ISSN: 0211-9714

THE OCCURRENCE OF ALIEN SPECIES FOR NORTHERN OF PORTUGAL AND THE FLORISTIC CORRIDORS: A BIOGEOGRAPHICAL APPROACH

La presencia de especies exóticas en el Norte de Portugal y los corredores florísticos: un enfoque biogeográfico

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BIBLID [0211-9714 (2008) 27, 163-182]
Fecha de aceptación: 11-12-2009

ABSTRACT: The occurrence and geographical distribution of fifty nine alien taxa are shown for the North of Portugal. New references *(Panicum dichotomiflorum*, *Penisetum villosum*, *Hakea sericea*, and *Montia perfoliata)* are included in this chorological upgrade of the non-indigenous flora identified. The geographical distribution of those taxa was correlated with the temperature, precipitation and altitudinal information coming from the fifteen thermopluviometric stations from the North of Portugal, and with the biogeographic map of COSTA *et al*. (1998). The multivariate statistical analysis involved showed apparent corridors of floristic dynamic for this alien species, along this area. The description of the altitudinal and thermopluviometric variation showed the importance of the Douro river in defining the complexity of the Atlantic-Mediterranean biogeographic transition in the North of Portugal. This floristic corridor allows an important access of this eminently thermophilous flora. This new approach shows the Atlantic influence extended by the lowlands of the eastern side, and the occidental chain mountain Gerês-Larouco-Alvão-Marão-Montemuro-Lapa as a different biogeographical area.

Keywords: Alien flora, biogeography, chorology.

RESUMEN: Se indica y comenta la presencia y la distribución geográfica de cincuenta y nueve taxa de flora alóctona en el Norte de Portugal. Son aportadas nuevas citas de diversas especies *(Hakea sericea*, *Montia perfoliata*, *Panicum dichotomiflorum* y *Penisetum villosum)* en esta actualización corológica de la flora alóctona identificada en la zona objeto de estudio. La distribución geográfica de estos taxa se correlaciona con la temperatura, precipitación y altitud procedentes de las quince estaciones termopluviométricas existentes en el Norte de Portugal. Al mismo tiempo, esta información corológica es también georreferenciada con el mapa biogeográfico de COSTA *et al.* (1998). El análisis estadístico multivariado muestra la presencia de un aparente corredor florístico para esta flora alóctona. El análisis de la variabilidad altitudinal y termopluviométrica en la dirección oeste-este permite observar una transción biogeográfica atlántico-mediterránea a través del río Duero, que permite un fluido acceso de esta flora eminentemente termófila. En este sentido, se detecta igualmente la presencia de otra área biogeográfica diferente, constituida por la cadena montañosa occidental Gerês-Larouco-Alvão-Marão-Montemuro-Lapa.

Palabras clave: Flora alóctona, biogeografía, corología.

INTRODUCTION

The ecological preoccupations related to the invasion processes are, at the moment, the subject of numerous studies, especially those processes involved in the functionality of the ecosystems (LEVINE *et al.*, 2003; ROSE & HERMANUTZ, 2004; NENTWIG, 2007) and, consequently, on the floristic diversity (MEINERS *et al.*, 2002; DAEHLER, 2003; STRAYER *et al.*, 2006). In this sense, some contributions have focused on the analysis of this type of alien flora for Portugal. Among them two types of works were published, those focusing on the chorological knowledge of this introduced floristic diversity (AGUIAR *et al.*, 2001, 2007; DUARTE *et al.*, 2004; ALMEIDA & FREITAS, 2006) and, on the other hand, those analysing the ecological implications of these particular flora (MARCHANTE *et al.*, 2004, 2008).

A better knowledge of the ecological behaviour of this alien taxonomic diversity for the North of Portugal is the main goal of this work. More specifically, the biogeographical approach is used in the current study. The main reason for this focus is to evaluate and characterize apparent biogeographical floristic corridors for the Portuguese Atlantic-Mediterranean transition. Numerous authors have published contributions regarding biogeographic characterizations for Portugal (ALBURQUERQUE, 1941, 1943; AZEVEDO, 1953a, b; GONÇALVES, 1985; MOLINA *et al.*, 1992; FRANCO, 1994; CORREIA, 1997; COSTA *et al.*, 1998). The border between the Atlantic and the Mediterranean has suffered small variations during the XXth century.

The alien flora is usually considered as an example of narrow adaptation to the environmental conditions, in order to interact properly with them and to guarantee their presence in the ecosystems (HUFBAUER & TORCHIN, 2007). Based on this underlying reason, the evaluation of alien taxa, to explain the biogeographic behaviour, could be an appropriate methodology. The floristic flows established for alien flora will be the result of an ecological adaptation to the combination of barriers and corridors existing in the area analysed. In fact, the Gerês-Montemuro-Lapa-Malcata Western mountain chain has always been considered as the traditional line to distinguish the Western Atlantic and the Eastern Mediterranean influences. This natural barrier is crossed by three flows: Douro, Tâmega and Paiva rivers (all them connecting to the Douro basin), and the climatic effect of these corridors has been the main problem to describe the biogeographic behaviour of Northern of Portugal (MARTINS *et al.*, 2006, 2008).

Evaluating the occurrence and geographical distribution of alien (invasive) flora has not been the aim of many ecological and biogeographical evaluations for Portugal. In fact information on the occurrence alien flora is usually obtained from the fundamental research on Portuguese flora, the most important resource for this floristic information of WILLKOM & LANGE (1880), SAMPAIO (1988), COUTINHO (1939), ROZEIRA (1944), MENDONÇA & VASCONCELLOS (1954), FRANCO (1971, 1984, 1998) and in related publications (DUARTE *et al.*, 2004; CRESPÍ *et al.*, 2005; ALMEIDA & FREITAS, 2006; AGUIAR *et al.*, 2001; AGUIAR *et al.*, 2007). The possible use of these alien species as ecologic indicators has not been evaluated so far. In this work this new potentiality, of using alien species as biogeographic indicators, will be discussed.

METHODS

The area analysed in the current study is shown in Figura 1a. Sixty taxa were selected for this work. This relation was obtained from the allocthones floristic taxa proposed by the Instituto de Conservação da Natureza e da Biodiversidade (ICNB, Environmental Ministery), published by the *Diário da República* (*Decreto-Lei* n.º 565/99 of December 22th of 1999, http://www.dre.pt/pdfgratis/1999/12/295A00.PDF) and the relation proposed by ALMEIDA & FREITAS (2006). The following alien species were selected for evaluation: *Acer pseudoplatanus* L., *Carpobrotus edulis* L. N.E. Br., *Rhus coriaria* L., *Arctotheca calendula* L. Levyns, *Aster squamatus* (Sprengel) Hieron, *Conyza bonariensis* (L.) Cronq., *Conyza sumatrensis*

(Retz.) E. Walker, *Conyza canadensis* (L.) Cronq., *Cotula coronopifolia* L., *Erigeron karvinskianus* DC., *Galinsoga parviflora* Cav. subsp. *hispida* (DC.) O. Bolòs & J. Vigo, *Senecio mikanioides* Otto ex Walp., *Soliva stolonifera* (Brot.) R. Br. ex G. Don., *Coronopus didymus* L. Sm., *Opuntia elata* Salm-Dyck, *Chenopodium ambrosioides* L., *Tradescantia fluminensis* Velloso, *Ipomoea acuminata* (Burm.) Merr., *Chamaesyce canescens* (L.) subsp. *canescens*, *Spartium junceum* L., *Trifolium vessiculosum* Savi, *Robinia pseudoacacia* L., *Miriophyllum brasiliense* Camb., *Elodea canadensis* Michx., *Hypericum calycinum* L., *Abutilon theophrasti* Medik, *Acacia dealbata* Link, *Acacia mearnsii* De Wild., *Acacia melanoxylon* R.Br., *Acacia longifolia* (Andrews) Willd., *Acacia retinodes* Schlecht., *Eucaliptus globulus* Labill, *Eschscholzia californica* Cham. in Nees., *Phytolacca americana* L., *Pittosporum tobira* (Thunb.) Aiton fil., *Arundo donax* L., *Bromus catharticus* Vahl, *Cortaderia selloana* (Schult. & Schult. f.) Ascherson & Graebner, *Panicum dichotomiflorum* Michx, *Paspalum paspalodes* (Michx) Scribner, *Pennisetum villosum* R. Br. ex Fresen, *Paspalum dilatatum* (Poiret in Lam), *Paspalum urvillei* Steud., *Paspalum vaginatum* Sw., *Setaria faberi* Herrmann, *Sorghum halepense* L. Pers., *Sporobolus indicus* L. R. Br., *Stenotaphrum secundatum* (Walter) O. Kuntz, *Polygonum capitatum* Buch. Ham. ex D. Don, *Polygonum orientale* L., *Reynoutria japonica* Houtt, *Eichornia crassipes* (Mart.) Solms., *Montia perfoliata* (Donn. ex Willd) Howell, *Hakea sericea* Schrader, *Hakea salicifolia* (Vent) B.L. Burtt., *Cydonia oblonga* Miller, *Datura stramonium* L., *Nicotiana glauca* R. C. Grahm., *Ailanthus altissima* (Mill.) Swingle, *Oxalis pres-caprae* L.

The reference plants were obtained from specimens of herbaria (the herbaria data were from the most important Portuguese herbaria: Universidade de Coimbra –COI–, Escola Superior Agrária de Bragança –ESAB–, Universidade de Trás-os-Montes e Alto Douro -HVR–, Estação Agronómica National –LISE–, Instituto Superior de Agronomia –LISI–, Museu de Ciências de Lisboa –LISU–, Universidade do Porto –PO–), and confirmed observations in field. Because the species analysed are neophytic taxa for the wild flora of this part of the country, a thermopluviometric-altitudinal correlation was established, in order to describe the potentiality of this species as biogeographic indicators. The biogeographic characterization of COSTA *et al.* (1998) was used for this chorological-phytoclimatic analysis (see Figure 1).

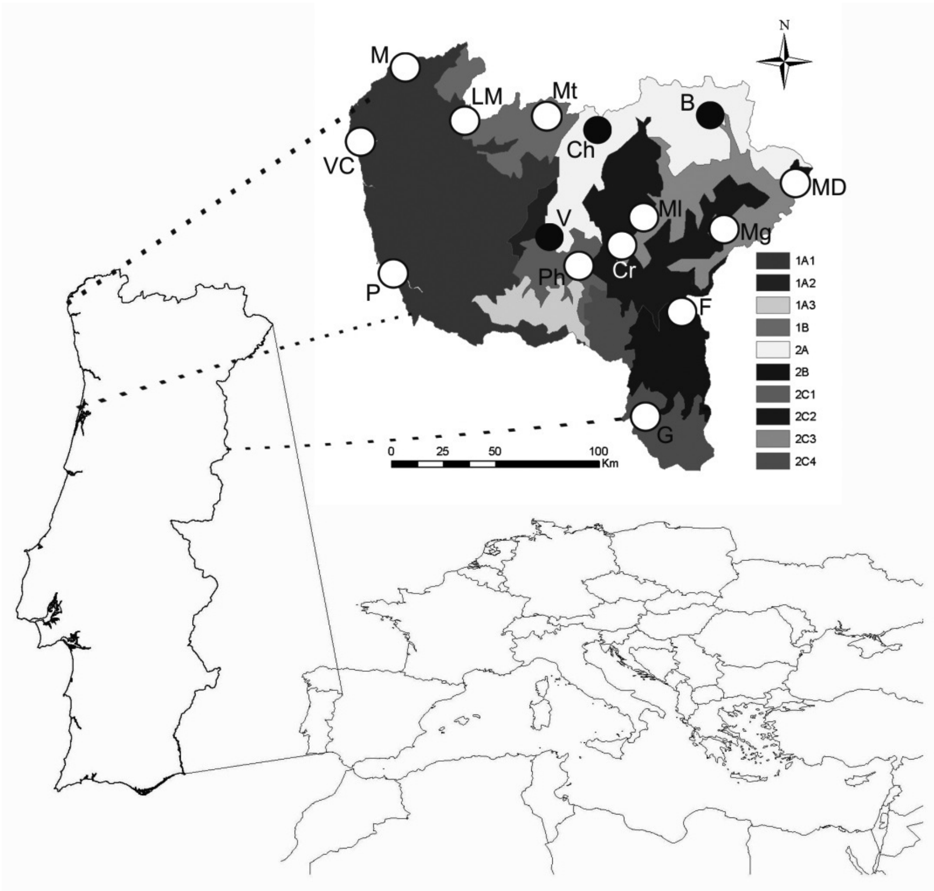


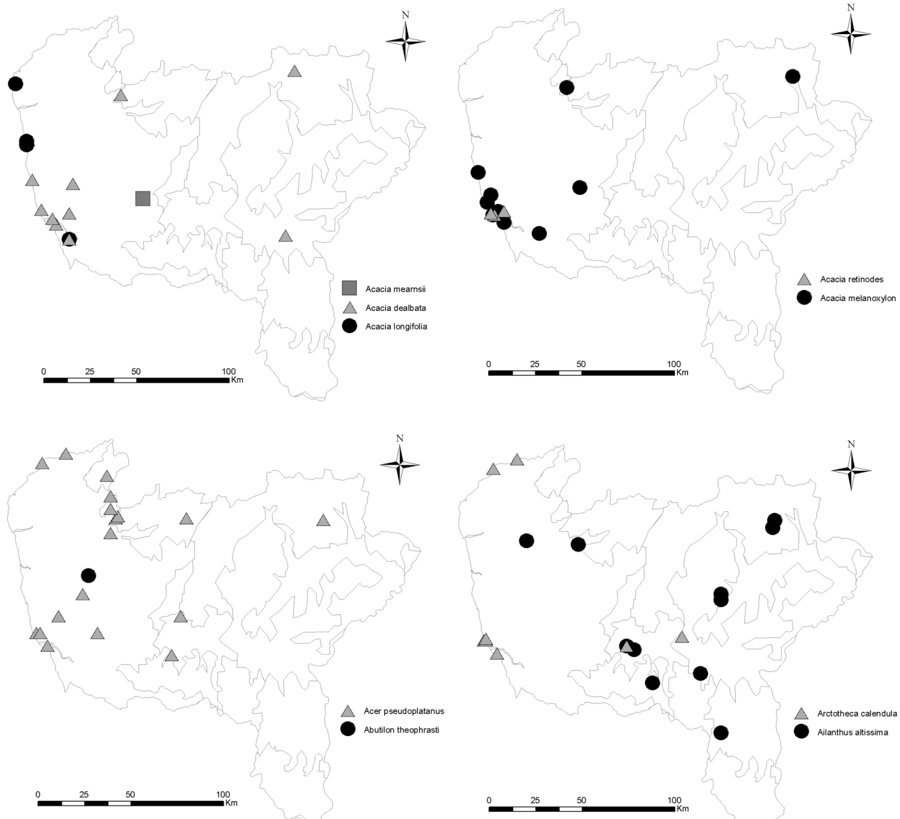
FIGURE 1. Location of the area analysed, and the thermopluviometric stations on biogeographic representation for the work area, based on the characterization of COSTA *et al.* (1998) for continental Portugal (1A1, Miniense Coastal super-district; 1B, Geresean-Sanabriensean sector; 1A2, Alvão-Marão super-district; 1A3, Beirensean-Duriensean super-district; 2C4, High Beirensean super-district; 2A, Orensean-Sanabriensean sector; 2B, Salmanticensean sector; 2C1, Dueresean superdistrict; 2C2, *Terra Quente* superdistrict; 2C3, Miranda-Bornes-Ansiães superdistrict).

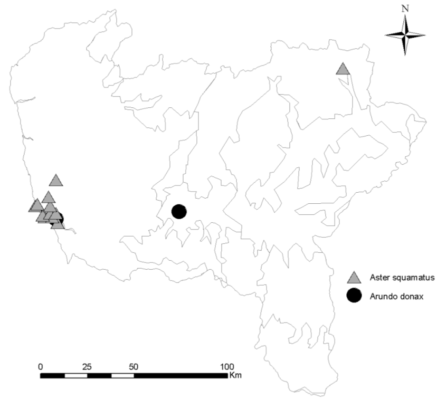
A multivariate analysis was applied for describing the biogeographical Atlantic-Mediterranean transition. The altitude of the thermopluviometric stations (the 15 stations shown in Figure 1), and 9 thermic and pluviometric variables were used (altitude per station –Alt–, average monthly temperature –T–, average lowest monthly temperature –Tm–, average highest monthly temperature –TM–, lowest monthly temperature –Tm1–, highest monthly temperature –TM2–, average monthly precipitation –P–, average lowest monthly precipitation –Pm–, average highest monthly precipitation –PM–, lowest monthly precipitation –Pm1–, highest monthly precipitation –PM2–, average monthly evapotranspiration –ETP–). These stations were grouped according to Costa's main biogeographic areas (Figure 1): 1A1 (Miniense Coastal super-district), 1B-1A2-1A3-2C4 (Geresean-Sanabriensean sector, Alvão-Marão super-district, Beirensean-Duriensean super-district, High Beirensean super-district; this is representing the Western mountain chain), 2A (Orensean-Sanabriensean sector) and 2B-2C1-2C2-2C3 (Salmanticensean sector, Dueresean superdistrict; *Terra Quente* superdistrict; Miranda-Bornes-Ansiães superdistrict). Finally, the numerical matrix, previously standardized, was analysed by a forward stepwise Canonical Discriminant Analysis (CDA), where the significance would be established (Wilks' Lambda and F to remove) to distinguish the four biogeographic main areas observed for the North of Portugal, according to the characterization of COSTA *et al*.

The biogeographic georeferenciation was elaborated by the overlapping of the occurrence maps and the characterization of COSTA *et al*. The numerical matrix of species per phytoclimatic area was obtained using four parametric variables, calculated for 658 different observations, for the whole biogeographic areas and organized per species. These variables were: average altitude (Alt), number of observations (No), relative presence per number of species detected by biogeographic area (Pb), relative presence per total number of observations by species (Ps), and relative quotient of presence (Ps/Pb). This matrix was standardized, and transformed into its Pearson's correlation matrix. From the Pearson's correlation matrix two different multivariate statistical analysis were elaborated: a) a similarity analysis, based on Chebychev distance metrics and Ward's amalgamations method based on the average values per phytoclimatic area, and b) a Principal Component Analysis (PCA). The statistic software program used was STATISTICA v. 8 (2008, StatSoft Inc.).

RESULTS

The maps of distribution per taxon are represented in Figure 2.

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Aster squamatus
Arundo donax
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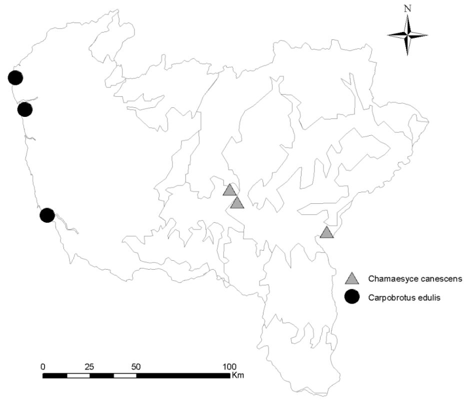
Km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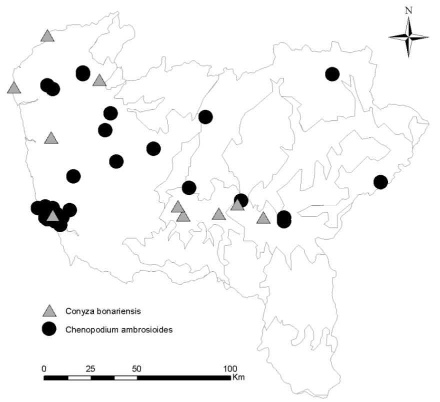
Carpobrotus edulis
0 25 50 100
Km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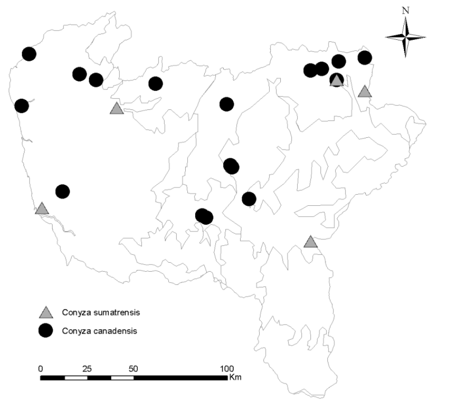
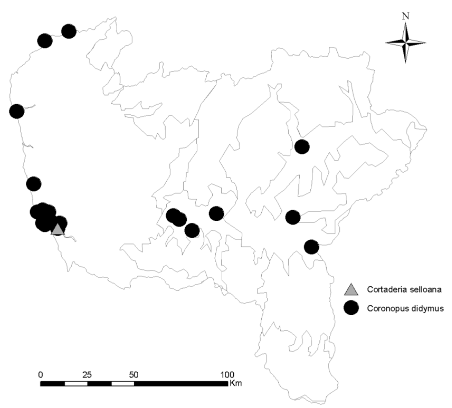
Chenopodium ambrosioides
0 25 50 100
Km


N
Conyza sumatrensis
Conyza canadensis
0 25 50 100
Km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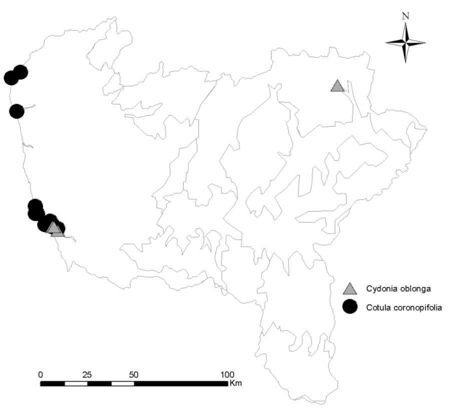
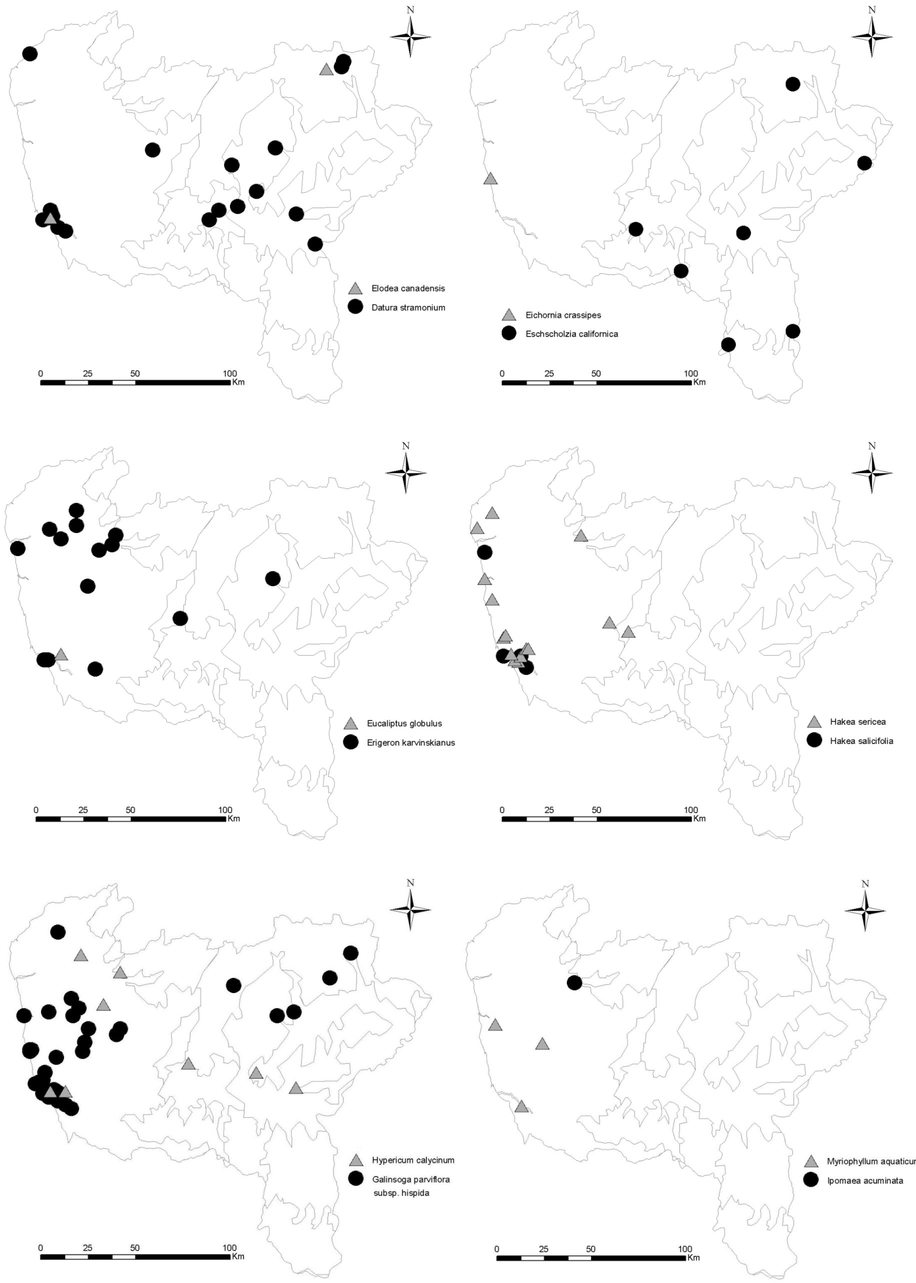
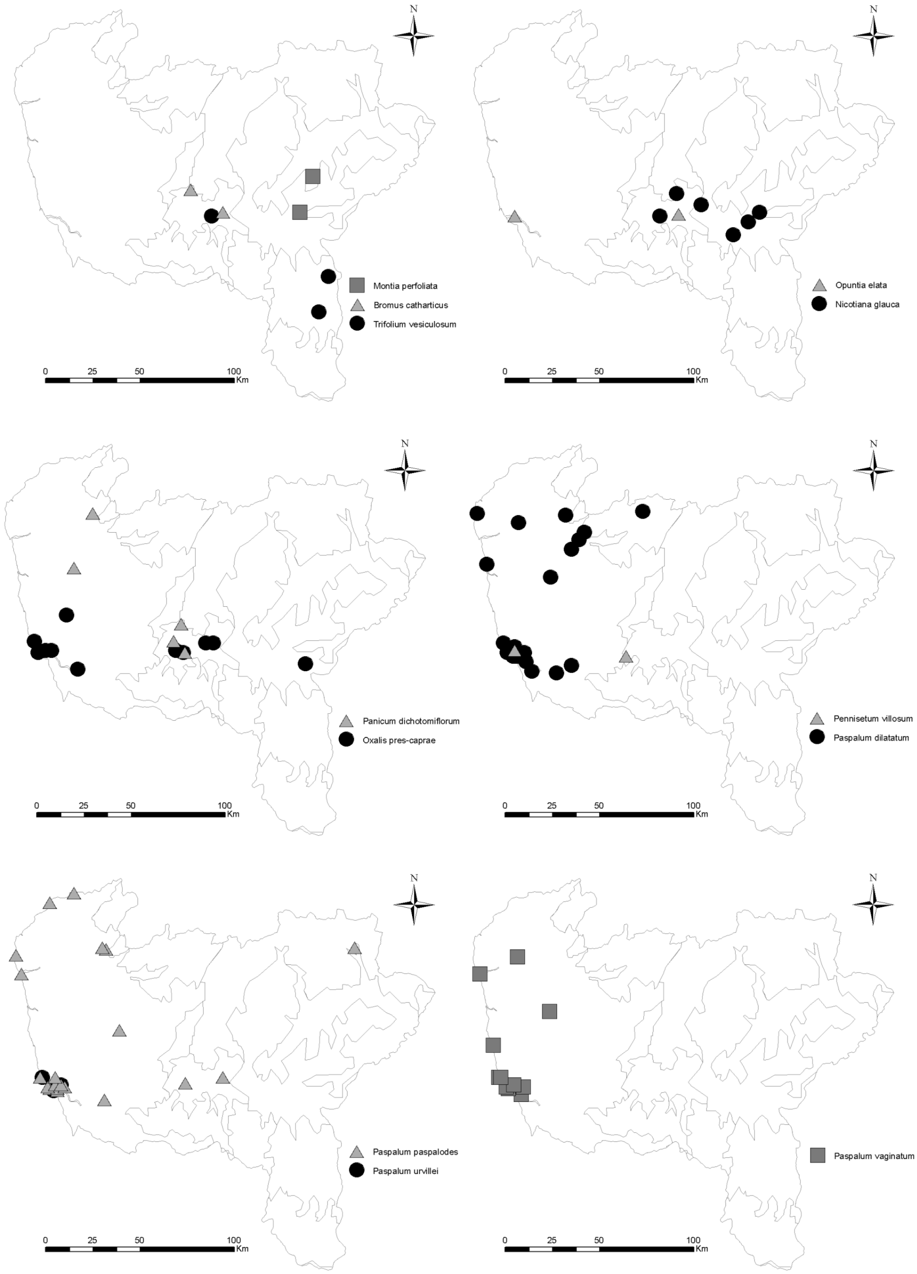
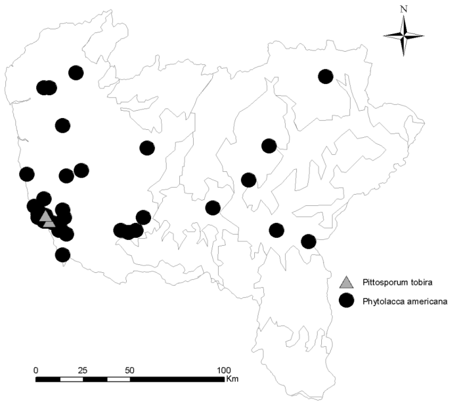
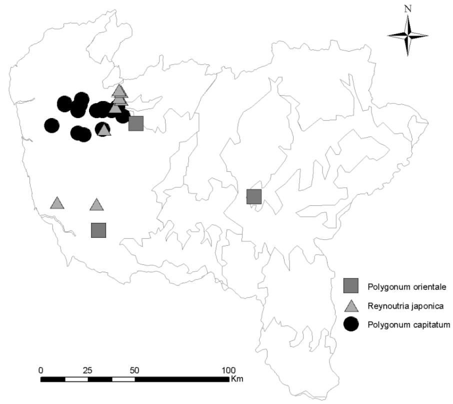
Cortaderia selloana
Coronopus didymus
0 25 50 100
Km

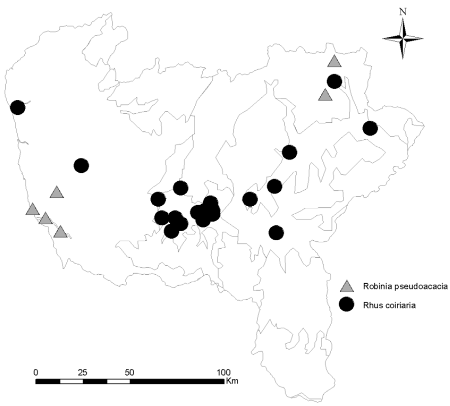

N
Cydonia oblonga
Cotula coronopifolia
0 25 50 100
Km

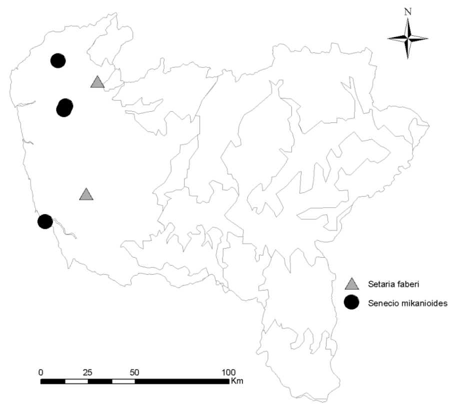

N
Elodea canadensis
Datura stramonium
0 25 50 100 Km
N
Eichornia crassipes
Eschscholzia californica
0 25 50 100 Km
N
Eucaliptus globulus
Erigeron karvinskianus
0 25 50 100 Km
N
Hakea sericea
Hakea salicifolia
0 25 50 100 Km
N
Hypericum calycinum
Galinsoga parviflora
subsp. hispida
0 25 50 100 Km
N
Myriophyllum aquaticum
Ipomaea acuminata
0 25 50 100 Km

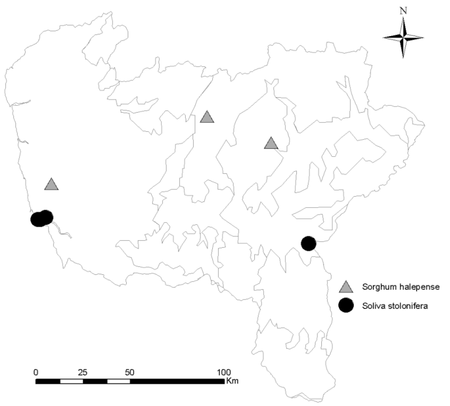

N
Montia perfoliata
Bromus catharticus
Trifolium vesiculosum
0 25 50 100 Km
N
Opuntia elata
Nicotiana glauca
0 25 50 100 Km
N
Panicum dichotomiflorum
Oxalis pres-caprae
0 25 50 100 Km
N
Pennisetum villosum
Paspalum dilatatum
0 25 50 100 Km
N
Paspalum paspalodes
Paspalum urvillei
0 25 50 100 Km
N
Paspalum vaginatum
0 25 50 100 Km

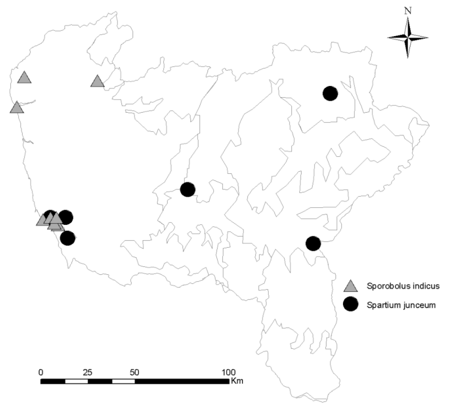

N
Pittosporum tobira
Phytolacca americana
0 25 50 100
Km


N
Polygonum orientale
Reynoutria japonica
Polygonum capitatum
0 25 50 100
Km


N
Robinia pseudoacacia
Rhus coiriaria
0 25 50 100
Km


N
Setaria faberi
Senecio mikanioides
0 25 50 100
Km


N
Sorghum halepense
Soliva stolonifera
0 25 50 100
Km


N
Sporobolus indicus
Spartium junceum
0 25 50 100
Km

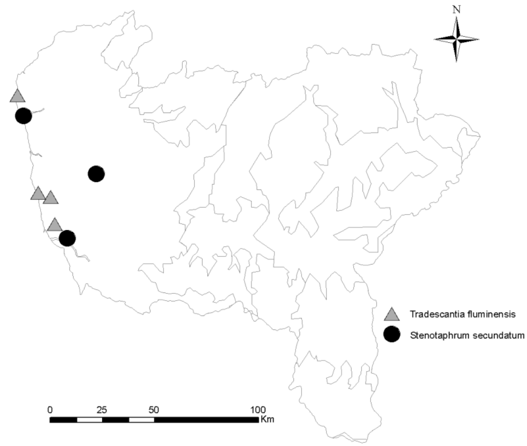


FIGURE 2. Maps of distribution per taxon for the selected area.

The thermopluviometric evolution for this area is shown in the dendrogram of Figure 3a and the CDA of Figura 3b. The CDA analysis shows the altitude and average monthly precipitation as the most discriminate variables (the graphic representation of their most discriminate average values –P and Alt– is exposed in Figure 3c). The apparent thermopluviometric isolate effect of the Western mountain chain is evident, the Atlantic stations P (Porto), Monção (M) and Viana do Castelo (VC), and the mountain stations LM (Lamas de Mouro), Mt (Montalegre) and G (Guarda) are clearly distanced from the rest of the thermopluviometric stations. These groups of biogeographic behaviours are correlated with the altitudinal increase of the thermopluviometric stations, as well as with the average values for precitipation (in accordance with the classification of RIVAS-MARTÍNEZ (1987).

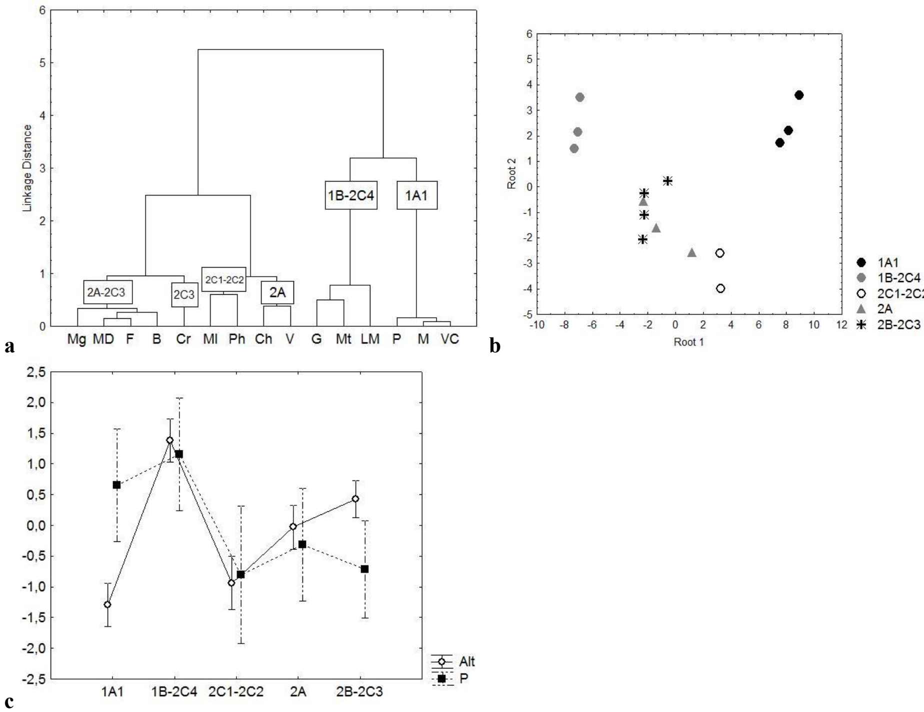


FIGURE 3a. Thermopluviometric evolution for the North of Portugal. The progressive continentalization from the Western to the Eastern side is clearly seen; at the same time, high precipitation and low average temperatures characterizes the Western mountain chain, traditionally considered as the border between the Atlantic (Western side) and the Mediterranean (Eastern side) biogeographies. 3b. Altitudinal evolution of the thermopluviometric stations, grouped based on the CDA. 3c. Those general behaviours for the thermopluviometric stations are confirmed for the most discriminate variables (Alt and P) obtained in the CDA.

The number of taxa detected per biogeographic area shown in Figure 4a. Based on this map, 1A1, 2C1 and 2C2 concentrate most of the alien floristic diversity, in contrast with 1A2, 1A3, 2C4 and 2B. The dendrogram elaborated from the floristic numerical matrix exposes two critical extreme behaviours: the group of biogeographic areas 1A1-2C1-2C2, in contrast with the rest of biogeographic areas. At the same time, two distinct tendencies are detected for the rest of the areas: 2C3-2A-1B and 2C4-2B-1A3-1A2 (Figura 4b). According to this result, the map of COSTA *et al.*

is now redefined (Figura 4c), joining the three groups of areas deduced, and the apparent floristic flux is described (Figura 4d).

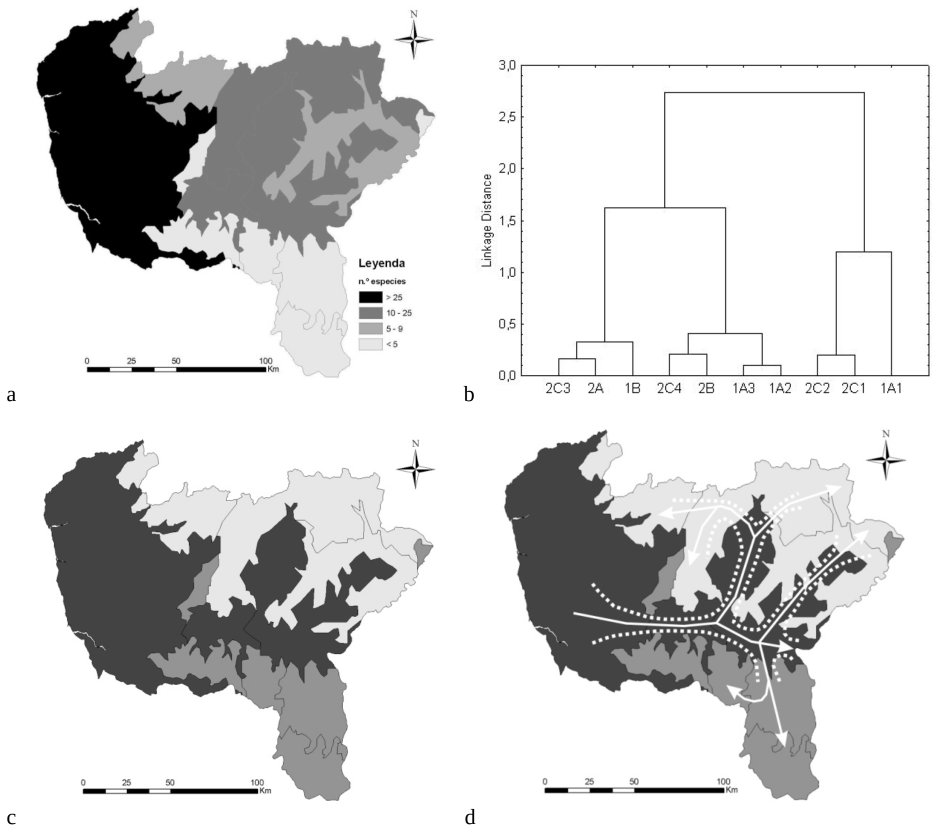


FIGURE 4a. Density of references per biogeographic area. 4b. Dendrogramatic representation of the similarity analysis upon the average values per biogeographic area, obtained from the Pearson correlation numerical matrix of references. 4c. Representation of the map of COSTA *et al.*, organized by the groups deduced in the previous tree (4b). d. Floristic flux suggested for the species analysed.

A floristic dynamic is depicted from these results. 1A1 is now closer to the more Mediterranean biogeographic areas 2C1 and 2C2, and clearly distanced from the more Atlantic biogeographies 1A2, 1A3 and 1B. These last three areas show more similarities with the more Mediterranean ones 2A, 2C3, 2B and 2C4. From this new perspective, the apparent floristic dynamic is now represented in Figura 5. The PCA graphic here represented show the floristic connection of 1A1 with the rest of the areas is evidently through 2C1 and 2C2. In contrast to the traditional biogeographic view of the Atlantic-Mediterranean transition for the North of Portugal, the Western mountain chain of Gerês-Larouco-Alvão-Marão-Montemuro-Leomil-Lapa should be considered the floristic transition to the most continental side (2A, 2B and 2C4).

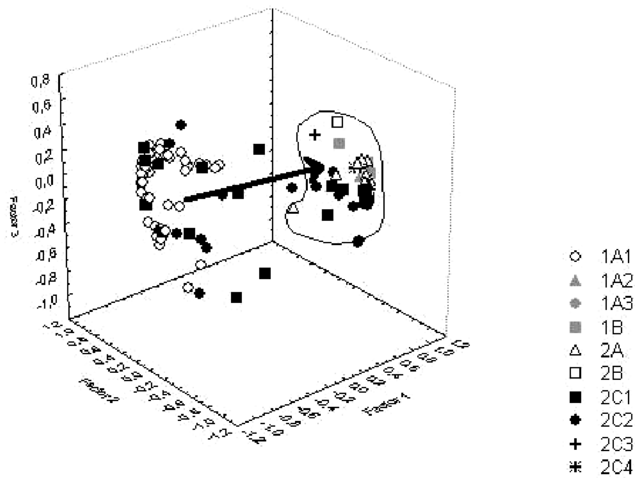


FIGURE 5. Principal Component Analysis upon the Pearson correlation matrix, calculated for the references matrix. The nexus effect of the 2C1 and 2C2 is the connection between 1A1 and the rest of the biogeographic areas (1B, 2A, 2B and 2C4).

DISCUSSION

The analysis of distribution shows some important data, about the existence of new or unknown references for some species. *Panicum dichotomiflorum* is finally confirmed for the Northern of Portugal (PO59075, TM: Ponte da Barca, entre ambos os rios, margem da albufeira; HVR4200, TM, Sabrosa, na estrada para o Pinhão, a 2 km de Sabrosa) and *Hakea sericea* is confirmed for Trás-os-Montes province (no reference was pointed out by PAIVA –1997– but it has been detected in TM, Cotorinho, próx. Serra do Marão, Vila Real), as well as *Penisetum villosum* (HVR4216, TM, Mesão Frio, Estação de Barqueiros, Quinta da Misericórdia) and *Montia perfoliata* (HVR4203, TM, Alfândega da Fé, Cabreira, perto Prado de Baixo,

A. L. Crespí & T. de Koe, 28-05-1994). Finally, the misunderstanding about *Opuntia elata* Salm-Dyck, identified as *Opuntia maxima* Mill. for the Iberian Peninsula (Berthet, 1990) has been resolved. The shape of the fruit is the diagnostic criteria used to distinguish between these two species. In our case, the fruit is longer than wider, which is characteristic of *O. elata*. The rounded fruit is characteristic of *O. maxima* (which is not present in Northern Portugal).

The use of alien species, to study distribution or similar ecological indicators, requires special attention about the colonizing and invasion behaviours. As Parker *et al.* (1999) pointed out, the differences in the access of new taxa is the response between those with little invasion hunger and those which display developed capacities for invasion, according to the local environmental conditions. Such circumstances will correlate with the distribution of these plants to the environmental conditions and, consequently, to the climatic characteristics: their occurrence will be directly correlated with their potentialities to colonize or invade according to their ecological capacities for adaptation. This diversity of behaviours not only relativizes the own phenomenon of the invasion and the invasibility (Radford & Cousens, 2000; Marco *et al.*, 2002; Barlow & Kean, 2004; Cadotte *et al.*, 2006), as in addition it constitutes a system of differentiation of behaviours between species that can be used like ecological indicators. This approach allows the perspective of continuities between apparent different biogeographic behaviours, in contrast with the discontinuous characterizations based on climacic vegetation.

This work uses the floristic perspective into a continuous biogeographic approach to characterize the complexity of the Atlantic-Mediterranean biogeographic transition in Portugal (in this case, in the North of Portugal). The intricate orography of the North of Portugal, could be one of the most important reasons for the high alien floristic diversity. Based on this apparent heterogeneous environment and the diversity of responses by this alien flora, the results describe apparent floristic corridors for this part of the country. The Douro river would be the connection between the Western (humid and temperate area) and Eastern side (dry and continental), traditionally separated by the «oceanic-semihiperoceanic» barrier characterized by the occidental chain Gerês-Larouco-Alvão-Marão-Montemuro-Lapa mountains (in the sequence of Ancares-Xures complex for Galicia, NW of Spain –Rodríguez Guitián & Ramil-Rego, 2007–). However, in floristic dynamic terms, the Douro river will allow the prolongation of the Atlantic influence inside the middle east, traditionally considered as the Mediterranean biogeographic area (Ribeiro, 1991). This important stream provides the progressive access of the Atlantic influence into the Eastern side of the Northeast of Portugal. On the other hand, the Western mountain chain (Juresian sector, and the Alvão-Marão and Beirensean Duriensean super-districts), traditionally considered as the border between the Atlantic and Mediterranen biogeographies for the North of Portugal, is now described as a different biogeographic area, clearly distanced from the Atlantic one. One of the most relevant results obtained in the current study describes a closer floristic dynamic of these mountain biogeographies with the highlands of the east side of this area (Bercian-Sanabriensean or Lusitan Duriensean). On the other hand, the Atlantic corridor from the Cantabrian-Atlantic province to the Duriensean and Terra Quente super-districts (2C1 and 2C2) is finally exhausted in the Salmanticensean sector (2B). This access of the Cantabrian-Atlantic into the Eastern side of the area analysed allow an important percentage of Atlantic flora in this corridor (CRESPÍ *et al.*, 2005). In contrast to the biogeographic characterizations published so far (ALBURQUERQUE, 1941, 1943; AZEVEDO 1953a, b; GONÇALVES, 1985; MOLINA *et al.*, 1992; FRANCO, 1994; COSTA *et al.*, 1998), the floristic Atlantic influence is recorded into the lowlands (up to 400-500 m) of the Eastern side. Floristic important implications are here concerned, especially in terms of the richness floristic diversity observed for those lowlands at the Eastern side (CRESPÍ *et al.*, 2005). The presence of the Douro river is decisive for breaking this isolation. In fact, the importance of the rivers to explain the invasibility has already been reported by AGUIAR *et al.*, (2001), for continental Portugal. In this case, the Douro river must be considered as the main floristic corridor between the west and the east side. The Gerês-Larouco-Alvão-Marão-Montemuro-Lapa chain doesn't show here a biogegraphic border between the Atlantic and the Mediterranean ones. The results obtained for the alien species here analysed describe this western mountain chain as a third biogeographical area. The relevant number of endemic taxa present into this biogeographical area could be pointed out as one of the main consequences of this different thermopluviometric behaviour (ROCHA, 2008).

The utilization of floristic information allows the description of the continuity between biogeographies. The establishment of apparent phytogeographic corridors could be a very useful application, especially for describing inter-glacial floristic dynamics or responses into climatic changes scenarios (HEIKKINEN, 2006; RICHARDS *et al.*, 2007). The alien taxa will also suppose an important contribution for understanding the biogeographic behaviour for the biogeographic description of this part of the Iberian Peninsula. Nevertheless, the floristic corridor here described is explained by characteristic termophilous species. The presence of no termophilous corridors will be the aim of further contributions.

ACKNOWLEDGEMENTS

This contribution was elaborated with the financial support of projects POCI/BIA-BDE/56044/2004 and the Acção Integrada Luso-Espanhola E-115/07. The authors also thank the revision and contributions suggested by the referee.

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