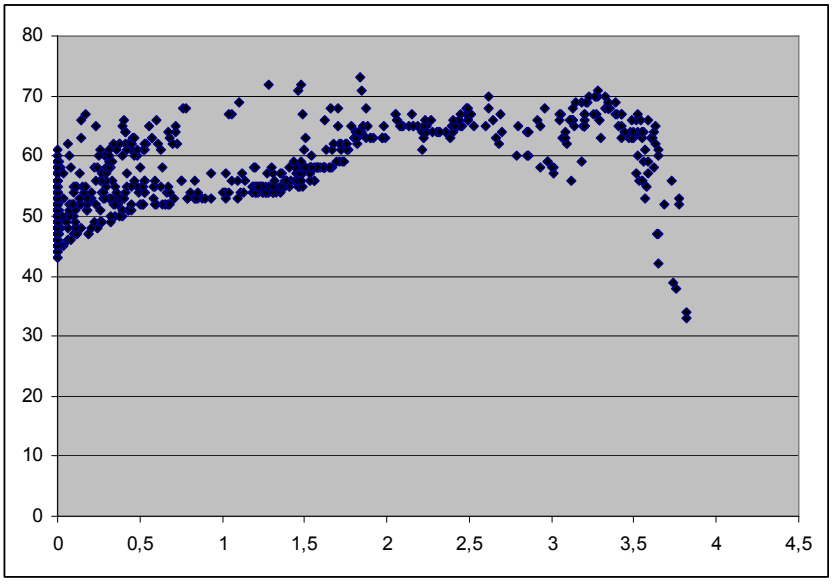

Fig. 2. Suitability (x10) of *Castanea sativa* stations considered (2nd NFI) in terms of values of the factor A.