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Research Article

Priority tree and shrubs for use in Landscape Architecture based on the dynamic states of native vegetation with the highest ecological value in mainland Portugal

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Abstract: The reduction of the native forests coverage in mainland Portugal increased in the past centuries, leading to a marked decrease in biodiversity in general, especially on typical species of mature forest environments. However, urban biodiversity seems to resist more effectively than rural to disturbances due to the lower incidence of fires, as well as to agriculture expansion. Thus, in this work, we analyzed the dynamics of the natural vegetation potential in each biogeographic sector, and selected, based on the evolutionary stages of the vegetation, a set of priority taxa for conservation. The criteria used are intended to highlight plants with ornamental value, but at the same time, some of them have high patrimonial value, belonging to the Red List of Vascular Flora of Mainland Portugal or protected by Annexes II, IV and V of the Sectorial Plan of the Natura 2000 Network at the European level. Our analysis resulted in the identification of 62 plants that can be increased in public spaces in order to improve their conservation status. For each biogeographic sector, the plants best adapted to the local edaphoclimatic conditions are presented. Forest habitats can now, through micro-reserves in urban areas, ensure their long-term conservation and greater awareness among the population. An integrated planning, where the socio-ecological strategy is designed for the long term, will benefit the quality of life of citizens in an urban environment. Furthermore, the creation of micro-reserves in urban parks (gardens) can prevent the extinction of many botanical values in the landscapes of the western Mediterranean Basin.

Keywords: European Forests, Urban Gardens, International Reserves, Ornamental Plants, IUCN Red List

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1. Introduction

In the context of the Mediterranean basin, forest habitats are those presenting more difficulties to recover, mainly due to the slower growth of dominant tree species, such as oaks (*Quercus* spp.), but also due to the threats to which they are exposed, with particular emphasis on urban expansion and fires [1–4]. The destruction of native forests presents centuries of history, marked mainly since the 15th century with the beginning of the maritime expansion, where the noblest woods were used for the construction of ships and caravels, destroying in few decades most of the tree cover in Portugal, and in several other European countries as well [5]. After destruction, a forest takes decades or even centuries to develop until it reaches floristic stability [6], which is why it presents a greater value relatively to herbaceous or shrub communities. With recurrent fires and the consequently destruction of the standing biomass, the recovery of the vegetation cover tends to be dominated by heliophilous shrubs, and the resettlement of typical species of forest habitats is more difficult due to the loss of organic matter in the soil [7]. For these reasons, the occupation of land by shrub cover increased steadily in recent decades at a national level, even contributing to the increment in the expansion of invasive alien species [8–10]. Although the European continent is widely studied, new reports of invasive species are continuously identified in this territory [11,12]. On the other hand, there is a global trend towards the use of exotic plants in urban areas, contributing to reduce biodiversity [13].

In fact, the absence of well-preserved forests in Portugal is mentioned in the national report on the Natura 2000 Network, which indicates that forests are the second group with the greatest need to increase the area and conservation level, right after the peatlands [14]. Thus, in face of the strong reduction in forest habitats, a good part of the plants belonging to these environments currently occupy areas that are considerably smaller in relation to their potential occurrence area. Some plants are so confined to certain places that, in the last assessment of the threat status using the criteria of the IUCN (International Union of Conservation of Nature), these were evaluated at the national level as Critically Endangered (CR), as in the case of *Quercus canariensis* and *Daphne laureola* L. [15].

Thus, the objective of this work is to contribute to the identification and valorisation of native plants whose habitat are more reduced. Within these, plants belonging to the most evolved states of the vegetation cover stand out, that is, those plants that characterize the upper limit of the carrying capacity in a given territory [16]. Currently, the shrubs and herbaceous species so characteristic of forest environments are strongly reduced to small nuclei due to the lack of habitat, and, therefore, need urgent conservation measures in order to not lose the genetic variability that still exists [5,17]. On the contrary, the importance of valuing forest and pre-forest species in urban areas is also present in their capacity as suppliers of ecosystem services, and in their level of conservation [18,19], such as the production of small fruits and berries, provisioning food to a very important set of species, such as birds [20–22]. These tree species normally have broad leaves and reach a larger size, unlike the typical bushes of the initial stages of ecological succession, which usually have narrow and long leaves, with high levels of essential oils [23,24]. The multifunctionality of the landscape is therefore a criterion of increasing interest [25], also in order to prevent destructive wildfires [26].

In view of the need to restore ecological balance, the use of native plants is gaining popularity in rural areas, primarily through hedges and auxiliary microforests for the biological control of plagues and diseases in agriculture [27,28]. On the other hand, the use of native plant species in urban green spaces contributes to the reduction in maintenance costs, mainly due to the lower water demand [29,30]. In addition, urban areas can assume themselves as conservation reservoirs, where citizens can enjoy and get contact with species that are rare in nature, or are often sheltered in inaccessible places, such as *Prunus lusitanica* L. or *Rhododendron ponticum* subsp. *baeticum* [31,32].

2. Materials and Methods

2.1. Data collection and analysis

This study used the main series of climatophilous vegetation described for mainland Portugal [33,34]. For its interpretation, phytosociological methodology was used, according to the Zurich-Montpellier landscape and sigmatist school [6,35,36]. Based on the phytosociological associations described for each biogeographical sector [33,37], we compiled the plants from the stages closest to the climatic potential (mature stages), especially from *taxa* characteristic of the *Quercetea ilicis*, *Querco-Fagetea* and *Rhamno catharticae-Prunetea spinosae* classes. We selected only trees and shrubs because they are the basic plants for the exercise of Landscape Architecture, allowing the creation of spatialities and relationships between the full/empty [38,39].

Since the biogeographic sector is the one that best represents the distribution of the series of vegetation in the landscape, the latest update of the biogeographic limits proposed by Rivas-Martínez *et al*. [37] for the Iberian Peninsula were used (Figure 1).

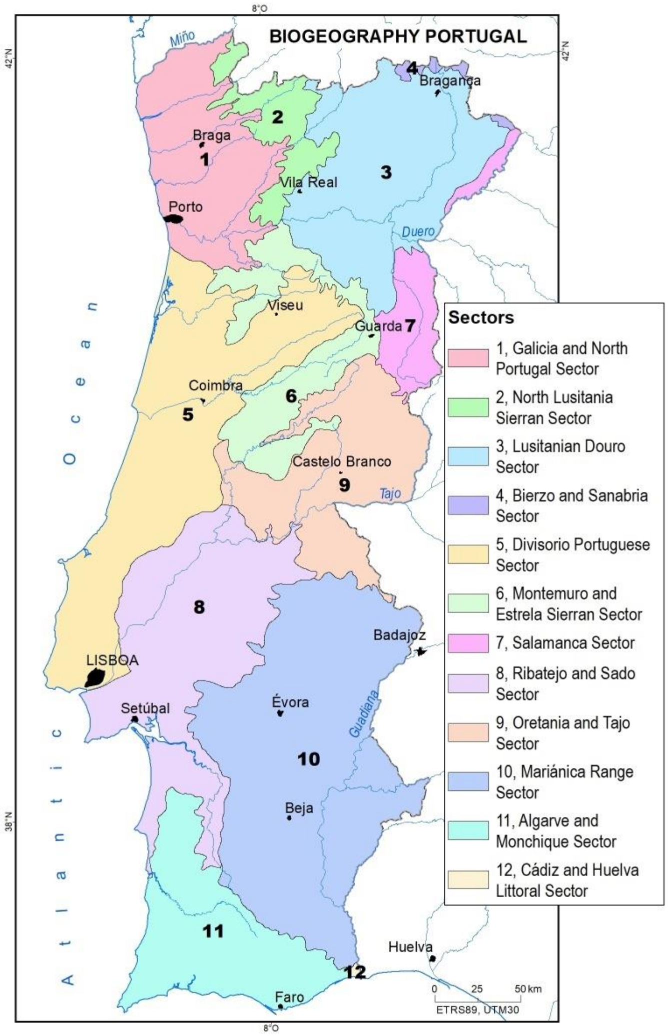

Figure 1. Biogeographic sectors in mainland Portugal (adapted from Rivas-Martínez [37]).

From each of the 12 biogeographic sectors in mainland Portugal, those plants belonging to the most evolved dynamic stages of the series of potential vegetation were selected; namely, the stage climax, as well as the first stage of substitution. This was based on the syntaxonomic framework of Portugal, and supported by the checklist of the Portuguese flora, comprising approximately 4 000 taxa [33,34].

To organize and accommodate the data collected, a spreadsheet with 10 sectors × 62 plants was created (excluding the Bierzo and Sanabria sector and the Cádiz and Huelva sector, due to their far larger pertinence the to Spanish territory and limited representativeness in Portugal). Thus, 10 sectors were clustered by using Ward's method with the Euclidean distance as agglomeration criterion in order to measure the relative dissimilarity of plants between the various biogeographic sectors. The XLSTAT software was used for hierarchical cluster analysis.

2.2. Characterization of the area

The northwest of Portugal is characterized by a temperate ocean-type bioclimate, with high rainfall, usually between 1 200 and 2 800 mm per year, which may reach 3 200 mm in some years [40]. In these surfaces, in terms of potential climatophilous vegetation, the forests of *Quercus robur* subsp. *broteroana* dominate [41]. The centre and south of Portugal are predominantly characterized by a Mediterranean oceanic bioclimate, marked by a period of summer dryness and rainfall concentrated in winter and spring, ranging between 300 and 1 200 mm of annual precipitation [40]. Oaks with marcescent and perennial leafs, such as *Quercus pyrenaica*, *Q. faginea*, *Q. broteroi*, *Q. suber* and *Q. rotundifolia* prevail in the southernmost zone [17].

Phytosociology is a science that incorporates evolutionary and regressive information about vegetation cover community until it reaches a mature forest, and studies the set of dynamic phases formed by different plants (Figure 2) [42]. In the Mediterranean basin, after a fire or the abandonment of an area, the first colonizing communities become established, normally constituted by annual herbaceous plants (phase 1). Through soil conservation, with no mobilization, perennial herbaceous communities appear (phase 2). These herbaceous communities are often later accompanied by small heliophilous shrubs (phase 3). The accumulation of organic matter in the soil over several years allows the installation of more demanding and taller heliophilous shrubs (phase 4). When the soils are well preserved, a set of species usually appears with broader leaf, a large size and tolerance to the shade of trees. These shrubs and mature trees are actually those that saw their area of occupation reduced in the past centuries in Portugal, frequently giving way to exotic species.

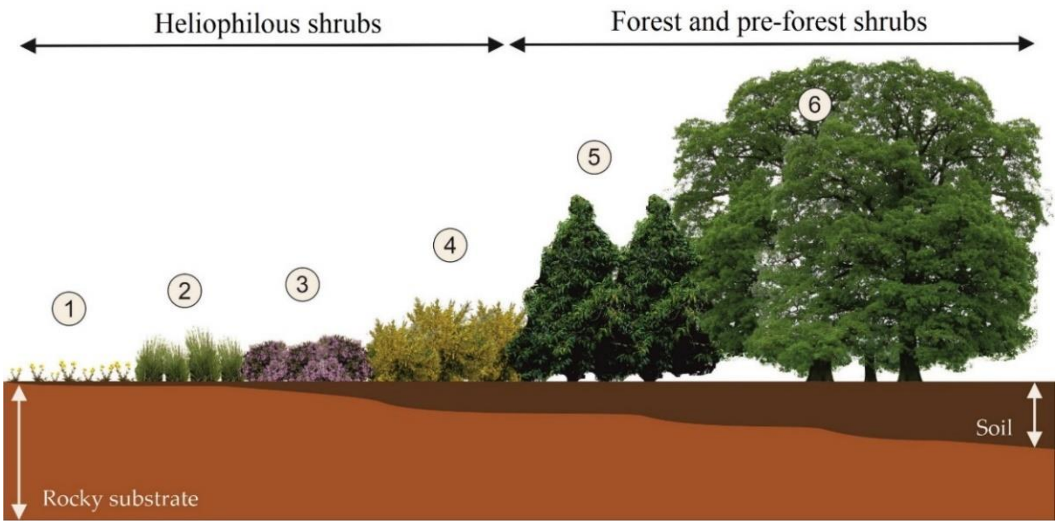

Figure 2. General dynamics of the climatophilous forest in Portugal: 1, annual grasslands; 2, perennial grasslands; 3, low shrubs; 4, shrubs edge; 5, pre-forest shrubs; 6, forests (adapted from Raposo *et al*. [43]).

3. Results

The analysis carried out on approximately 4 000 species of the native flora, identified 62 taxa with high ecological value for use in Landscape Architecture (Figure 3). The high diversity of edaphoclimatic conditions existing in mainland Portugal is reflected in its distribution, with 45% of the species appearing only in one or two biogeographical sectors. This fact reveals the importance of properly selecting native species adapted to each territory. On the contrary, species with greater ecological amplitude in Portugal, such as *Quercus suber* and *Arbutus unedo*, were identified in all biogeographical sectors. Thus, each biogeographic sector is characterized by its own potential species pool, with oaks dominating.

The distribution of the species identified by the biogeographic sectors showed some quantitative differences (Figure 4). Although the effective areas of the biogeographic sectors are different, it is noted that the mountain areas are richer in trees and pre-forest shrubs, namely the Montemuro and Estrelense Sierras sector. In general, the sectors with greater oceanic influence or greater ombroclimatic index present greater diversity of trees and preforest shrubs, such as the Algarve and Monchique sector and the Divisorio Portuguese sector.

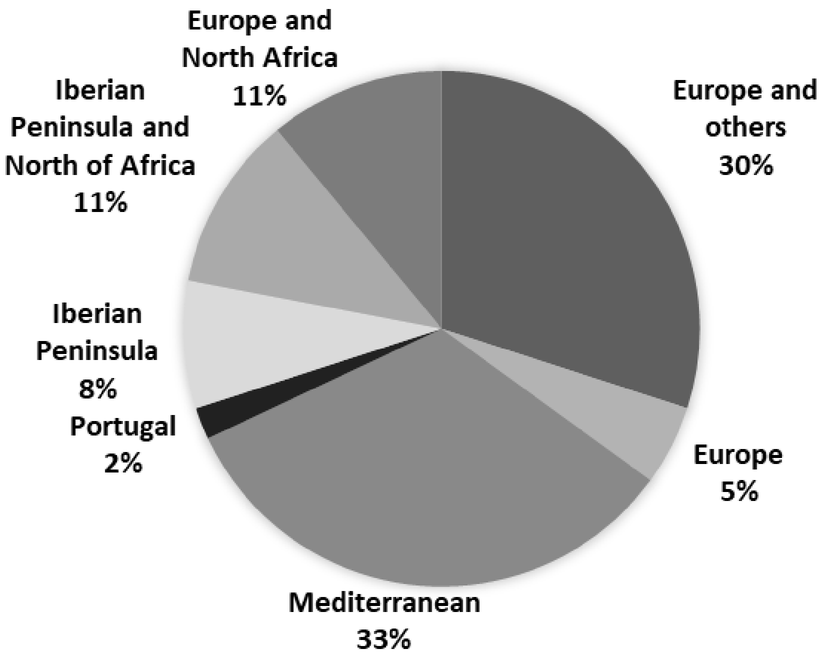

Figure 3. Generic chorology of the taxa identified.

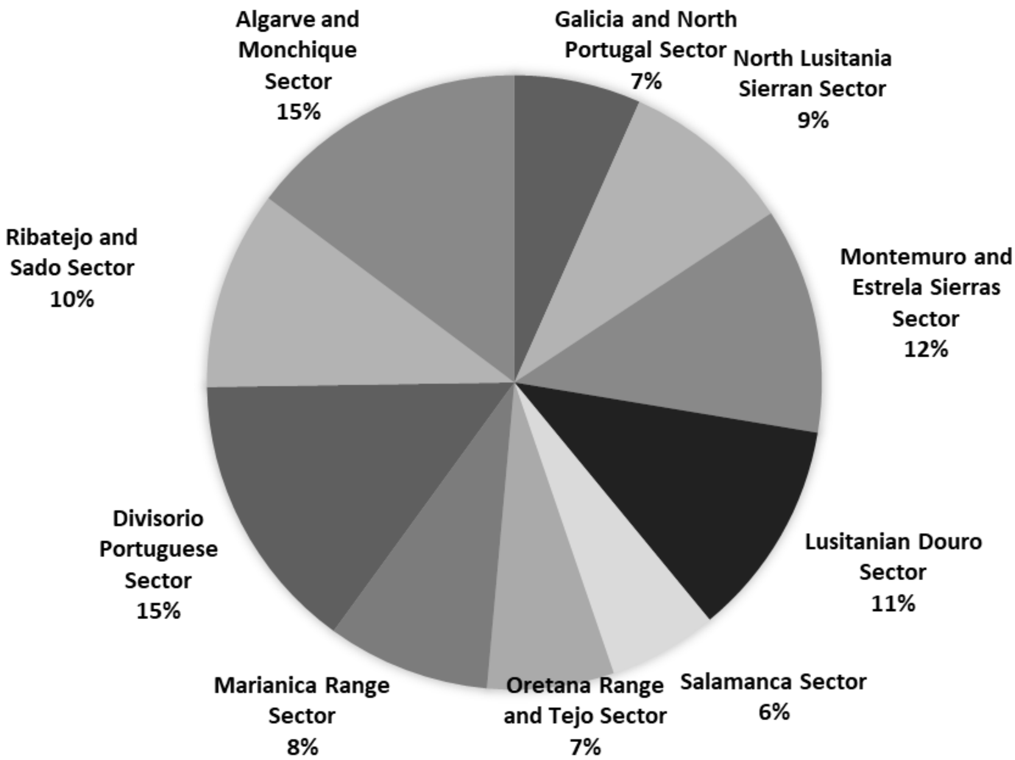

Figure 4. Percentage of the number of taxa in each Portuguese biogeographic sector.

The maximum number of taxa per biogeographical sector was reached in the Divisorio Portuguese sector (5) and in the Algarve and Monchique sector (11), while the lowest number of taxa corresponds to the Salamanca sector (7), with only 12 taxa.

The dissimilarity analysis among the different biogeographic sectors (Figure 5) grouped the mountain areas of central and northern Portugal, characterized by a bioclimate temperate and cold-resistant vegetation into the cluster B. Despite the greater diversity of species in the south of the country, typical of Mediterranean bioclimates, the environmental conditions closer to the ocean, allow the occurrence of several species in common, forming a cluster of coastal sectors (A2), namely, the Divisorio Portuguese sector, Ribatejo and Sado sector, and Algarve and Monchique sector. The remaining four sectors, with less oceanic influence and a marked Mediterranean bioclimate, were grouped together in the cluster A1.

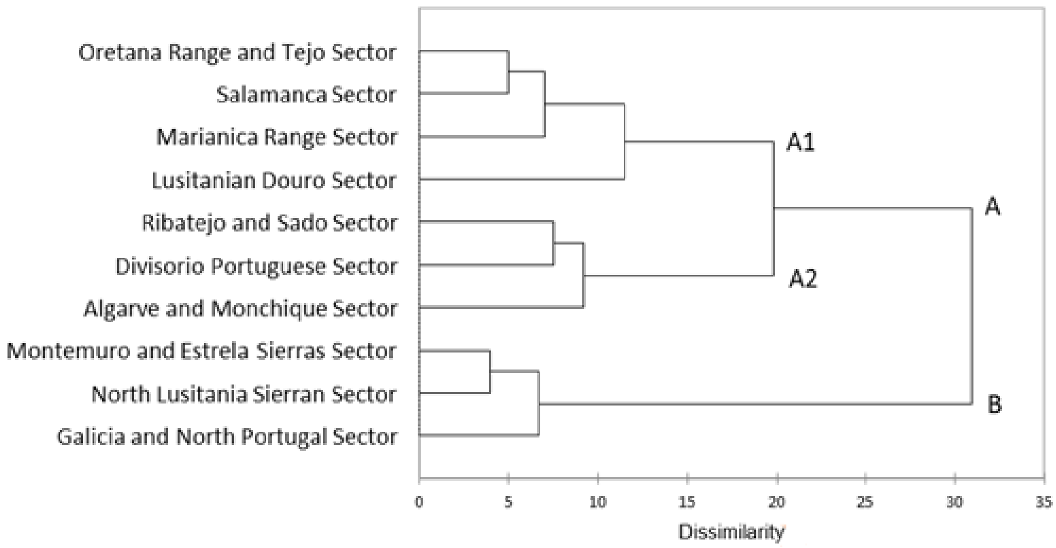

Figure 5. Dendrogram of the presence of priority taxa in each biogeographic sector.

Table 1 shows the distribution of the selected plant species in the 10 biogeographic sectors. However, it is also necessary to consider the specific habitat preferences of each species, e.g., since *Frangula alnus* or *Tamarix africana* thrive in areas with edafo-hygrophilic compensation. Another case is, for example, *Vaccinium uliginosum*, although it currently lives in crevices of granite rocky outcrops, it is possible that its distribution area would be greater, if the grazing pressure was reduced.

Table 1. Occurrence of plants in each biogeographic sector (1, Galicia and North Portugal sector; 2, North Lusitania Sierran sector; 3, Lusitanian Douro sector; 5, Divisorio Portuguese sector; 6, Montemuro and Estrela Sierras sector; 7, Salamanca sector; 8, Ribatejo and Sado sector; 9, Oretana Range and Tejo sector; 10, Marianica Range sector; 11, Algarve and Monchique sector).

Biogeographic Sector	1	2	3	5	6	7	8	9	10	11	Presence
Nº of taxa	14	19	24	31	25	12	22	14	18	31	
Acer monspessulanum L.	-	-	●	●	●	-	-	-	-	-	III
Amelanchier ovalis Medik.	-	●	●	-	-	-	-	-	-	-	II
Arbutus unedo L.	●	●	●	●	●	●	●	●	●	●	X
Bupleurum fruticosum L.	-	-	-	●	-	-	●	-	-	●	III
Buxus sempervirens L.	-	-	●	-	-	-	-	-	-	-	I
Chamaerops humilis L.	-	-	-	-	-	-	-	-	-	●	I

Crataegus monogyna L.	●	●	●	●	●	●	●	●	-	●	IX
Coronilla glauca L.	-	-	-	●	-	-	-	-	-	-	I
Frangula alnus Mill.	●	●	●	-	●	●	●	●	-	●	VIII
Ilex aquifolium L.	●	●	-	-	●	-	-	-	-	-	III
Juniperus communis subsp. *alpina* (Suter) Celakn	-	●	●	-	●	-	-	-	-	-	III
Juniperus navicularis Gand.	-	-	-	-	-	-	●	-	-	-	I
Juniperus oxycedrus subsp. *lagunae* (Pau ex Vicioso) Rivas-Mart.	-	-	●	-	-	-	-	●	-	-	II
Juniperus turbinata Guss.	-	-	-	●	-	-	●	-	-	●	III
Laurus nobilis L.	●	-	-	●	-	-	●	-	-	●	IV
Lavandula viridis L´Hér.	-	-	-	-	-	-	-	-	-	●	I
Myrica faya Aiton	-	-	-	●	-	-	-	-	-	●	II
Myrica gale L.	-	-	-	●	-	-	●	-	-	-	II
Myrtus communis L.	-	-	-	●	-	-	●	●	●	●	V
Nerium oleander L.	-	-	-	-	-	-	-	-	●	●	II
Olea europaea var. *sylvestris* (Mill.) Rouy ex Hegi	-	-	●	●	-	●	●	●	●	●	VII
Phillyrea angustifolia L.	-	●	●	●	●	●	●	-	●	●	VIII
Phillyrea latifolia L.	-	-	-	●	-	-	-	-	-	●	II
Pinus pinea L.	-	-	-	-	-	-	●	-	-	●	II
Pistacia lentiscus L.	-	-	-	●	-	-	●	-	●	●	IV
Pistacia terebinthus L.	-	-	●	-	-	●	-	-	-	-	II
Prunus insititia L.	-	●	●	-	●	-	-	-	-	-	III
Prunus lusitanica L.	●	●	-	-	●	-	-	-	-	-	III
Prunus mahaleb L.	-	-	●	-	-	-	-	-	-	-	I
Prunus spinosa L.	●	-	●	●	●	●	-	-	●	-	VI
Pyrus bourgaeana Decne	-	-	●	●	-	●	●	●	●	●	VII
Pyrus cordata Desv.	●	●	-	-	●	-	-	-	-	-	III
Quercus robur subsp. *broteroana* O.Schwartz	●	●	-	-	●	-	-	-	-	-	III
Quercus broteroi (Cout.) Rivas-Mart.	-	-	-	●	-	-	●	-	●	●	IV
Quercus canariensis Willd.	-	-	-	-	-	-	-	-	-	●	I
Quercus coccifera L.	-	-	-	●	-	-	-	-	●	●	III
Quercus faginea Lam.	-	-	●	-	-	-	-	-	-	-	I
Quercus faginea subsp. *alpestris* (Boiss.) Maire	-	-	-	-	-	-	-	-	-	●	I
Quercus lusitanica Lam.	-	-	-	●	-	-	●	-	-	●	III
Quercus pyrenaica Willd.	●	●	-	-	●	-	-	●	-	-	IV

Quercus suber L.	•	•	•	•	•	•	•	•	•	•	X
Quercus rivasmartinezii Capelo & Costa	-	-	-	•	-	-	•	-	-	-	II
Quercus rotundifolia Lam.	-	-	•	•	•	•	-	•	•	•	VII
Rhamnus alaternus L.	-	-	-	•	-	-	-	•	•	•	IV
Rhamnus catharticus L.	-	-	•	-	-	-	-	-	-	-	I
Rhamnus oleoides L.	-	-	-	•	-	-	•	•	•	-	IV
Rhododendron ponticum subsp. *baeticum* (Boiss. & Reut.) Hand.-Mazz	-	-	-	-	•	-	-	-	-	•	II
Rosa sempervirens L.	-	-	-	•	-	-	-	-	-	-	I
Ruscus aculeatus L.	•	-	•	•	•	•	•	•	•	•	IX
Sambucus nigra L.	•	•	•	•	•	•	-	-	-	•	VII
Sorbus aria (L.) Crantz	-	•	-	-	•	-	-	-	-	-	II
Sorbus aucuparia L.	-	•	-	-	•	-	-	-	-	-	II
Sorbus latifolia L.	-	-	-	-	•	-	-	-	-	-	I
Sorbus torminalis (L.) Crantz	-	•	•	-	•	-	-	-	-	-	III
Tamarix africana Poir.	-	-	-	•	-	-	•	-	•	•	IV
Teucrium fruticans L.	-	-	-	•	-	-	-	-	•	•	III
Vaccinium myrtillus L.	-	•	-	-	•	-	-	-	-	-	II
Vaccinium uliginosum L.	-	-	-	-	•	-	-	-	-	-	I
Viburnum lantana L.	-	-	•	-	-	-	-	-	-	-	I
Viburnum opulus L.	-	-	•	-	-	-	-	-	-	-	I
Viburnum tinus L.	•	•	-	•	•	-	-	-	-	•	V

4. Discussion

The importance of using native species has been evident since the dawn of landscape architecture in Portugal [39,44]. Since then, several studies focused on understanding the essence of the Portuguese garden, be it the form, composition or function [45,46]. The search for an identity, intrinsic to Man, is reflected in the preservation of singular and characteristic elements of the landscape, thus increasing the historical and cultural value of the *oikos* (intended as both natural environment and attached "social spaces", where the community life takes place) [38]. One of the natural elements that contributes most to the differentiation and enrichment of landscapes is the flora. In fact, the presence of certain floristic elements in the landscape indicates certain characteristics of the environment, functioning as true bioindicators [6,42]. As an example, reference should be made to the definition of geographical areas with homogeneous characteristics based on the natural distribution of species, reflecting the existing edaphoclimatic conditions, as is the case of the delimitation of biogeographical units [37]. Associated with these conditions, specific land uses characterize certain regions. The Douro vineyards, the Fundão cherry trees or the orange groves in Algarve are examples of this. On the contrary, the uniqueness of indigenous plants contribute to the support and enhance nature tourism, as well as reinforce the identity of the landscapes [47,48].

Although the selection of species to be used in landscape architecture is sometimes conditioned by the availability of specimens, the landscape architect should consider, whenever possible, native species with high ecological and heritage value [49]. Even in compact cities, the use of native plant species can contribute to reinforcing cultural identity [50].

Elements of indigenous paleotropical flora, such as *Prunus lusitanica* and *Rhododendron ponticum* subsp. *baeticum* [31], which are strongly threatened, not only relate to climate changes that occurred along the Cenozoic Era [51], but also to threats to which they are currently exposed, with special emphasis on forest fires and the invasion of exotic species [52]. However, in general, the use of native species presents a number of advantages over allochthonous species [49,53], namely: i) less water needs; ii) greater adaptation to climate change; iii) an increase in landscape identity; iv) biological balance, as well as; v) the conservation of plants with high patrimonial value. Natural values must be disseminated in urban areas, as it is only possible to value and preserve something when it is known [54,55].

Other plants can be used in gardens, such as herbs. However, some plants, especially those with a seasonal cycle, are more existing in maintenance. An example of this are the geophytes *Lilium martagon* and *Doronicum plantagineum* L. (both threatened), two species with high ornamental value, but which require greater care in use. As during a time of year the aerical part disappears, they must be used in a consortium with evergreen plants, so that the area is not empty.

5. Final considerations

Autochthonous forests in mainland Portugal have been consecutively reducing their area of occupancy, giving rise to the expansion of exotic species and the dominance of heliophile scrubs. Given this scenario with strong environmental consequences, the study of the dynamics of the potential climatophilous vegetation series allowed the identification of 62 priority ornamental taxa for conservation in mainland Portugal. Each species was classified at a biogeographic sector level in order to serve as a basis for the correct use of species in the landscape.

Coastal and higher altitude areas present a greater diversity of species, reflecting the climatic variations that occurred in the past, forcing plants to adapt. These places represent true biodiversity refuges, as in the case of the presence of *Prunus lusitanica* in Portugal, whose ideal climatic conditions occurred in the pre-Messinian phase of the Cenozoic era, when the Mediterranean area was still hosting subtropical forests [31,56].

This work contributes to the adaptation of the territory to climate change, since it suggests the enhancement of species correctly adapted to the edaphic and climatic conditions of each biogeographic unit, as in other works carried out in the Iberian Peninsula [57,58]. For this, urban forests managers should give priority to the selection of local ecotypes. In this sense, it is suggested to create at least one arboretum (nursery) of native plants in each biogeographic sector in order to represent all the existing tree and shrub diversity. Meanwhile, significant advances in the knowledge about the propagation methods of some native species are necessary, as is the case of *Juniperus navicularis* whose known propagation methods have reduced germination rates. In addition, the creation of micro-reserves in urban environments can contribute to the conservation of species with high patrimonial value, to environmental awareness and education or even to increase agroforestry systems [59].

This document presents an important technical and scientific contribution to more in-depth studies on landscape planning [60]. Vegetation series, which constitute the vegetative potential of the territory [17], are indicators of the uses and the good adequacy of functions through territorial management instruments.

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writing—original draft preparation, M.R.; writing—review and editing, R.Q.C. and C.P.G.; supervision, R.Q.C. and C.P.G.

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