ANALYSIS OF THE DISTRIBUTION OF *Quercus robur* L. IN GALICIA, SPAIN

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Abstract

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Thirty-nine *Quercus robur* L. plots distributed all over Galicia, Spain were sampled. The sample tried to represent as objectively as possible all the locations with a significant presence of the species. This study aims to analyze the distribution of oak formations within the Galician territory and attempts a classification of these formations based on a series of discriminant parameters. Twenty-eight ecological parameters were used to characterize the biotope, and 14 parameters were used to characterize the studied oak forests from the perspective of forest mensuration and silviculture. By using Twinspan software, the selected method enabled a two-way classification of different plots that were randomly sampled. Any plot can be automatically incorporated into this classification until the whole study area is classified.

Key words: ecology, forest mensuration, Galicia, *Quercus robur*, silviculture

Introduction

Species of genus *Quercus* (‘oaktrees’ in a wider sense) (Pulido, 2002) are the dominant species in a large part of the forests in the temperate zone of Northern hemisphere and in subtropical transition areas. At present, nearly 400 species of this genus are recognized. Mexico shows the largest number of species. These are spread throughout North America, Europe and a large part of Asia, but they are not present in the southern hemisphere (Miller, Lamb, 1985). Most of climax vegetation in Galicia should be composed of different species of genus *Quercus*, which form part of Galician deciduous forests.

The surface area of these forests has gradually decreased. The main reasons for decrease were the following: the need to clear plots of land to establish crops and pastures, timber and wood extraction for domestic and industrial use, forest fires, unfortunate silvicultural treatments, or massive reforestation with pine and eucalyptus (Guitián Rivera, 1993, 1995; Rigueiro, 1995). At present, the surface area covered by this type of forests in Galicia has increased substantially, as shown by the data contained in the III Spanish National Forest Inventory (DGCONA, 2001). According to this information, pure stands of native hardwoods cover approximately 27% of the total woodland area, 375.922 ha (Xunta de Galicia, 2001). The relevance of these data is even higher considering the evolution of these forests: in 1986, hardwood forests covered only 20% of total woodland area (Xunta de Galicia, 1988). In this context, pure stands of *Quercus robur* cover an area of 187.789 ha, almost 14% of total woodland are in Galicia, although this species can also be mixed with other native hardwoods, such as *Pinus pinaster* and *Eucalyptus globulus*. Therefore, the study species covers a considerably larger area (Xunta de Galicia, 2001).

These data might suggest that the current situation of the stands is ideal, which is far from true because most stands are highly weathered and genetically impoverished (Silva-Pando, Rigueiro, 1992). The studied stands did not receive any silvicultural treatments, or received unfortunate treatments, such as selective cutting of the best individual trees and tree pollarding (Hochbichler, 1993; Kenk, 1993). The presence of large diameter oaks is common, but these trees are usually badly formed and rotten (Díaz-Maroto, 1997). However, the existing social demand for the preservation and recovery of oak formations suggests a change of attitude. An appropriate forest policy must combine different aspects such as yield, preservation, and recreational use. In addition, the potentiality of the species must be determined and its potential for expansion must be assessed. Therefore, data must be obtained about distribution of the species and classification of the habitats that the species covers within study area. The main aim of this study is to collect information required. The initial hypothesis of this study suggests that the distribution of *Quercus robur* in Galicia is induced by physiographic and climatic features of territory rather than by potential soil conditioning factors (Izco, 1987; Izco et al., 1990; Díaz-Maroto et al., 2005).

Materials and methods

Study area

The study area covers the Autonomous Community of Galicia, Spain (Fig. 1), with an area of almost 3 million hectares. The relief of the land is complicated, with an average elevation of 508 m and slopes steeper than 20% in half of the surface area. This zone has a rich lithological composition. The climate is varied but follows a general wet pattern, with annual rainfall between 600 and more than 3.000 mm. Summer-green deciduous forests prevail (Guitián Rivera, 1995; Díaz-Maroto, 1997).

Within this category, the climax formations that largely cover the Galician territory, from the sea level up to 1.100–1.200 m, are forests of *Quercus robur* L. Atlantic climate is the dominant in most of Galicia, and is ideal for development of a mixed oak forest with presence of other tree species, and different shrub and herbaceous species. These species form different associations included in the phytosociological order *Quercetalia robori-petraea* (Amaral, 1990; Rivas-Martínez, 1987; Silva-Pando, Rigueiro, 1992; Díaz-Maroto, 1997). First, acidophil hill or low-montane oak forests (*Blechno spicanti-Quercetum roboris*) occur, which are characteristic of northern part of Galicia. On the western half, acidophil humid or hyper-humid hill oak forests (*Rusco aculeati-Quercetum roboris*) occur in locations under 550–600 m where the summer drought period is not intense. In the interior and in the south of Galicia, humid or hyper-humid montane oak forests are present (*Vaccinio myrtilli-Quercetum roboris*) in zones with a more continental climate and, sometimes, with Mediterranean influence (Rivas-Martínez, 1987; Izco, 1987; Silva-Pando, Rigueiro, 1992).

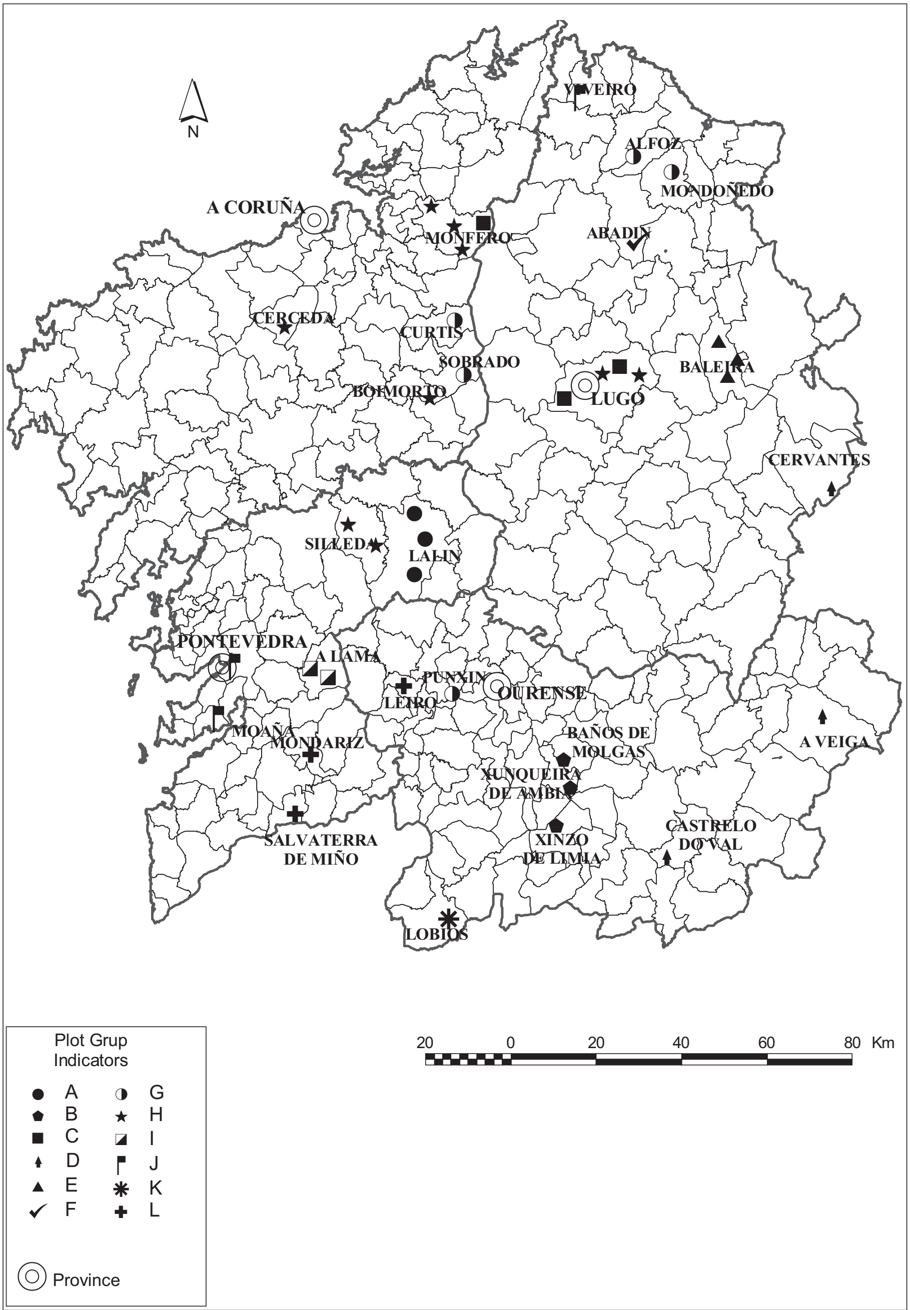

Fig. 1. Location of the sample plots and results of the two-way classification in the study area, Galicia.

Sampling design and data collection

A stratification of the study area was first planned (Gandullo et al., 1991). However, in this case, land stratification based on a specific characteristic that defined the distribution of these formations (Daget, Godron, 1982) was not possible because of the dispersion and heterogeneity of the stands of *Quercus robur* in Galicia. Therefore, study area was considered as a unit. However, some locations were removed because of the peculiarities of biotope, which made presence of *Quercus robur* extremely difficult (Silva-Pando, Rigueiro, 1992; Díaz-Maroto, 1997). The initial information was obtained from vegetation tiles of the Forest Map of Spain (Ruíz de la Torre, 1991). The study area was defined and the sampling zones were chosen based on data provided by staff of the forest ranger station, and based on information from our previous studies. The definition of the area tried to cover all the locations within study area where the occurrence of this type of forest was possible and considered locations that showed some peculiarity (from the perspective of soil, climate, etc.) (Daget, Godron, 1982; Díaz-Maroto, 1997). Then, the prevailing environmental conditions were explored and analyzed in order to choose the site of average characteristics that defined each sampling zone and to select the ideal location for each plot within the sampling zones. According to general tendency currently followed by different authors, among whom Greig-Smith (1983), square plots 10 m long by 10 m wide were laid out. A total of 39 sampling points were measured (Fig. 2). Table 1 shows data of the location and physiography of each sampling points.

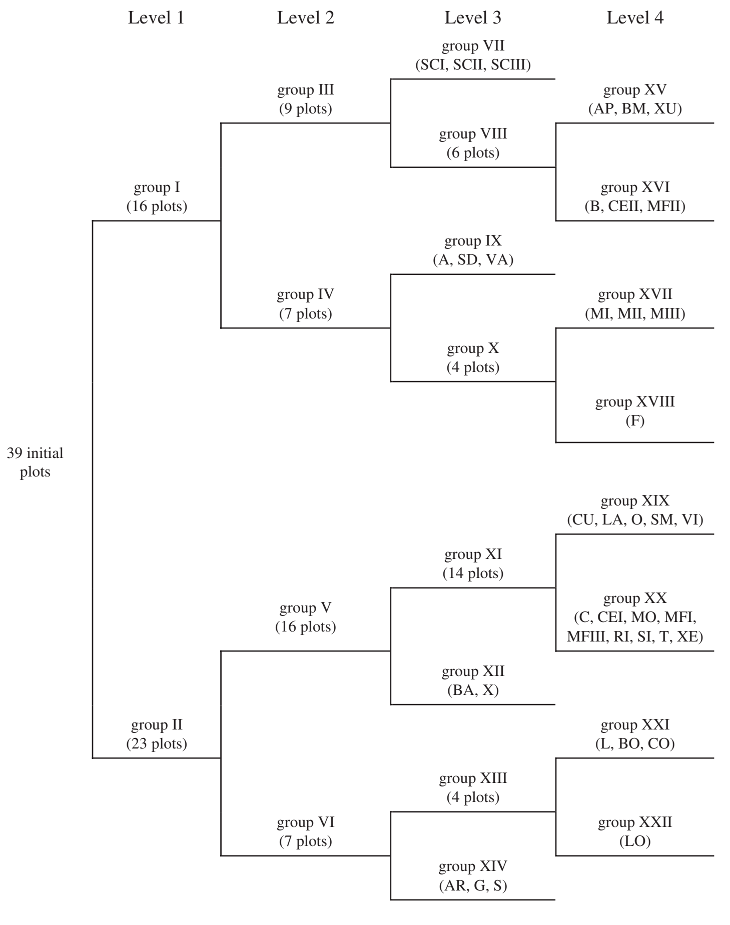

Fig. 2. Distribution of the groups of plots obtained by discriminant analysis with Twinspan software.

T a b l e 1. Sample plots with name, code, province where they are located, and physiographic data (elevation, slope and orientation).

Plot name	Plot code	Province	Elevation (m)	Slope (%)	Orientation
Cerceda	C	A Coruña	420	17	north
Cerqueiros I	CEI	A Coruña	393	55	northwest
Lourizán	L	Pontevedra	60	8	northwest
San Miguel de Bacurín	B	Lugo	500	0	–
Ancares	A	Lugo	1075	60	north
A Pena	AP	Ourense	650	0	–
A Rúa	AR	Pontevedra	240	14	north
Baños de Molgas	BM	Ourense	565	10	northwest
Barcía	BA	Pontevedra	740	12	southwest
Boimente	BO	Lugo	510	8	northeast
Cerqueiros II	CEII	A Coruña	400	60	east
Coiró	CO	Pontevedra	320	20	northeast
Curtis	CU	A Coruña	480	27	south
Fragavella	F	Lugo	620	48	southeast
Gomaríz	G	Ourense	220	27	north
Lagoa	LA	Lugo	110	8	southwest
Lobios	LO	Ourense	790	53	north
Monfero	MO	A Coruña	500	48	northwest
Monte Marronda I	MI	Lugo	800	72	northeast
Monte Marronda II	MII	Lugo	670	58	northeast
Monte Marronda III	MIII	Lugo	540	60	northeast
Monte San Fitoiro I	MFI	Lugo	620	0	–
Monte San Fitoiro II	MFII	Lugo	630	15	northwest
Monte San Fitoiro III	MFIII	Lugo	690	25	north
Ourantes	O	Ourense	380	65	northeast
Ribeiro	RI	A Coruña	360	21	southeast
Salvaterra do Miño	S	Pontevedra	80	12	northeast
Serra do Candán I	SCI	Pontevedra	540	38	northwest
Serra do Candán II	SCII	Pontevedra	550	22	northwest
Serra do Candán III	SCIII	Pontevedra	600	12	north
Serra do Invernadeiro	SD	Ourense	1300	35	north
Siador	SI	Pontevedra	600	27	northwest
Sobrado dos Monxes	SM	A Coruña	520	0	–
Teixeiro	T	A Coruña	300	10	east
Valdín	VA	Ourense	1080	36	east
Viloalle	VI	Lugo	265	23	southeast
Xesta	X	Pontevedra	740	25	southwest
Xestoso	XE	Pontevedra	600	19	northeast
Xunqueira de Ambía	XU	Ourense	565	7	northwest

Physiographic and forest mensuration data were collected at each sampling point. In addition, a botanical inventory was conducted and the soil profile was studied in order to identify and describe different soil horizons. A representative sample of each horizon was collected (Díaz-Maroto, Vila-Lameiro, 2005). A set of parameters was developed with the information obtained from the plot inventory, climatological data adapted to different sampling points, and results of the physical and chemical analyses of soil samples. These parameters defined the physiographic, climatic and soil habitat of *Quercus robur* in Galicia. Moreover, these parameters defined forest mensuration and silvicultural features of oak stands, and offered floristic data.

Classification method

The method proposed by Hill (1973) and Hill et al. (1975) was used. By using Twinspan software (Hill, 1979a, b), this method enabled a two-way classification of different land plots, randomly sampled. This classification is dynamic because any point in the territory can be automatically added to classification after the classification is obtained, until the whole study area is classified (Aramburu et al., 1984). The sampled plots were grouped according to some characteristics, such as presence of specific associated botanical species (Hill et al., 1975; Barrio, 2003), value of specific ecological or silvicultural parameters, etc. (Gandullo et al., 1991; Díaz-Maroto, 1997).

To verify the results obtained by using Twinspan software, particularly in terms of the selection of parameters used in the two-way classification, a bi-variable correlation analysis was conducted by using SPSS statistical package. The aim of this analysis was to study the possible interdependence (or not) of the parameters (Jobson, 1991).

Classification parameters

The selection of the parameters used to analyze and classify the stands of oaks in Galicia was performed by following the criteria of amount and discrimination power. In principle, the maximum amount of parameters was not limited, so that the parameters that showed differentiating characteristics within the area covered by *Quercus robur* were chosen. At the same time, these parameters are useful to define biotopes (Castroviejo, 1988; Gandullo et al., 1983, 1991; Johnson et al., 2002; Díaz-Maroto et al., 2005). With the data collected at each sampling point, 42 parameters were designed, among which 28 were ecological parameters (Table 2) that described the biotope and environmental conditions that determined the regeneration and growth of oak forests (Ashton, Larson, 1996; Humphrey, Swaine, 1997; Kelly, 2002; Díaz-Maroto, Vila-Lameiro, 2005). Fourteen parameters characterized studied stands from the perspective of forest mensuration and silviculture (Timbal, Aussenac, 1996; Díaz-Maroto, 1997). The following parameters were selected:

a) *Physiographic parameters*: The physiographic parameters selected (Table 2) were: (1) average elevation (ELV), (2) average slope (SLP), (3) soil depth down to parent material (DPT) and (4) distance to the sea in a straight line (DSE).
b) *Climatic parameters*: To describe the climate of each zone, the following parameters were selected (Table 2): (5) total annual rainfall (TR), (6) summer rainfall (SR), (7) average annual temperature (AT), (8) annual average of absolute maximum temperatures (AMT) and (9) annual average of absolute minimum temperatures (AmT).
c) *Soils parameters:* Nineteen soil parameters were considered. The first eight assessed chemical properties of soil, next eight assessed soil fertility, and the last three evaluated physical characteristics of soil (Table 2): (10) total pH in H_2O (PH), (11) surface pH in H_2O (PHS), (12) total organic matter (OM), (13) surface organic matter (OMS), (14) total nitrogen (N), (15) surface nitrogen (NS), (16) total carbon/nitrogen ratio (C/N), (17) surface carbon/nitrogen ratio (C/NS), (18) total available phosphorus (P), (19) surface available phosphorus (PS), (20) total exchangeable potassium (K), (21) surface exchangeable potassium (KS), (22) total exchangeable calcium (Ca), (23) surface exchangeable calcium (CaS), (24) total exchangeable magnesium (Mg) and (25) surface exchangeable magnesium (MgS), (26) amount of total sand (ARE), (27) amount of total silt (SLT), and (28) amount of total clay (CLA). When total value of each parameter in the whole soil profile was considered, a standard weighted mean of the whole soil profile was used for parameters (26), (27) and (28). For the other parameters, the weighted mean was considered by using the method by Russel, Moore (1968). In the case of surface values, the information from the upper 20 cm of the soil was considered, except when more than one horizon was present at this depth. In that case, a weighted mean was calculated.

T a b l e 2. Average values, standard deviation (SD), coefficient of variation (CV), maximum and minimum values for physiographic, climatic and soil parameters of the stands of *Quercus robur* (n = 39). Variables without units are dimensionless.

Parameter	Average	SD	CV	Maximum	Minimum
ELV (m)	539	260	0.482	1.300	60
SLP (%)	27	21	0.777	72	0
DPT (cm)	94	26	0.276	150	46
DSE (km)	42	28	0.666	135	0.5
TR (mm)	1371.9	311.6	0.227	1947.0	772.0
SR (mm)	164.0	51.4	0.313	283.0	61.0
AT (°C)	11.5	1.5	0.130	14.6	7.3
AMT (°C)	24.0	2.0	0.083	28.8	20.0
AmT (°C)	0.8	2.4	3.000	6.2	–4.3
PH	4.85	0.46	0.093	6.15	3.92
PHS	4.71	0.51	0.107	6.53	3.82
OM (%)	8.64	5.19	0.600	23.31	1.04
OMS (%)	12.85	7.76	0.604	34.21	1.19
N (%)	0.307	0.178	0.580	0.793	0.042
NS (%)	0.442	0.232	0.525	1.019	0.050
C/N	14.6	4.5	0.310	29.6	6.9
C/NS	16.8	4.3	0.253	30.1	10.4
P (ppm)	21.8	28.9	1.336	117.2	0.4
PS (ppm)	19.8	29.2	1.475	119.5	0.4
K (ppm)	73	40	0.548	231	9
KS (ppm)	103	50	0.485	252	19
Ca (ppm)	120	216	1.800	1297	3
CaS (ppm)	170	285	1.676	1704	4
Mg (ppm)	29	21	0.724	85	0
MgS (ppm)	49	38	0.775	143	0
ARE (%)	65.78	20.50	0.312	88.67	13.83
SLT (%)	22.53	20.75	0.921	84.89	7.44
CLA (%)	11.22	5.09	0.454	26.82	1.27

d) *Forest mensuration parameters*: They must meet one basic condition to serve as classification parameters: they must be independent of age and site quality, so that stands of different ages and with different site qualities can be compared (Díaz-Maroto, 1997; Barrio, 2003). This condition excludes very important variables, such as basal area, quadratic mean diameter or dominant height (Assmann, 1970). However, most of these variables are contained in the classification parameters used (Pardé, Bouchon, 1988). Therefore, only 4 out of 14 forest mensuration/silvicultural parameters were selected (Table 3): (29) coefficient of variation of diameter distribution (CVD), (30) coefficient of variation of height distribution (CVH), (31) relative spacing (RS) (Hart, 1928; Schütz, 1990) and (32) Czarnowski's index (CZI), understood as the number of trees in a square plot, the side of which equals the arithmetic mean height of the trees measured in that plot.

Each classifying parameter was divided into three intervals. The limits of intervals were defined so that each interval included approximately one third of the total number of plots. Because the distribution of plots according

T a b l e 3. Average values, standard deviation (SD), coefficient of variation (CV), maximum and minimum values for forest mensuration and silvicultural parameters of the stands of *Quercus robur* (n = 39). Variables without units are dimensionless (Díaz-Maroto, 1997).

Parameter	Average	SD	CV	Maximum	Minimum
Tree/ha	935.19	473.66	0.5065	2058.98	333.33
G (m^2/ha)	57.0043	41.2624	0.7238	171.8132	11.1362
D (cm)	27.38	10.13	0.3699	46.38	12.10
Dg (cm)	29.09	10.66	0.3664	50.29	12.50
SDD (cm)	9.38	4.43	0.4723	24.35	2.88
D_0 (cm)	42.90	14.37	0.3350	70.11	20.55
H (m)	15.33	4.09	0.2668	25.10	7.87
Hg (m)	15.75	4.15	0.2635	25.13	7.97
SDH (m)	3.31	0.83	0.2507	4.99	1.74
H_0 (m)	17.96	4.43	0.2466	28.87	9.28
CVD	0.3474	0.1093	0.3146	0.5534	0.1749
CVH	0.2186	0.0488	0.2235	0.3144	0.1522
RS	0.2075	0.0619	0.2983	0.3342	0.1014
ICZ	22.32	15.64	0.7007	71.00	6.92

Legend: G – basal area, D – arithmetic mean diameter, Dg – quadratic mean diameter, SDD – standard deviation for diameter distribution, D_0 – dominant diameter, H – arithmetic mean height, Hg – quadratic mean height, SDH – standard deviation for height distribution, H_0 – dominant height (Assmann, 1970)

to the values of each parameter was not known in principle, the limits were established based on the values of the average and standard deviation of parameters. By using this division, any plot that might be analyzed in the future could be easily included in any of the groups of the classification (Martínez et al., 1992):

lower interval < average of parameter – standard deviation (< A – SD)
middle interval average of parameter ± standard deviation (> A – SD; < A + SD)
upper interval > average of parameter + standard deviation (> A + SD)

Continuous variables can be transformed in a binary fashion (presence = 1, absence = 0) by establishing a number of classes, so that each variable is transformed into so many attributes as number of classes considered (Aramburu et al., 1984; Gandullo et al., 1991). The presence-absence matrix was developed by using intervals defined. Then, studied stands of *Quercus robur* were classified by using Twinspan software (Hill, 1979a, b), and different plot groups were obtained.

In addition, floristic inventories were analyzed by applying Twinspan software to plant species present in the whole of sampling points. In this case, the variables used were discrete, absence or presence of certain species (Hill et al., 1975; Gandullo et al., 1991; Díaz-Maroto, 1997; Barrio, 2003).

Results

Figure 2 shows distribution of the different plots. Four levels of groups were obtained because minimum plot division was not considered. Most of the final groups of classification were included in the fourth level and some of them in the third level. In the other levels, T a b l e 4. Characteristics of the 1st level of the two-way classification.

Number of groups	Discriminant parameters	Plots
Group I	DPT > A + SD AT < A – SD DSE > A + SD	B, A, AP, BM, CEII, F, MI, MII, MIII, MFII, SCI, SCII, SCIII, SD, VA, XU
Group II	DPT < A + SD AT > A – SD DSE < A + SD	C, CEI, L, AR, BA, BO, CO, CU, G, LA, LO, MO, MFI, MFIII, O, RI, S, SI, SM, T, VI, X, XE

T a b l e 5. Characteristics of the 2nd level of the two-way classification.

Number of groups	Discriminant parameters	Plots
Group III	AT < A – SD AT > A + SD	B, AP, BM, CEII, MFII, SCI, SCII, SCIII, XU
Group IV	A – SD <AT< A + SD	A, F, MI, MII, MIII, SD, VA
Group V	AT < A + SD	C, CEI, BA, CU, LA, MO, MFI, MFIII, O, RI, SI, SM, T, VI, X, XE
Group VI	AT > A + SD	L, AR, BO, CO, G, LO, S

T a b l e 6. Characteristics of the 3rd level of the two-way classification.

Number of groups	Discriminant parameters	Plots
Group VII	AMT > A + SD	SCI, SCII, SCIII
Group VIII	AMT < A + SD	B, AP, BM, CEII, MFII, XU
Group IX	DSE > A + SD	A, SD, VA
Group X	DSE < A + SD	F, MI, MII, MIII
Group XI	AmT < A + SD	C, CEI, CU, LA, MO, MFI, MFIII, O, RI, SI, SM, T, VI, XE
Group XII	AmT < A + SD	BA, X
Group XIII	ELV > A + SD DSE < A – SD DSE > A + SD	L, BO, CO, LO
Group XIV	ELV < A – SD A – SD <ELV< A + SD A – SD <DSE< A + SD	AR, G, S

certain plot divisions were not significant enough (Hill et al., 1975; Aramburu et al., 1984; Díaz-Maroto, 1997). At least one of the inequalities that characterize these groups must be fulfilled (Hill, 1979a, b). Tables 4, 5, 6 and 7 show the different levels of the two-way classification.

T a b l e 7. Characteristics of 4th level of the two-way classification.

Number of groups	Discriminant parameters	Plots
Group XV	DSE > A + SD	AP, BM, XU
Group XVI	DSE < A + SD	B, CEII, MFII
Group XVII	TR < A + SD	MI, MII, MIII
Group XVIII	TR > A + SD	F
Group XIX	DPT < A – SD DPT > A + SD	CU, LA, O, SM, VI
Group XX	A – SD <DPT< A + SD	C, CEI, MO, MFI, MFIII, RI, SI, T, XE
Group XXI	SLP < A + SD	L, BO, CO
Group XXII	SLP > A + SD	LO

In the first level, the initial 39 plots were divided into 2 groups (I and II) of 16 and 23 plots, respectively (Fig. 2) according to three discriminant parameters (DPT, AT and DSE) (Table 4). In the second level, the 16 plots in group I were divided again into two groups, III and IV, of 9 and 7 plots respectively. The 23 plots in group II were divided into groups V and VI, of 16 and 7 plots, respectively (Fig. 2), by using one discriminant parameter, AT (Castroviejo, 1988) (Table 5).

In the third level, the 9 plots in group III were divided into 2 new groups, VII and VIII, of 3 and 6 plots, respectively (Fig. 2), defined by only one climatic parameter, AMT. The 7 plots in group IV were divided into group IX, of 3 plots, and group X, of 4 plots, both of them defined by one physiographic parameter, DSE. The 16 plots in group V were divided into groups XI and XII, of 14 and 2 plots, respectively, which were characterized by one thermal climatic parameter, AmT (Castroviejo, 1988; Humphrey, Swaine, 1997). The last division of level 3 corresponded to the seven plots in group VI, which were divided into 2 new groups, XIII and XIV, of 4 and 3 plots, respectively. The new groups were characterized by 2 discriminant parameters, ELV and DSE, both of them physiographic (Gandullo et al., 1983; Castroviejo, 1988) (Table 6). The first significant division within the fourth level corresponded to the 6 plots in group VIII, which were divided into 2 new groups, XV and XVI, of 3 plots each (Fig. 3), which were characterized by one discriminant parameter, DSE. The next significant division of plots in level 4 corresponded to group X, composed of 4 plots, which were divided into groups XVII and XVIII, of 3 and 1 plots, respectively. These groups were characterized by the discriminant parameter TR (Gandullo et al., 1983; Castroviejo, 1988; Humphrey, Swaine, 1997). Within the fourth level, the most relevant division in terms of the number of plots was the division of group XI, of 14 plots, into 2 new groups, XIX and XX, of 5 and 9 plots, respectively, characterized by one physiographic discriminant parameter, DPT. The last significant division in the fourth level corresponded to the 4 plots in group XIII, which were divided into 2 new groups, XXI and XXII, of 3 and 1 plots, respectively, and defined by one physiographic parameter, SLP (Gandullo et al., 1983; Castroviejo, 1988) (Table 7).

T a b l e 8. Final groups that resulted from the use of Twinspan software (FAO classification, 1999, was used to determine soil type).

Group	Discriminant parameters	Plots	Characteristics
A	AMT > A + SD	SCI, SCII, SCIII	Steep slopes, elevations ≈ 600 m, deep soils and DSE ≈ 50 km. Heavy rainfall and wide thermal regime. Micaceous and quartzitic schist substrate. Silt texture. Dystric Cambisols.
B	DSE > A + SD	AP, BM, XU	Transition zones to *Q. pyrenaica*. Scarce slopes, elevations ≥ 600 m, large DPT and marked continentality. TR ≈ 800 mm and SR ≈ 100 mm with a wide thermal regime. Granite substrate. Sand texture. Dystric Cambisols.
C	DSE < A + SD	B, CEII, MFII	ELV between 400–600 m, DPT > 120 cm, lower continentality than in group B. Heavy rainfall and similar thermal regime. Granite substrate with Dystric Cambisols, and presence of schists with Fluvisol in Cerqueiros II.
D	DSE > A + SD	A, SD, VA	*Quercus robur* at treeline, very steep slopes, large soil depths and marked continentality. Climate typical of high mountain. Dystric Cambisols and Ranker (Humic Cambisol) in Valdín.
E	TR < A + SD	MI, MII, MIII	ELV between 540–800 m, extreme slopes, large DPT and continentality. TR > 1. 100 mm, wide thermal regime. Schist and quarzite substrate. Silt-sand texture. Ranker and Leptic Podzol in Monte Marronda I.
F	TR > A + SD	F	ELV: 620 m, SLP: 48%, DPT: 110 cm, marine influence. Climatic characteristics typical of mountain zones. Granite substrate with varied texture. Leptic Podzol.
G	DPT < A – SD DPT > A + SD	CU, LA, O, SM, VI	ELV ≈ 600 m, variable slope, medium and small soil DPT with marine influence. High total rainfall, SR > 150mm. Variable parent material and soil type.
H	A – SD <DPT< A + SD	C, CEI, MO, MFI, MFIII, RI, SI, T, XE	Plots with higher elevations and higher continentality than the previous group. Oceanic climate characteristics with continental influence. Schist and granite substrates prevail. Dominant sand texture.
I	AmT > A + SD	BA, X	ELV > 700 m, medium SLP and DPT. High total and summer rainfall values with temperatures influenced by elevation. Sand texture and Dystric Cambisols.
J	SLP < A + SD	L, BO, CO	Scarce slope and marked oceanic influence that determines the climatic characteristics (heavy rainfall mild temperatures). Sand texture. Dystric Cambisols.
K	SLP > A + SD	LO	The plot in Lobios shows a higher continentality and a steeper slope than the plots in the previous group. TR > 1. 200 mm and medium temperatures. Granite substrate with sand substrate. Soil Leptic Podzol.
L	ELV < A – SD A – SD <ELV< A + SD A – SD <DSE< A + SD	AR, G, S	Medium-low elevation and DPT > 80 cm. Medium thermal range. Gomaríz shows the lowest rainfall values, compensated by fog and mist. Sand texture. Dystric Cambisols and Ranker in Gomaríz.

Table 8 shows relations among the 12 groups that result from use of the Twinspan method (Hill, 1979a, b). In order to obtain a clearer definition of the 12 final groups, these groups were renamed by using alphabetic letters.

By applying Twinspan software to the plant species present in the plots, a second two-way classification of the plots was obtained, based on presence or absence of certain species. This classification was not considered representative because 17 final groups were obtained, many of which were composed of 1 plot (Díaz-Maroto, 1997).

Finally, a bi-variable correlation analysis was conducted to study possible interdependence (or not) of the parameters used in discriminant analysis (Jobson, 1991). Thirtyeight parameters were selected for analysis. The selected parameters characterized the physiography (4), climatology (5), soil (19) and stage of development of the stand, based on various forest mensuration and silvicultural parameters (10) (Gandullo et al., 1991; Ashton, Larson, 1996; Timbal, Aussenac, 1996; Díaz-Maroto, 1997; Humphrey, Swaine, 1997; Kelly, 2002).

Discussion

The most relevant antecedents of this work include many phytosociological studies about the studied species (Izco, 1987; Izco et al., 1990; Silva-Pando, Rigueiro, 1992). Other authors, such as Bellot (1966), Losa (1973) and Castroviejo (1988), collected phytosociological data from these forests in different zones of Galicia. Díaz-Maroto (1997) and Díaz-Maroto et al. (2005) performed several studies of the ecology and forest mensuration of the stands of *Quercus robur* in Galicia. Dantas (1958), Gandullo et al. (1983) and Díaz-González, Fernández-Prieto (1994), among others, reported data from areas near Galicia. The studies by Miller, Lamb (1985), Hix (1988), Grime et al. (1988), Röhrig, Ulrich (1991), Bary-Lenger, Nebout (1993) and Johnson et al. (2002) reported data from other territories. The method of discriminant analysis was followed. This method proved effective in the classification of areas or biotopes covered by different tree species (Hix, 1988; Kent, Coker, 1996). Hill et al. (1975) analyzed the classification of native pinewoods in Scotland, Aramburu et al. (1984) analyzed the distribution of *Quercus pyrenaica* Willd. in the Spanish Central System, and Gandullo et al. (1991) conducted an ecological study of the Canarian laurisilva by using the same method. The results obtained in this study partly coincide with results reported by Castroviejo (1988), who considered the slope and the average temperature as parameters that differentiate oak forests from the rest of plant communities analyzed by the author. Although Castroviejo (1988) aimed to identify different formations, the present study tries to find significant peculiarities within the same tree formations, Galician forests of *Quercus robur*.

Level 1

The plots in group I show the following common characteristics: (1) they are located in mountain or mid-mountain zones, or in plain zones with elevations near or higher than 500 m above sea level; (2) most plots are located in continental zones, as shown by the value of the parameter DSE > A + SD; (3) in relation with the previous point, the values of AT are lower than the values that correspond to A – SD of the plots considered, which agrees with the location of plots in zones with relatively high average elevation (Castroviejo, 1988; Barrio, 2003); (4) the value of soil depth is higher than A + SD, which could be related to the fact that several plots in this group are located in plain zones. The characteristics that identify the plots in group II are relatively opposite to the characteristics that define the plots in group I. However, the incorporation of a plot into one group or another is not completely strict at this level of the two-way classification (Gandullo et al., 1991; Díaz-Maroto, 1997) because some plots in group II may show a specific characteristic that is more common within group I.

Level 2

The 9 plots in the third group generally correspond to zones of lower elevation and with a stronger Atlantic influence than the 7 plots in the fourth group, which are located in the highest elevations. Another characteristic common to the plots in group IV is the fact that almost all of them are located in zones where *Quercus robur* is mixed with other tree species, such as *Quercus petraea* (Ancares and Serra do Invernadeiro), *Quercus pyrenaica* (Valdín), *Castanea sativa, Betula celtiberica*, or even *Fagus sylvatica* (Monte Marronda). This mixture of species is more evident in the plots with less anthropic changes (Ancares, Monte Marronda and Serra do Invernadeiro), where a mixed oak forest occurs. In Galicia, this type of forest is called “fraga” (Bellot, 1966; Izco et al., 1990; Silva-Pando, Rigueiro, 1992; Guitián Rivera, 1993, 1995).

The 16 plots in group V are usually located in zones characterized by a stronger continental influence, with higher average elevation than the 7 plots in group VI. The division of plots into these 2 groups is not too strict, perhaps because only one discriminant parameter was considered. The fact that the average annual temperature is higher than A + SD in the plots that form group IV can be due to the stronger marine influence in almost all the plots, particularly in Lourizán, Boimente and Coiró (Fig. 2). The marine influence is much weaker in Lobios. However, all the plots correspond with potential vegetation *Rusco aculeati-Quercetum roboris* (Rivas-Martínez, 1987; Silva-Pando, Rigueiro, 1992).

Level 3

The 3 plots in group VII are located in Serra do Candán, within a very large oak forest. The 6 plots in group VIII are characterized by an AMT lower than A + SD. These plots do not show other common characteristics that can lead to clustering, except for the fact that these zones are covered by mature trees, with lower tree density, except Monte San Fitoiro II (Díaz-Maroto, 1997).

The plots in group IX are located in mountain zones with elevations higher than 1.000 m above sea level and show a marked continentality. Because *Quercus robur* occurs at tree-line (Rivas-Martínez, 1987; Silva-Pando, Rigueiro, 1992; Timbal, Aussenac, 1996; Díaz-Maroto, 1997), these stands show certain peculiarities, such as presence of hybrids (Valdín and Ancares), replacement of *Quercus robur* with *Quercus petraea* (Ancares) or with *Quercus pyrenaica* (Valdín), or occurrence of stunted trees (Serra do Invernadeiro). Three of the 4 plots that form group X are located in the same zone, Monte Marronda (Fig. 2) (mixed forest with occurrence of *Quercus robur, Fagus sylvatica, Castanea sativa*, etc.). Therefore, these plots show very similar physiographic, climatic and soil characteristics. The plot in Fragavella is located in a zone relatively near the previous zone, but Fragavella is a pure stand of *Quercus robur*. The 4 plots belong to the same phytosociological association, *Blechno spicanti-Quercetum roboris* (Rivas-Martínez, 1987; Silva-Pando, Rigueiro, 1992). These plots show lower continentality than the plots in group IX and are located at lower elevations, although they are also located in mountain or mid-mountain zones (Díaz-Maroto, 1997).

The 14 plots in group XI do not show common characteristics, except for the discriminant parameter (AmT < A + SD). These plots are generally located in low zones and the plots in Lagoa and Viloalle show some Atlantic influence (Fig. 2). Conversely, the 2 plots that form group XII, Barcía and Xesta, show very similar characteristics and were grouped into a single group, which is independent of the plots in group XI. These plots are located in near zones, which are the oak forests of rivers Verdugo and Oitavén, in the province of Pontevedra (Fig. 2). Three of the 4 plots in group XIII show a marked marine influence, suggested by the parameter DSE < A – SD. These plots are Lourizán, Boimente and Coiró (Fig. 2). However, the plot in Lobios does not meet the mentioned inequality. The 3 plots in group XIV correspond to oak stands located near rivers that make part of riparian forests.

Level 4

The 3 plots that form group XV are located in near zones within the province of Ourense (Fig. 2). These plots are located in the contact area between *Quercus robur* and *Q. pyrenaica*, and show similar values for forest mensuration parameters (Díaz-Maroto, 1997; Barrio, 2003). The division of these plots into group XV can be related with these similarities. The division of plots into group XVI is much less evident than in the previous case, although the plots in group XVI show similar climatic characteristics, at least Bacurín and Monte San Fitoiro II. The distance to the sea for the plots in group XVI is lower than for the previous group. The plots in group XVII are located within the same tree stand, Monte Marronda (Fig. 2). They form an independent group because they show similar characteristics. However, there are enough characteristics that differentiate these plots from Fragavella, which leads to division into group XVIII, formed exclusively by this plot. The mentioned differences can respond to the presence of cattle in Fragavella. Many forests formed by species of genus *Quercus* were subjected to agricultural and forest exploitation, which caused serious regeneration problems (Ashton, Larson, 1996; Pulido, 2002; Nelly, 2002).

The 5 plots in group XIX do not show many common characteristics that suggest division of these plots into one group, except for the characteristics derived from the discriminant parameter. The plot in Lagoa is located near the plot in Viloalle (Fig. 2). Both of them are located near the sea and show considerable marine influence. The plot in Curtis is near the plot in Sobrado dos Monxes, located in the central zone of the province of A Coruña (Fig. 2). The proximity of the plots may have influenced the division into one group. All these plots are located near rivers. The fact that the mentioned plots are oak forests located in trough zones probably implies a number of common characteristics (Amaral, 1990; Silva-Pando, Rigueiro, 1992; Bary-Lenger, Nebout, 1993). The 9 plots in group XX are generally located in more continental zones and at a higher elevation than the plots in the previous group. In particular, Cerceda, Cerqueiros I, Monfero, Ribeiro and Teixeiro are located in A Coruña (Fig. 2), relatively near each other, and with very similar climatic characteristics (Bellot, 1966; Losa, 1973; Díaz-Maroto, 1997). A similar situation occurs in Siador and Xestoso, in Pontevedra; and Monte San Fitoiro I and II (Díaz-Maroto, 1997; Barrio, 2003), located within the same tree stand, in Lugo.

The last significant differentiation of plots occurs in group XIII, where 3 out of the 4 plots that form this group are divided into group XXI (Lourizán, Boimente and Coiró) and show similar characteristics (Díaz-Maroto, 1997). Among these characteristics are proximity to the sea and, therefore, scarce continentality (Fig. 2). However, the situation of the plot in Lobios is similar to the plot in Fragavella (group X), there are enough characteristics that differentiate this plot from the others, which leads to the establishment of two different groups.

The most significant conclusions of the classification of plots follow:

- Most of the sampled stands are located in zones with a steep slope or at the bottom of a trough, due to the anthropic pressure on oak formations. These formations are located in places at low and medium altitude with variable orientations.
  These stands show considerable air humidity requirements and a wide thermal regime. The lithological composition of the sampled stands is siliceous, with dominant sand texture, and soils of the Dystric Cambisol type prevail (FAO, 1999).
- Twenty-eight classifying parameters were considered. Physiographic, climatic and soil parameters were used. Because these parameters were significantly different in each studied stand, they could be used to define the biotopes under *Quercus robur* forests. In addition, 4 forest mensuration parameters that were weakly related to age and site quality were used.
- The discriminant parameters obtained in the characterization of the groups were physiographic (DPT, DSE, ELV and SLP) or climatic (AT, AMT, AmT and TR) in all cases. The rest of the classification parameters considered in the analysis did not show any influence, which could suggest that distribution of oak forests within the Galician territory is strongly related with physiographic and climatic characteristics but not with soil determining factors. This statement confirms initial hypothesis.
- As a result of the classification of plots, a total of 12 final groups were obtained. All the groups belonged to the third and fourth levels of the two-way classification. Some of these groups were formed by only one plot and showed a limited validity. The discriminant analysis method, based on the value of certain parameters, proved effective in the classification of the areas or biotopes covered by *Quercus robur* in Galicia. Conversely,

the application of Twinspan software to the plant species present in the studied plots did not offer a coherent classification. A two-way classification into 17 final groups was obtained. Many of the resulting groups were formed by one plot. The results obtained suggest the need to conduct more botanical inventories and to limit the scale of the study to the scale of phytosociological association, or even less.

Bi-variable correlation analysis confirmed – for a reliability level of 95% – that physiographic, climatic and soil parameters do not show interdependence with forest mensuration and silvicultural parameters, which measure the development of the stand. Nevertheless, only physiographic and climatic parameters were discriminant in the two-way classification of the stands of *Quercus robur* in Galicia. These data support the initial hypothesis of this study.

Translated by the authors

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Díaz-Maroto I.J., Vila-Lameiro P.: **Analýza rozšírenia** *Quercus robur* L. **v Galícii, Španielsko.**

Skúmali sme 39 plôch s *Quercus robur* L. rozšírených v celej Galícii v Španielsku. Pokúšali sme sa vzorkami čo najobjektívnejšie reprezentovať všetky miesta s významným výskytom tohto druhu. Táto štúdia je zameraná na analýzu rozšírenia dubových formácií na území Galície a pokúša sa o klasifikáciu týchto formácií na základe sérií rozlišujúcich parametrov. Bolo použitých 28 ekologických parametrov na charakterizovanie biotopu a 14 parametrov na charakterizovanie skúmaných dubových lesov z hľadiska lesníctva i meraní. Vybraná metóda pomocou Twinspan softwaru umožňuje dvojitú klasifikáciu rôznych, náhodne skúmaných plôch. Ktorákoľvek plocha môže byť automaticky zahrnutá do tejto klasifikácie, pokiaľ je klasifikovaná celá výskumná plocha.