Universidade de Évora - Instituto de Investigação e Formação Avançada
Universidade do Algarve - Faculdade de Ciências e Tecnologia

Programa de Doutoramento em Ciências Agrárias e Ambientais

Tese de Doutoramento

Contributos para a gestão e conservação dos azereirais de Prunus lusitanica L. na Europa e Norte de África

Mauro André Maurício Raposo

Orientador(es) | Carlos José Gomes
Francisco María Vásquez Pardo
Sara Del Río González

Évora 2022

Universidade de Évora - Instituto de Investigação e Formação Avançada
Universidade do Algarve - Faculdade de Ciências e Tecnologia

Programa de Doutoramento em Ciências Agrárias e Ambientais

Tese de Doutoramento

Contributos para a gestão e conservação dos azereirais de Prunus lusitanica L. na Europa e Norte de África

Mauro André Maurício Raposo

Orientador(es) | Carlos José Gomes
Francisco María Vásquez Pardo
Sara Del Río González

Évora 2022

A tese de doutoramento foi objeto de apreciação e discussão pública pelo seguinte júri nomeado pelo Diretor do Instituto de Investigação e Formação Avançada:

Presidente	Pedro Manuel Anastácio (Universidade de Évora)
Vogais	Carlos José Gomes (Universidade de Évora) (Orientador) Eusebio Cano-Carmona (Universidad de Jaén) José Cabezas Fernández (Universidad de Extremadura) José Carlos Augusta da Costa (Universidade Técnica de Lisboa - Instituto Superior de Agronomia) Paula Maria Simões (Universidade de Évora) Ángel Penas-Merino (Universidad de León)

Évora 2022

“A diversidade gera estabilidade.”

Gonçalo Ribeiro Telles

ÍNDICE GERAL

LISTA DE FIGURAS ………………………………………………………………….. vii

LISTA DE TABELAS ……………………………………………………………… x

AGRADECIMENTOS ………………………………………..…………..…. xii

RESUMO …………………………………………………………………….……... xiv

ABSTRACT ……………….……………………………………….…………….... xv

CAPÍTULO I. INTRODUÇÃO

I.1. Enquadramento ……………………………………………….…………… 3

I.2. Objetivos …………………………………………………….……………….. 8

I.3. Motivação pessoal ………………………………………….………………..… 8

I.4. Estrutura da Tese e resultados publicados …………………………………….. 10

I.5. Referências ……………………………………………………..…………. 14

CAPÍTULO II. ANÁLISE GEOBOTÂNICA DAS COMUNIDADES DE *PRUNUS LUSITANICA*

II.1. Intróito ……………………………………………………………………… 21

II.2. Artigo: Phytosociological analysis of *Prunus lusitanica* communities in the Iberian Peninsula and South of France

Abstract ……………………………………………………………………….…. 30

Introduction ……………………………………………………………………… 30

Materials and methods ………………………………………………………… 31

Results ………………………………………………………….………………... 31

Discussion ……………………………………………………………………….. 35

Conclusions ……………………………………………………….……………….. 37

References ………………………………………………………………………… 39

CAPÍTULO III. AVALIAÇÃO DO ESTADO DE CONSERVAÇÃO DE *PRUNUS LUSITANICA* NO CENTRO DE PORTUGAL CONTINENTAL

III.1. Intróito ……………………………………………………….…………….. 43

III.2. Artigo: *Prunus lusitanica* L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal

Abstract …… 51

Introduction …… 51

Materials and methods …… 52

Characterization of the Area under Study …… 52

Data Colletion …… 54

Ecological Modeling …… 55

Results and Discussion …… 55

Conclusions …… 60

References …… 60

CAPÍTULO IV. ORIGINALIDADES EDAFO-HIGRÓFILAS IDENTIFICADAS NO SUL DE PORTUGAL CONTINENTAL

IV.1. Intróito …… 65

IV.2. Originalities of Willow of *Salix atrocinerea* Brot. in Europe Mediterranean

Abstract …… 71

Introduction …… 71

Materials and methods …… 72

Data Colletion …… 72

Results and Discussion …… 73

Conclusions …… 81

References …… 83

CAPÍTULO V. PRINCIPAIS AMEAÇAS AO ESTADO DE CONSERVAÇÃO DAS COMUNIDADES DE *PRUNUS LUSITANICA*

V.1. Intróito …… 87

V.2. Artigo: Selective Shrub Management to Preserve Mediterranean Forests and Reduce the Risk of Fire: The Case of Mainland Portugal

Abstract …… 93

Introduction …… 93

Materials and methods …… 95

Vegetation Dynamics …… 96

Results and Discussion ………………………………………………………………….. 97

Post-Fire Analysis ………………………………………………………………………... 97

Vegetation Cover Management ………………………………………………………… 98

Conclusions ……………………………………………………………………………….. 99

References ……………………………………………………………………..……….. 100

V.3. Artigo: Evaluation of Species Invasiveness: A Case Study with *Acacia dealbata* Link. on the Slopes of Cabeça (Seia-Portugal)

Abstract ………………………………………………………………………….……….. 105

Introduction ………………………………………………………………………………. 105

Framework ……………………………………………………………………………. 105

Characteristics of *Acacia dealbata* that favor invasion …………………………..… 106

Materials and methods ………………………………………………………………..…… 107

Characterization of the area under study ……………………………………………. 107

Data Collection and Analysis ………………………………………………………….. 107

Results and Discussion …………………………………………………………………. 108

Conclusions ………………………………………………………………………………. 111

References ……………………………………………………………………………..… 112

CAPÍTULO VI. CONSIDERAÇÕES FINAIS

VI.1. Conclusões ……………………………………………..……………………… 117

VI.1.1. Referências ……………………………………………………………..… 119

ANEXOS ……………………………………………………….……………………... 121

ÍNDICE DE FIGURAS

Capítulo II

Figure 1. Study area and sampling points (adapted by Rivas-Martínez et al., 2017b).

Figure 2. Dendrogram with *P. lusitanica* communities. A1 (1-5) - *Luzulo henriquesii-Prunetum lusitanicae*; A2 (6-14) – *Frangulo alni-Prunetum lusitanicae*; B1.1 (15-16) – *Smilaco asperae-Prunetum lusitanicae* ass. nova; B1.2 (17-23) – *Viburno tini-Prunetum lusitanicae*; B2.1 (24-29) - *Lonicero periclymeni-Prunetum lusitanicae* ass. nova; B2.2 (30-34) – *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae*.

Figure 2. Nebulous aspect of the relict *Lonicero periclymeni-Prunetum lusitanicae ass. nova* in Vallée des Aldudes – France (in 9/9/2018).

Figure 3. Ecological condition of the *P. lusitanica* communities in the western Pyrenees (in 9/9/2018).

Capítulo III

Figura S1. Sobreposição das áreas ardidas entre 1990 e 2018 na zona da Serra da Estrela (adaptado de (Nunes et al., 2020))

Figura S2. Comportamento do azereiro após incêndio. (a) Situação mais seca sem regeneração de toiça. (b) Situação húmida com regeneração de toiça (fotografias: Mauro Raposo, 7 de agosto de 2019)

Figure 1. Mata da Margaraça (Arganil, Portugal) after the rural fire that occurred in October 2017 (picture taken in 2018)

Figure 2. Location of the areas under study

Figure 3. Thermopluviometric graphics of the areas under study: (a) Mação; (b) Seia; (c) Lousã; (d) Arganil (data acquired at Portal do Clima web platform, available at www.portaldoclima.pt, accessed on 14 June 2021, in accordance with the methodology presented by Walter and Lieth (1967) and Walter (2012) [34,35]).

Figure 4. Details of *P. lusitanica*. From left to right: flowering; fruiting; natural regeneration.

Figure 5. *P. lusitanica* pollen grains under the Scanning Electron Microscope (SEM), collected in Mata da Margaraça. (a) Tricolpate pollen in polar view on the left side and equatorial view on the right side. (b) Tricolpate pollen in polar view detail of the exine sculpturing with some puncta between the striae.

Figure 6. Percentage of organic matter per plot and depth of sampling (P1—habitat with good conservation status; P2—habitat with poor conservation status; P3—periphery of habitat 5230*pt2; P4—areas dominated by *A. dealbata*).

Figure 7. Exotic plants with invasive behavior in the areas under study. (a) Invasion of the banks of the River Alvôco with *A. dealbata*; (b) *H. sericea* fruiting near Ribeira do Aziral (Mação); (c) aggressive seminal regeneration of *E. globulus* in Serra da Estrela.

Figure 8. Map of the potential occurrence area of *P. lusitanica* in the central region of mainland Portugal.

Figure 9. Importance of ecological factors in modeling the potential occurrence area of *P. lusitanica* in Serra da Estrela (Tavg - average temperature; Tmax - maximum temperature; Tmin - minimum temperature; elev - elevation; prec - precipitation; srad - solar radiation; vapr - water vapor pressure; wind - wind speed).

Capítulo IV

Figure 1. Sampling sites in the southwest of the Iberian Peninsula.

Figure 2. Dendrogram with the communities dominated by *Salix atrocinerea* and *Salix salviifolia* subsp*. australis*, occurring throughout the southwest of the Iberian Peninsula and the island of Sardinia. B22 (27–38)—C.l.-S.a*.: Carici lusitanicae-Salicetum atrocinereae*; B22 (19–26)—F.b.-S.a.: *Frangulo baeticae-Salicetum atrocinereae* ass. nova hoc. loco; B22 (47–53)—v.s.-S.a.: *Viti sylvestris-Salicetum atrocinereae*; B21 (54–84)—C.m.-S.a.: *Carici microcarpae-Salicetum atrocinerea*; B1 (39–46)—M.c.-S.a.: *Myrto communis-*

Salicetum atrocinerea; A2 (1–13)—S.a.-a.: *Salicetum atrocinereo-australis*; A1 (14–18)—C.f.-S.a.: *Clematido flammulae-Salicetum australis* ass. nova hoc. loco.

Capítulo V

Figure 1. Location of burnt areas in mainland Portugal in 2017 (Source: GNR—Guarda Nacional Republicana, Forestry Technical Oces, Landsat and Copernicus, obtained through the website of ICNF—Institute for Nature Conservation, available at www.icnf.pt).

Figure 2. Dynamics of climatophilic vegetation in theMediterranean: 1—annual grasslands; 2—perennial grasslands; 3—heathland; 4—broomland; 5—maquis scrubland; 6—forest (Author: M. Raposo, 2020).

Figure 3. Vegetation regeneration ninemonths after a rural fire in Mata da Margaraça (Arganil, Portugal).

Figure 4. Heliophile shrubs with fine texture and fast combustibility. (a) *Calluna vulgaris*; (b) *Cytisus scoparius*; and (c) *Erica cinerea*.

Figure 5. Pre-forested bushes with broad texture and slower combustibility. (a) *Arbutus unedo*; (b) *Viburnum tinus*; and (c) *Prunus lusitanica*.

V2.3. Artigo: Evaluation of Species Invasiveness: A Case Study with *Acacia dealbata* Link. on the Slopes of Cabeça (Seia-Portugal)

Figure 1. Location of the *A. dealbata* subpopulation studied.

ÍNDICE DE TABELAS

Capítulo I

Tabela SI. Especificações dos trabalhos publicados no âmbito da presente Tese.

Table 1. Origin of the used relevés.

Table 2. *Smilaco asperae-Prunetum lusitanicae* ass. nova hoc loco (*Salici purpureae-Populetea nigrae*, *Populetalia albae*, *Populion albae*, *Fraxino angustifoliae-Ulmenion minoris*).

Table 3. *Viburno tini-Prunetum lusitanicae* (*Salici purpureae-Populetea nigrae*, *Populetalia albae*, *Populion albae*, *Fraxino angustifoliae-Ulmenion minoris*).

Table 4. *Lonicero periclymeni-Prunetum lusitanicae ass. nova* (*Rhamno catharticii-Prunetea spinosae, Pyro spinosae-Rubetalia ulmifolii, Lonicerion periclymeni*).

Table 5. Relevés of the *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae* (*Querco-Fagetea sylvaticae, Betulo pendulae-Populetalia tremulae, Corylo avellanae-Populion tremulae*).

Table 6. Synthesis of the presence of characteristic and differentials plants of the associations of *P. lusitanica* (1 - L.h.-P.l.: *Luzulo henriquesii-Prunetum lusitanicae*; 2 - F.a.-P.l.: *Frangulo alni-Prunetum lusitanicae*; 3 - S.a.-P.l.: *Smilaco asperae-Prunetum lusitanicae* ass. nova; 4 - V.t.-P.l.: *Viburno tini-Prunetum lusitanicae*; 5 - L.p.-P.l.: *Lonicero periclymeni-Prunetum lusitanicae* ass. nova; 6 - P.-C.p.l.: *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae*.

Table 7. Ecological framework of *Prunus lusitanica* communities in Iberian Peninsula and south of France (L.h.-P.l.: *Luzulo henriquesii-Prunetum lusitanicae*; F.a.-P.l.: *Frangulo alni-Prunetum lusitanicae*; S.a.-P.l.: *Smilaco asperae-Prunetum lusitanicae* ass. nova; V.t.-P.l.: *Viburno tini-Prunetum lusitanicae*; L.p.-P.l.: *Lonicero periclymeni-Prunetum lusitanicae* ass. nova; P.-C.p.l.: *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae*).

Capítulo III

Table 1. Bioclimatic data of the area under study: T - annual average temperature in Celsius degrees; P - average annual rainfall in millimeters; Tp - positive annual temperature in Celsius degrees; Pp - positive rainfall in millimeters; Io - annual ombrothermic index; It - thermicity index; Ic – simple continentality index (index based on Rivas-Martínez et al. [21]).

Table 2. Size of the population nuclei of *P. lusitanica*.

Table 3. Main exotic plants with invasive behavior identified in the areas under study.

Capítulo IV

Table 1. Synoptic table with the communities of *Salix atrocinerea* and *Salix salviifolia* subsp*. australis* in south-west Europe.

Table 2. *Frangulo baeticae-Salicetum atrocinereae* ass. nova hoc. loco (*Salici atrocinereae-Alnenion glutinosae, Alnion glutinosae, Alnetalia glutinosae, Alnetea glutinosae*).

Table 3. *Cheirolopho uliginosii-Molinietum arundinaceae* ass. nova hoc loco (*Brizo minoris-Holoschoenenion vulgaris, Molinio arundinacea-Holoschoenion vulgaris, Holoschoenetalia vulgaris, Molinio-Arrhenatheretea*).

Table 4. *Clematido flammulae-Salicetum australis* ass. nova hoc loco (*Salicion salviifoliae, Salicetalia purpureae, Salici purpureae-Populetea nigrae*).

Capítulo V

Table 1. Synthesis of the dynamic evolution of climatophilic vegetation cover in mainland Portugal.

Table 2. Main native shrub genera to conserve and control in fuel management bands in Portugal.

Agradecimentos

Em primeiro lugar, um agradecimento especial ao meu orientador Professor Doutor Carlos Pinto Gomes pelos conhecimentos transmitidos ao longo dos anos, como inspiração e pelo acompanhamento em muitos locais de ocorrência do azereiro, sobretudo a França, Espanha e Marrocos. Em segundo lugar aos orientadores Professora Doutora Sara del Río e ao Doutor Francisco Vázquez Pardo, de Espanha, pela paciência, partilha de conhecimentos e acompanhamento aos locais de ocorrência do azereiro.

Ao projeto Life-Relict (LIFE16 NAT/PT/000754) que permitiu contactar de forma mais próxima com as comunidades da Laurissilva continentais e garantir o meu suporte financeiro durante boa parte da minha Tese.

Ao Professor Doutor Angel Penas pela capacidade de transmitir conceitos de forma clara e dar-me a conhecer os azereiros existentes no *Arroyo de Fresnedelo* (Espanha).

Ao Professor Doutor Jean-Jacques Lazare pela colaboração, ensinamentos e acompanhamento no campo aos núcleos de azereiros de *Banca* (França).

Ao Professor Doutor Salvador Rivas Martínez, pelos avanços científicos fundamentais nas áreas da Fitossociologia, Biogeografia e Bioclimatologia, o qual tive a oportunidade de conhecer em vida, aproveitando diretamente os conhecimentos transmitidos em encontros internacionais de fitossociologia.

Ao Professor Doutor Leonel Nunes pela colaboração e incentivo na publicação do conhecimento científico produzido ao longo da presente Tese.

Ao Doutor Alexandre Silva pela partilha de informação, disponibilidade e apoio na estadia durante parte da realização dos trabalhos de campo na Serra da Estrela.

Ao Professor Doutor Ricardo Quinto Canas pela amizade e acompanhamento na prospeção do azereiro no Município de Mação durante as suas férias.

Ao colega João Ribeiro pela disponibilidade em acompanhar-me à Catalunha para prospetar áreas de ocorrência de azereiro e partilhar conhecimentos sobre Sistemas de Informação Geográfica.

À Sociedade Portuguesa de Botânica pela partilha de alguns dados sobre a localização de núcleos de azereiro em Portugal Continental.

À União de Freguesias de Vide e Cabeça, pelo Doutor João Orlindo, pela simpatia e apoio nas estadias durante a prospeção do azereiro.

À Câmara Municipal da Pampilhosa da Serra, pela Eng. Sandra Chora e restantes funcionários que colaboraram nas várias prospeções de campo.

À Câmara Municipal de Mação que facilitou a realização dos trabalhos e campo, através da estada.

Ao Professor Doutor Mouhaydine Tlemcani, do Departamento de Engenheira Mecatrónica da Universidade de Évora, que facilitou a viagem e as deslocações em Marrocos.

Ao climatologista Mário Marques pela partilha de dados climáticos nacionais.

Ao meu amigo e colega Daniel Bento pelo apoio e incentivo.

À minha família que sempre me apoiou e por vezes mudou as suas rotas, permitindo-me conhecer um pouco mais da floresta Laurissilva, nomeadamente nas Ilhas da Madeira e Açores.

Contributos para a gestão e conservação dos azereirais de *Prunus lusitanica* L. na Europa e Norte de África

RESUMO

As comunidades de azereiro são relíquias paleotropicais que vivem desde o sudoeste de França, centro e norte da Península Ibérica, até ao norte de Marrocos, porém, encontram-se em estado de conservação desfavorável, face às ameaças a que estão sujeitas. De modo a contribuir para alterar este cenário, apresentam-se nesta Tese cinco artigos científicos publicados em revistas internacionais que resultam das investigações realizadas durante este estudo. De forma a melhorar o conhecimento sobre as comunidades de azereiro, realizou-se uma revisão bibliográfica e visitaram-se alguns locais de ocorrência de modo a perceber a sua ecologia. Este conhecimento base permitiu melhorar os esforços na prospeção de novas áreas de azereiro. Em cada núcleo de azereiros contabilizou-se o número de indivíduos separados por dois grupos de alturas e posteriormente realizaram-se inventários fitossociológicos, de acordo com os fundamentos e metodologias da Escola de Zürich-Montpellier. Em todos os locais visitados, as principais ameaças ao estado de conservação dos azereirais foram registadas. Como principais resultados deste estudo destaque-se a identificação de cinco novas associações fitossociológicas, nomeadamente dois novos azereirais, dois novos salgueirais e uma nova comunidade de herbáceas vivazes. Tendo em conta os dados históricos identificou-se uma redução do número de azereiros no centro de Portugal. Relativamente às ameaças, tendo em conta a redução do risco de incêndio apresentaram-se métodos de controlo mais favoráveis à conservação, nomeadamente através do corte seletivo do coberto arbustivo, onde se identificaram os diferentes tipos de matos a conservar e a controlar. Estima-se também, com base em oito variáveis climáticas, a área potencial de ocorrência do azereiro no centro de Portugal e identificam-se os fatores mais determinantes para a sua área de distribuição. Por último, apresentam-se duas fórmulas para calcular o poder invasivo de espécies vegetais invasoras com base em dados espaciotemporais, melhorando o apoio á decisão dos gestores territoriais.

Contributions to the management and conservation of Portuguese-laurel of *Prunus lusitanica* L. in Europe and North Africa

ABSTRACT

The Portuguese-laurel communities are paleotropical relics that live from southwestern France, central and northern Iberian Peninsula, to northern Morocco, however, they are in an unfavorable state of conservation, given the threats to which they are subject. In order to contribute to changing this scenario, this Thesis presents five scientific articles published in international journals that result from the investigations carried out during this study. In order to improve knowledge about the Portuguese-laurel communities, a literature review was carried out and some places of occurrence were visited in order to understand their ecology. This basic knowledge made it possible to improve the efforts in prospecting new areas of the bird cherry tree. In each nucleus of oak trees, the number of individuals separated by two height groups was counted and later phytosociological inventories were carried out, in accordance with methodologies of the Zürich-Montpellier School. In all the places visited, the main threats to the conservation status of the Portuguese-laurel were registered. The main results of this study include the identification of five new phytosociological associations. Taking into account the historical data, a reduction in the number of ocher trees in central Portugal was identified. With regard to threats, taking into account the reduction in the risk of fire, control methods were presented that were more favorable to conservation, namely through selective cutting of the shrub cover, where the different types of scrub to be conserved and controlled were identified. It is also estimated, based on eight climatic variables, the potential area of occurrence of the Portuguese-laurel in central Portugal and the most determining factors for its distribution area are identified. Finally, two formulas are presented to calculate the invasive power of invasive plant species based on spatiotemporal data, improving decision support for territorial managers.

CAPÍTULO I

INTRODUÇÃO

CAPÍTULO I

CAPÍTULO I. INTRODUÇÃO

I.1. Enquadramento

Após a extinção dos dinossauros no Cretáceo, há cerca de 65,5 milhões de anos, o globo terrestre foi marcado por um período de amenidade climática, caracterizado por um clima quente e húmido, o que terá favorecido o desenvolvimento de diversas famílias de plantas e animais (Aguiar and Pinto 2007). Pensa-se que o Paleogeno terá durado cerca de 42 milhões de anos, onde as florestas tropicais se expandiram praticamente por toda a superfície terrestre (Aguiar & Pinto, 2007; Wicander & Monroe, 2000). Porém, o arrefecimento progressivo a nível global, sentido sobretudo a partir do Mioceno (iniciado há cerca de 23 milhões de anos), fez reduzir de forma significativa as florestas mais próximas dos polos. Posteriormente, as glaciações ocorridas durante o Pleistoceno foram responsáveis pela extinção da maioria das plantas tropicais na Europa (Brito, 2009).

A floresta Laurissilva é um testemunho vivo da influência de climas quentes e húmidos em boa parte da bacia mediterrânica durante o Paleogeno (Barrón, 2003; Pignatti, 1978). Atualmente, a vegetação de origem tropical na Europa encontra-se muito alterada e confinada. Os melhores exemplos da Laurissilva encontram-se nas ilhas atlânticas pertencentes aos arquipélagos dos Açores, Madeira, Canárias e Cabo Verde, constituindo motivo de atração turística. No entanto, embora menos conhecidos e de forma muito localizada, na Península Ibérica e no Norte de África, estão presentes também alguns bosquetes testemunho de uma Laurissilva Continental. A identificação destes bosques é possível pela presença de plantas do tipo lauroide, constituídas por folhas persistentes, simples, coriáceas e frequentemente aromáticas. Plantas como o azereiro (*Prunus lusitanica*), o azevinho (*Ilex aquifolium*), a adelfeira (*Rhododendron ponticum* subsp*. baeticum*), o loureiro (*Laurus nobilis*) e o samouco (*Myrica faya*), entre outras, partilham atualmente os mesmo biótopos com a flora mediterrânica mais recente, motivo pelo qual formam comunidades com elevada biodiversidade (Aguiar & Pinto, 2007).

Todavia, estes bosquetes da Laurissilva Continental apresentam sérios problemas de conservação, não só devido ao contexto climático atual (mediterrânico), marcado por um período de secura estival durante o verão, mas também devido à ação antrópica. Algumas destas plantas encontram-se ameaçadas a nível global, segundo a última avaliação apresentada pela União Internacional para a Conservação da Natureza, como é o caso de *Prunus lusitanica,* avaliada com a categoria Em Perigo, pelo critério A2c (Vivero, 1998). Saliente-se ainda que, apesar de *Rhododendron ponticum* subsp. *baeticum* não ter sido avaliado, poderá vir a adquirir uma categoria semelhante à do azereiro. Ainda com a agravante ao nível da estrema dificuldade de regeneração natural nas áreas do seu habitat. Tratam-se, portanto, de verdadeiras relíquias paleotropicais que urge conservar. Como corolário, em boa hora, a Comunidade Económica Europeia reconheceu estas formações como um habitat prioritário para a conservação a nível Europeu, sob a designação de "Matagais arborescentes de *Laurus nobilis*", integrado no Anexo I da Diretiva 92/43/CEE. No caso dos azereiros, Portugal ao transpor a Diretiva Habitats incluiu-os neste habitat, através do subtipo "Azereirais" (5230*pt2). No entanto, o Relatório Nacional do artigo 17 da Rede Natura 2000 (2007-2012), referente ao último sexénio, indica que as comunidades de azereiro em Portugal encontram-se numa situação desfavorável ao nível da conservação. Perante este cenário, pode concluir-se que as políticas ambientais Europeias e respetiva aplicação a nível nacional e regional, estão a revelar-se, neste caso, insuficientes para a necessária conservação dos azereirais.

No entanto, a fim de promover a importância do estudo da conservação das comunidades de azereiro e adelfeira, a Universidade de Évora elaborou e submeteu uma candidatura ao programa *LIFE Nature and biodiversity*, que em boa hora foi aprovado com a seguinte designação: LIFE RELICT – Preserving Continental Laurissilva Relics (LIFE16 NAT/PT/000754). Este projeto, onde tenho desenvolvido atividades, permitiu-me melhorar o conhecimento nas áreas de ocorrência do azereiro em Portugal, nomeadamente a Mata da Margaraça, localizada na Serra do Açor e o vale de Loriga, na Serra da Estrela. Os dados recolhidos no âmbito deste projeto não foram incluídos nesta Tese porque as ações de conservação ainda se encontram a decorrer neste momento; embora as intervenções se tenham iniciado em 2018, ainda não existem dados suficientemente robustos para inferir quaisquer conclusões, estando o seu término previsto para 2022.

Assim, com base em estudos desenvolvidos anteriormente na Universidade de Évora (Pinto-Gomes et al., 2017; Raposo et al., 2016), decidiu-se aprofundar o conhecimento sobre as comunidades de azereiro. Embora Calleja (Calleja, 2006) tenha estudado o azereiro na sua componente geobotânica, demográfica, conservacionista e biológica na Península Ibérica, Beltrán (Beltrán, 2001) estudou a distribuição e ecologia do azereiro; Guitián et al. (Rodríguez-Guitián et al., 2007) abordou a ecologia e florística dos azereirais da Cantábria, enquanto que Romo (Romo, 2009) tratou as comunidades de azereiro de Marrocos; já Bolós (Bolós, 1956) publicou trabalhos sobre as comunidades de azereiro da Catalunha. Também Ladero (Ladero, 1976) reconheceu as comunidades de azereiro do centro da Península Ibérica. Por outro lado, Costa et al. (J. C. Costa et al., 2015) estudaram as comunidades de azereiro do Centro de Portugal, enquanto que Honrado et al (Honrado et al., 2007) dedicou-se ao estudo das comunidades de azereiro da Serra do Gerês. Todavia, Pulido et al (Pulido et al., 2008) desenvolveu trabalhos sobre os principais fatores limitantes da dispersão do azereiro. Contudo, existem ainda várias outras publicações sobre dados corológicos e análise relevantes sobre as comunidades de azereiro (Allorge, 1941; Arriba & Díaz, 2014; Calleja, 2012; Calleja et al., 2014; A. M. Costa & Calleja-Alarcón, 2013; Escudero, 2014; López-Sáez, 1995; Pulgar & Manso, 2010; Ribeiro et al., 2015; Sañudo & Manso, 2015; Silveira, 2001), na verdade, existe pouca informação sobre a relação entre as ameaças identificadas e os possíveis métodos de gestão mais adequados à conservação dos azereirais.

De modo a identificar e caracterizar as comunidades de azereiro e as respetivas ameaças à sua conservação, realizaram-se um conjunto de saídas de campo tendo em vista abranger toda a sua corologia e posições ecológicas. Inicialmente realizou-se uma pesquisa bibliográfica, que foi complementada com informações partilhadas de outros investigadores, sobre os locais de ocorrência do azereiro. Posteriormente, visitaram-se esses territórios e prospetaram-se outros locais com condições ecológicas semelhantes. Os trabalhos de campo tiveram início em 2017, no entanto, face aos constrangimentos da pandemia, relativas ao Covid-19 (SARS-CoV-2), houve alguma dificuldade em sair de Portugal após 2019. Porém, foi ainda possível visitar vários núcleos com azereiros, nomeadamente nas montanhas do Rife, em Marrocos, nos Pirenéus Ocidentais, em França, e outras comunidades autónomas de Espanha, particularmente Castela e Leão, Estremadura e Catalunha. Por forma a melhor e compreender as comunidades de azereiro, visitaram-se também as espécies vicariantes de *Prunus hixa* Willd. na ilha da Madeira e *Prunus azorica* (Hort. Ex Mouill.) Rivas Mart., Lousã, Fern. Prieto, Dias, J.C. Costa & Aguiar na ilha de São Miguel, nos Açores, consideradas pelas floras antigas subespécies de *P. lusitanica*. Deste modo, foi possível recolher dados e compreender a grande maioria dos núcleos de azereiro a nível global.

O azereiro (*Prunus lusitanica* L.), conhecido também como loureiro-de-Portugal ou ginjeira-brava, é uma angiospérmica pertencente à família das *Rosaceae*, subfamília *Prunoideae*, de distribuição Franco-Ibero-Magrebina. Trata-se de uma árvore, ou arbusto de grande porte, que em condições favoráveis pode atingir 20 metros de altura, mas frequentemente apresenta-se com 6-8 metros de altura. Dentro do género *Prunus*, constituído na sua maioria por táxones de folha caduca, pertence ao subgénero *Laurocerasus* (Duhamel) Rehder, que engloba dois táxones perenifólios inermes. O azereiro diferencia-se de *Prunus laurocerasus*, principalmente por apresentar folhas sem glândulas, pecíolos geralmente de cor avermelhada obscura e inflorescência com (8)10-25(28) centímetros, muito mais comprida que as folhas (Blanca & Díaz de la Guardia, 1998). A descrição de *P. lusitanica* L. foi publicada pela primeira vez em 1753 por Carl Linnaeus, na sua famosa obra *Species Plantarum*, sendo que posteriormente houve diversas publicações de alteração de nome e descrição, contendo propostas como *Padus lusitanica* (L.) Mill., Gard. Dict. Ed. 8, n.º 5 (1768), *Cerasus lusitanica* (L.) Dum. Cours., Bot. Cult. 3: 389 (1802) e *Laurocerasus lusitanica* (L.) M. Roem., Fam. Nat. Syn. Monogr. 3: 92 (1847), contudo, atualmente consideram-se apenas sinónimos. *Prunus lusitanica* L. apresenta ritidoma praticamente liso, de cor acinzentada, ramos glabros, lisos ou um pouco angulosos. As suas folhas variam entre 7 e 15 centímetros de comprimento e 2,5 e 5,5 centímetros de largura, de textura coriácea, ovado-lanceoladas ou oblongo-lanceoladas, crenadas ou aserradas, acuminadas, glabras, de cor verde escura e lustrosa, na página inferior mais pálida e desprovida de glândulas. O pecíolo varia entre 1 e 3 centímetros de comprimento é glabro e apresenta geralmente um tom vermelho escuro. A época de floração ocorre entre maio a junho emitindo entre 30 a 80 flores brancas **odoríferas** (embora a Flora Ibérica, certamente por lapso, não refira esta característica) por cacho, de 10 a 25 centímetros, inicialmente eretas ou suberetas e posteriormente pendulinas com a maturação dos frutos. Pedicelos de 4 a 11 milímetros, patentes ou ereto-patentes. Recetáculo de 2,5 a 3 milímetros, largamente acopado, quase hemisférico, na face anterior pubescente. Sépalas de 1 a 1,5 milímetros, ereto-patentes ou patentes, largamente triangulares ou triangular-ovadas, obtusas, algo ciliadas, até ao ápice, pubescentes na página interna ou subglabras. Pétalas de 3 a 5 milímetros, patentes, largamente obovadas ou suborbiculares, inteiras, obtusas e brancas. Ovário glabro. O fruto tem de 8 a 13 milímetros, de formato ovoide ou subgloboso, atenuado no ápice, glabro, primeiro verde, depois purpúreo e na maturação negro e lustroso, sem pruína. O mesocarpo é pouco espesso, de sabor amargo e algo áspero. O endocarpo é liso, de ovoide a subgloboso.

Porém, apesar do contexto climático atual, desfavorável para o azereiral, o Painel Intergovernamental sobre Mudanças Climáticas, mais conhecido por IPCC, projeta uma redução da precipitação anual, o que poderá reduzir as áreas potenciais de ocorrência (IPCC, 2007). Contudo, saliente-se que mesmo com uma redução da precipitação, as comunidades de azereiro poderiam beneficiar caso esta precipitação ocorresse de forma mais regular e continua ao longo do ano, onde a precipitação concentrada atualmente nos meses de inverno e primavera deixaria de ser desperdiçada por escorrência superficial e passaria a ser melhor utilizada pelas plantas (del Río et al., 2018). Portanto, as ações de gestão deverão contemplar as mudanças climáticas. Assim, para além desta série ameaça, as principais ameaças às comunidades de azereiro têm origem antrópica, relacionando-se sobretudo com incêndios, cortes sucessivos, reconversão em áreas produtivas para agricultura ou silvicultura, alteração do ciclo hidrológico, entre outras. A ocorrência de incêndios rurais, combinada com a proliferação de plantas invasoras, constituem as principais ameaças ao habitat do azereiral. A acácia (*Acacia dealbata*) é uma das espécies florestais mais invasoras em Portugal Continental (Marchante et al., 2014; Nunes et al., 2020), apresentando a capacidade de colonizar de forma invasiva vales, encostas e cabeços, substituindo os principais tipos de vegetação potencial natural na paisagem (edafoxerófila, climatófila e edafo-higrófila).

I.2. Objetivos

De forma a responder aos problemas apresentados anteriormente, procurou-se nesta Tese aprofundar o conhecimento sobre as comunidades de azereiro relativamente aos seguintes aspetos:

- Melhorar o conhecimento sobre a distribuição natural de *P. lusitanica*;
- Identificar e caracterizar a ecologia das principais séries edafo-higrófilas dos cursos de água temporários, de modo a reconhecer as distintas associações fitossociológicas;
- Reconhecer as principais ameaças à conservação dos azereirais;
- Avaliar a dinâmica populacional do azereiro no centro de Portugal Continental, com base em dados históricos e atuais;
- Criar ferramentas de apoio à decisão para o controlo de espécies vegetais invasoras;
- Propor técnicas de gestão adequadas ao melhoramento do estado de conservação e valorização dos azereirais;
- Identificar os principais fatores climáticos que influenciam a área de distribuição natural do azereiro.

Todos estes objetivos foram, de um modo geral atingidos, encontrando-se aprofundados nos artigos publicados, no âmbito da presente Tese.

I.3. Motivação pessoal

Desde o início da formação em Arquitetura Paisagista que ganhou sensibilidade para aprofundar o conhecimento sobre plantas autóctones ameaçadas. Assim, não só pelo papel fundamental que o Arquiteto Paisagista desempenha no incremento da identidade da paisagem, através do projeto em si, bem como pelo conhecimento da dinâmica da paisagem e pela utilidade do bioindicador vegetal, como ferramenta de análise e diagnóstico célere do território, decidiu-se aprofundar o estudo destas comunidades reliquiais.

No curso de Arquitetura Paisagista da Universidade de Évora, o estudo da flora e vegetação foi lecionado principalmente pela Professora Doutora Maria da Conceição Lopes Castro e pelo Professor Doutor Carlos José Pinto Gomes, os quais me acompanharam e motivaram para a importância do conhecimento dos valores paisagísticos. Tendo desenvolvido na minha Tese de mestrado com base na ciência Fitossociológica, intitulada “O interesse das séries de vegetação para o projeto em Arquitetura Paisagista (Distrito de Évora)” e tendo trabalhado como técnico superior no projeto da Lista Vermelha da Flora Vascular de Portugal Continental, senti a necessidade e o gosto de aprofundar o conhecimento na área da Geobotânica através da presente Tese.

Para além do estatuto de ameaça do azereiro, o seu habitat é rico em plantas com elevado valor ornamental, que proporcionam um aspeto sempre verde ao longo do ano. Embora a sensação de sazonalidade proporcionada por plantas de folha caduca seja motivo de interesse, na verdade, muitos jardins da Península Ibérica revelam uma procura do “sempre verde”, através da criação de áreas relvadas despropositadas e com elevadas necessidades hídricas. Todavia, a utilização de espécies ameaçadas nos centros urbanos apresenta várias vantagens, entre as quais gostaria de destacar, a importância como reservatório vivo, garantindo a salvaguarda genética no caso da destruição em meio natural e por outro lado, a contribuição para a educação e sensibilização ambiental, evitando a deslocação do cidadão para locais, por vezes, de difícil acesso, uma vez que só se pode valorizar aquilo que se conhece. Aliás, o azereiro é largamente utilizado nos jardins públicos e privados de França e Inglaterra.

Neste sentido, de forma a tirar o máximo partido das qualidades plásticas do material vegetal em cada área de intervenção é necessário conhecer em profundidade as suas características ecologias. A bioclimatologia como ciência que relaciona os parâmetros bioclimáticos com a área de distribuição natural de táxones e sintáxones; a biogeografia estuda a corologia de táxones e sintáxones; a fitossociologia estuda a relação e a sociabilidade entre as plantas a nível espacial e temporal. Estes ramos da ciência constituem uma base sólida que permitem ao projetista tomar decisões no exercício da sua atividade, onde se inclui a base do ordenamento da paisagem, procurando adequar da melhor forma possível o propósito de determinada atividade com as condições biofísicas do lugar.

I.4. Estrutura da Tese e resultados publicados

Apesar de ter em mente o trabalho de identificação e caracterização de todas as comunidades e associações de *P. lusitanica* existentes em França, Península Ibérica e Norte de África, a sua primeira publicação (*Originalities of Willow of Salix atrocinerea Brot. in Mediterranean Europe*) resultou da observação de comunidades originais de salgueiros, em cursos de água temporários e situações tempori-higrófilas de caracter fontinal. Como corolário deste trabalho, foram publicadas duas novas associações de salgueiros e um novo arrelvado vivaz para o território nacional.

Retomando o objetivo do estudo das comunidades de azereiro, verificou que uma das grandes ameaças ao estado de conservação é o flagelo dos fogos rurais. Assim, apercebeu-se que era essencial e imprescindível publicar um trabalho sobre a gestão dos matos heliófilos, tendo em vista a melhoria do estado de conservação das formações florestais e preflorestais, bem como o incremento da resiliência aos fogos e consequentemente a redução do risco de incêndio (*Selective Shrub Management to Preserve Mediterranean Forests and Reduce the Risk of Fire: The Case of Mainland Portugal*).

Tomando por base os dados recolhidos sobre a corologia, ecologia e estado de conservação das comunidades de azereiro, sem perder de vista a sua linha condutora de investigação publicou o seguinte artigo: *Prunus lusitanica L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal*.

No seguimento desta publicação e munido de dados referentes às invasões por acácia-mimosa nas superfícies potenciais de azereiro, resultou a publicação do seguinte artigo: *Evaluation of Species Invasiveness: A Case Study with Acacia dealbata Link. on the Slopes of Cabeça (Seia-Portugal)*.

Por último, na posse de um conhecimento detalhado sobre todas as comunidades e associações existentes na Península Ibérica e França, publicou um artigo sobre a análise fitossociológica das comunidades de azereiro, intitulado: *Phytosociological analysis of Prunus lusitanica communities in the Iberian Peninsula and south of France*.

Embora tenha sido este o percurso decorrido, para melhor compreensão, alterou-se a sequência dos conteúdos, de acordo com a Tabela I.

Tabela SI. Especificações dos trabalhos publicados no âmbito da presente Tese.

Título	Ano	Revista	Quartil	Fator de Impacto	Citações
Phytosociological analysis of *Prunus lusitanica* communities in the Iberian Peninsula and south of France	2021	*Plant Biosystems*	Q2	2,8	-
Prunus lusitanica L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal	2021	*Diversity*	Q1	2,5	1
Originalities of Willow of *Salix atrocinerea* Brot. in Mediterranean Europe	2020	*Sustainability*	Q1	3,3	3
Selective Shrub Management to Preserve Mediterranean Forests and Reduce the Risk of Fire: The Case of Mainland Portugal	2020	*Fire*	Q1	2,4	10
Evaluation of Species Invasiveness: A Case Study with *Acacia dealbata* Link. on the Slopes of Cabeça (Seia-Portugal)	2021	*Sustainability*	Q1	3,3	-

Assim, a Tese apresentada está dividida em seis capítulos corelacionados entre eles com exceção do primeiro capítulo, relativo à introdução, e do último capítulo, relativo às conclusões gerais do trabalho. Os quatro capítulos centrais que compõe o corpo desta Tese são baseados em cinco artigos científicos, publicados em revistas internacionais indexadas. O segundo capítulo analisa e caracteriza as associações fitossociológicas dominadas por azereiro na Península Ibérica e no Sudoeste de França. O terceiro capítulo aprofunda o estado de conservação do azereiro nas serras do centro de Portugal Continental. O quarto capítulo apresenta novas associações edafo-higrófilas identificadas na sequência do trabalho de campo realizado para a atualização corológica do azereiro. O quinto capítulo aborda as principais ameaças à conservação dos azereirais, nomeadamente o problema das plantas invasoras e a sua propagação após fogo, bem como a gestão seletiva do coberto vegetal.

Todos os capítulos são divididos em duas partes, exceto os capítulos referentes à Introdução e às Conclusões. A primeira parte de cada capítulo apresenta as principais ideias desenvolvidas em cada artigo e as respetivas referências bibliográficas citadas. A segunda parte consiste na apresentação dos artigos publicados, estruturados pela seguinte sequência:

Capítulo I: Apresenta o enquadramento da floresta Laurissilva Continental no contexto da flora atual e determina os objetivos do presente estudo. De seguida, referem-se os principais motivos subjacente à realização deste trabalho.

Capítulo II: Baseado num artigo publicado na revista *Plant Biosystems*: **Raposo, M., del Río, S., Pinto-Gomes, C., & Lazare, J.-J. (2021). Phytosociological analysis of *Prunus lusitanica* communities in the Iberian Peninsula and south of France. *Plant Biosystems* - An International Journal Dealing with all Aspects of Plant Biology, https://doi.org/10.1080/11263504.2021.1998242**. Nesta publicação descrevem-se duas novas associações fitossociológicas de *Prunus lusitanica*. Uma para o Concelho de Mação (Portugal), que corresponde ao limite sul da área de distribuição natural do azereiro em Portugal e outra, para os Pireneus Ocidentais (França), que representa a etapa madura de uma minorisérie de vegetação.

Capítulo III: Fundamentado num artigo publicado na revista *Diversity*: **Raposo, M., Nunes, L.J., Quinto-Canas, R., del Río, S., Vázquez Pardo, F.M., Galveias, A., & Pinto-Gomes, C. (2021).** ***Prunus lusitanica*** **L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal.** ***Diversity*** **13, (8): 359. https://doi.org/10.3390/d13080359**. Nesta publicação avalia-se o estado de conservação de *P. lusitanica* nas serras do centro e sul de Portugal Continental, apresentando-se contagens atuais do número de indivíduos, as principais ameaças à sua conservação e uma modelação ecológica da área de distribuição potencial do azereiro com base em dados climáticos.

Capítulo IV: Sustentado num artigo publicado na revista *Sustainability*: **Raposo, M., Quinto-Canas R., Cano-Ortiz A., Spampinato G. & Pinto-Gomes C. (2020). Originalities of Willow of** ***Salix atrocinerea*** **Brot. in Mediterranean Europe.** ***Sustainability*** **12, (19): 8019. https://doi.org/10.3390/su12198019**. Nesta publicação descrevem-se duas novas associações de salgueiro e um novo prado vivaz para Portugal Continental. Este artigo resulta da recolha de dados realizada durante o trabalho de campo efetuado para a atualização da corologia de *P. lusitanica*.

Capítulo V: Alicerçado em dois trabalhos publicados. O primeiro na revista *Fire* e o segundo na *Sustainability* que seguidamente se apresentam:

Raposo, M., Pinto-Gomes, C., & Nunes L.J. (2020). Selective Shrub Management to Preserve Mediterranean Forests and Reduce the Risk of Fire: The Case of Mainland Portugal. ***Fire*** **3, (4): 65. https://doi.org/10.3390/fire3040065**. Nesta publicação apresenta-se uma caracterização dos matos mais frequentes nos azereirais e relaciona-se a morfologia dos arbustos e a classe fitossociológica a que pertencem, tendo em vista o controlo seletivo do coberto vegetal para reduzir o risco de incêndio e concomitantemente valorizar os estados florestais e préflorestais dos bosques mediterrânicos.

Raposo, M., Pinto-Gomes, C., & Nunes, L.J. (2021). Evaluation of Species Invasiveness: A Case Study with ***Acacia dealbata*** **Link. on**

the Slopes of Cabeça (Seia-Portugal). ***Sustainability*** **13, 20: 11233. https://doi.org/10.3390/su132011233**. Neste artigo apresentam-se duas fórmulas para estimar, com base em dados espaciotemporais, a expansão de núcleos de plantas invasoras para um determinado território, tendo sido utilizado como caso de estudo a acácia-mimosa.

Capítulo VI: Corresponde ao último capítulo desta Tese que encerra as conclusões obtidas, nos distintos capítulos, e perspetivas de trabalho para o futuro.

I.5. Referências

Aguiar, C., & Pinto, B. (2007). Paleo-história e história antiga das florestas de Portugal continental: Até à Idade Média. *Árvores e florestas de Portugal: floresta e sociedade, uma história comum*, 15–53.

Allorge, P. (1941). A propos du Prunus lusitanica L. de la vallée de la Hayra (Basses-Pyrénées). *Bulletin de la Société Botanique de France*, *88*(1), 61–69. https://doi.org/10.1080/00378941.1941.10834214

Arriba, E. P. de, & Díaz, P. M. U.-E. (2014). Presencia de Prunus lusitanica L. subsp. Lusitanica (laurel de Portugal o loro) en la cuenca alta del río Ega (Álava). *Flora Montiberica*, *58*, 34–44.

Barrón, E. (2003). Evolución de las floras terciarias en la Península Ibérica. Mongraf. *Jard. Bot. Córdoba*, *11*, 63–74.

Beltrán, R. S. (2001). *Prunus lusitanica L. en la Península Ibérica.* [Tesis Doctoral.]. Universidad Politécnica de Madrid.

Bolós, O. de. (1956). De Vegetatione Notulae, II. *Collectanea Botanica*, *V.*(12), 244–252.

Brito, S. D. (2009). *História da Terra durante os últimos 65Ma: Exemplos Portugueses com interesse para o ensino.* [Tese em Geologia]. Universidade Nova de Lisboa.

Calleja, J. A. (2006). *Geobotánica, estructura demográfica, consevación y biología predispersiva de Prunus lusitanica L. (loro) en la Península Ibérica.* [Memoria de Tesis Doctoral.]. Universidad Autónoma de Madrid.

Calleja, J. A. (2012). Tamaños poblacionales y regeneración de Prunus lusitanica L. en el noreste de la Península Ibérica. *Orsis, organismes i sistemes: revista de botànica, zoologia i ecologia*, *26*, 21–35.

Calleja, J. A., Mingorance, L., Sim-Sim, M., & Lara, F. (2014). Ampliación de la distribución conocida de algunas hepáticas localizadas en poblaciones ibéricas de Prunus lusitanica L. *Bol. Soc. Esp. Briol.*, *42*(43), 41–46.

Costa, A. M., & Calleja-Alarcón, J. A. (2013). Plant size and abiotic factors determine the intra-specific variation in the multi-stemmed architecture of Prunus lusitanica in the Northeast limit of its global distribution. *Forest Systems*, *22*(3), 423–432. https://doi.org/10.5424/fs/2013223-03546

Costa, J. C., Monteiro-Henriques, T., Bingre, P., & Espírito-Santo, D. (2015). Warm-Temperate Forests of Central Portugal: A Mosaic of Syntaxa. Em E. O. Box & K. Fujiwara (Eds.), *Warm-Temperate Deciduous Forests around the Northern Hemisphere* (pp. 97–117). Springer International Publishing. https://doi.org/10.1007/978-3-319-01261-2_5

del Río, S., Álvarez-Esteban, R., Cano, E., Pinto-Gomes, C., & Penas, Á. (2018). Potential impacts of climate change on habitat suitability of Fagus sylvatica L. forests in spain. *Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology*, *152*(6), 1205–1213. https://doi.org/10.1080/11263504.2018.1435572

Escudero, Y. C. (2014). *Macroecología de la reproducción en «Prunus lusitanica» L.: Variabilidad geográfica y efectos de la marginalidad en un árbol relicto* [Http://purl.org/dc/dcmitype/Text, Universidad de Extremadura]. https://dialnet.unirioja.es/servlet/tesis?codigo=41489

Honrado, J., Alves, P., Lomba, Â., Torres, J., & Caldas, F. B. (2007). Ecology, diversity and conservation of relict laurel—Leaved mesophytic scrublands in mainland Portugal. *Acta Botanica Gallica*, *154*(1), 63–77. https://doi.org/10.1080/12538078.2007.10516045

IPCC. (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Ladero, M. (1976). Prunus lusitanica L. (Rosaceae) en la Península Ibérica. *Anales del Instituto Botánico A.J. Cavanilles*, *33*, 207–218.

López-Sáez, J. A. (1995). Las comunidades de Prunus lusitnica del valle del Tiétar (Serra de Gredos, Ávila). *Anales de Biología*, *20*, 111–113.

Marchante, H., Morais, M., Freitas, H., & Marchante, E. (2014). *Guia prático para a identificação de plantas invasoras em Portugal*. Imprensa da Universidade de Coimbra. http://dx.doi.org/10.14195/978-989-26-0786-3

Nunes, L. J. R., Raposo, M. A. M., Meireles, C. I. R., Pinto Gomes, C. J., & Ribeiro, N. M. C. A. (2020). Control of Invasive Forest Species through the Creation of a Value Chain: Acacia dealbata Biomass Recovery. *Environments*, *7*(5), 39. https://doi.org/10.3390/environments7050039

Pignatti, S. (1978). Evolutionary Trends in Mediterranean Flora and Vegetation. *Vegetatio*, *37*(3), 175–185.

Pinto-Gomes, C., Vázquez-Pardo, F., Matos, R., Castro, M. C., Raposo, M., Silva, A., Fonseca, A., Martinho, S., Costa, A., Garcia, C., Mendes, P., Santos, P., & Meireles, C. (2017). Será possível conservar as comunidades relíquiais de La urissilva de Portugal continental). *I European Meeting of Phytosociology, Biogeografy and Syntaxono my of Atlantic Regions.*

Pulgar, I., & Manso, D. (2010). Datos sobre Prunus lusitanica L. (Rosaceae) en Galicia. *Nova Acta Científica Compostelana (Bioloxía)*, *19*, 33–47.

Pulido, F., Valladares, F., Calleja, J. A., Moreno, G., & González-Bornay, G. (2008). Tertiary relict trees in a Mediterranean climate: Abiotic constraints on the persistence of Prunus lusitanica at the eroding edge of its range. *Journal of Biogeography*, *35*(8), 1425–1435. https://doi.org/10.1111/j.1365-2699.2008.01898.x

Raposo, M., Mendes, P., Cano-Ortiz, A., & Pinto-Gomes, C. (2016). Séries de vegetação prioritárias para a conservação no centro e sul de Portugal continental. *Botanique*, *1*, 133–148.

Ribeiro, S., Delgado, F., & Azevedo, L. (2015). Os bosques de azereiro (Prunus lusitanica L. subsp. Lusitanica) no concelho de Oleiros. *Cardo. Boletim Cultural e Informativo.*, *7*, 21–24.

Rodríguez-Guitián, M. A., Franco, R. R., & Rego, P. R. (2007). Caracterização ecológica y florística de las comunidades lauroides del occidente de la Cornisa Cantábrica (Noroeste ibérica). *Lazaroa*, *28*, 35–65.

Romo, À. (2009). Contribution to the knowledge of the Moroccan mountain vegetation. *Collectanea Botanica (Barcelona)*, *28*, 111–124.

Sañudo, Í. P., & Manso, D. (2015). Prunus lusitanica L. (Rosaceae) en A Coruña (Galicia, NW Península Ibérica). *NACC: Nova acta científica compostelana. Bioloxía*, *22*, 5.

Silveira, P. C. da. (2001). *Contribuição para o conhecimento da flora vascular da Serra do Açor e respectiva interpretação fitogeográfica*.

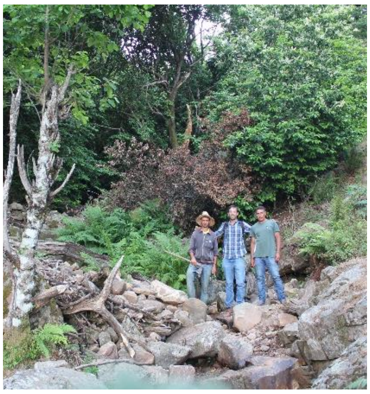
Vivero, J. L. (1998). *IUCN Red List of Threatened Species: Prunus lusitanica subsp. lusitanica*. IUCN Red List of Threatened Species. https://www.iucnredlist.org/en

Wicander, R., & Monroe, J. S. (2000). *Historical Geology: Evolution of Earth and Life Through Time*. Brooks/Cole.

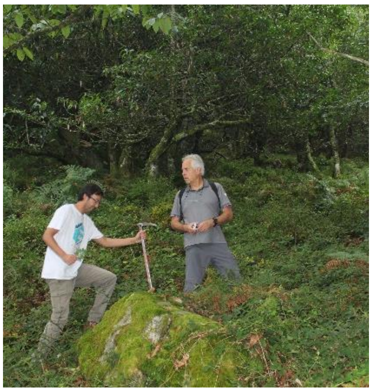
CAPÍTULO II

ANÁLISE GEOBOTÂNICA DAS COMUNIDADES DE *PRUNUS LUSITANICA*

Espanha



Marrocos



França

Publicado como:

Raposo, M., del Río, S., Pinto-Gomes, C., & Lazare, J.-J. (2021). Phytosociological analysis of *Prunus lusitanica* communities in the Iberian Peninsula and south of France. *Plant Biosystems* - An International Journal Dealing with all Aspects of Plant Biology, https://doi.org/10.1080/11263504.2021.1998242

CAPÍTULO II

CAPÍTULO II. ANÁLISE GEOBOTÂNICA DAS COMUNIDADES DE *PRUNUS LUSITANICA*

II.1. Intróito

No Capítulo II aprofundamos o conhecimento fitossociológico sobre as comunidades de *P. lusitanica*, onde descrevemos duas novas associações, correspondendo uma delas a uma minorisérie de vegetação. Na primeira parte apresenta-se uma breve caracterização ecológica do azereiro e uma sumula de todas as associações fitossociológicas dominadas por *P. lusitanica* da Península Ibérica. Na segunda parte refere-se a metodologia usada e apresenta-se um mapa de localização dos inventários, com referência aos limites biogeográficos ao nível do setor. Nos resultados apresenta-se uma análise hierárquica, através de dendrograma, de modo a identificar o nível de dissimilaridade entre as comunidades estudadas. Para cada associação apresenta-se uma caracterização ao nível biogeográfico, bioclimático, posição ecológica, principais plantas características, enquadramento serial e o respetivo esquema sintaxonómico. Na quarta parte destacam-se as diferenças entre as comunidades de *P. lusitanica* estudadas, através da comparação de quadros sintéticos, pelas plantas características, situação ecológica e discutem-se as filiações sintaxonómicas. Na quinta e última parte sumarizam-se as principais conclusões que o leitor deve reter, destacando a importância de conhecer as associações de *P. lusitanica* para uma melhor gestão e conservação destas comunidades reliquiais.

Embora as comunidades de *P. lusitanica* na Península Ibérica estejam estudadas, nomeadamente na sua componente florística, ecológica e climática (Beltran, 2006; J. A. Calleja et al., 2009; J. Calleja & Ollero, 2009; Lara et al., 2007; Pulgar & Manso, 2010; Pulido et al., 2008), a reduzida área de ocupação atual, bem como a categoria de “Em Perigo” a nível global (Vivero, 1998), de acordo com os critérios da IUCN (International Union for Conservation of Nature), suscitam um especial interesse de conservação. É neste âmbito que urge enquadrar as comunidades de *P. lusitanica* da Península Ibérica, Norte de África e França a nível Fitossociológico. A correspondência fitossociológica permite não só enquadrar as comunidades vegetais ao nível da dinâmica das séries de vegetação e na paisagem, bem como estabelecer o enquadramento legal e respetivas estratégias de valorização, tal como acontece na Diretiva Habitats (92/43/CEE).

Neste sentido, novos dados recolhidos em núcleos de azereiro nos Pireneus Ocidentais (França) e no Concelho de Mação (Portugal), permitiram o reconhecimento de duas novas associações fitossociológicas, que apresentam composições florísticas originais. Ambas com funções ecológicas relevantes, uma vez que *Smilaco asperae-Prunetum lusitanica* corresponde ao limite sul da área de distribuição do azereiro em Portugal Continental e *Lonicero periclymeni-Prunetum lusitanicae* ao limite norte da área de distribuição global do azereiro, servindo de referências para identificar possíveis impactes das mudanças climáticas futuras.

Neste estudo não incluímos a associação *Polysticho setiferi-Prunetum lusitanicae* descrita para as montanhas do Rife, no norte de África (Romo, 2009), embora tenhamos visitado parte do território. Esta exclusão deve-se ao facto dos inventários publicados apresentarem bastantes variações florísticas, tendo sido separados na análise estatística. Dos dezasseis táxones característicos de associação e unidades superiores, apenas *Paeonia coriacea* var. *maroccana* está presente em mais de 50% dos inventários, motivo pelo qual os inventários se aproximam de várias associações de *P. lusitanica* da Península Ibérica. Numa análise mais cuidada é possível identificar duas variantes. A primeira variante deste azereiral, de carácter mais higrófilo, está associado a ribeiras com caudal permanente e menor declive, onde surge acompanhado por *Alnus glutinosa, Ilex aquifolium, Blechnum spicant, Frangula alnus, Hedera maderensis* subsp*. iberica, Osmunda regalis* e *Lonicera peryclimenum* subsp*. hispanica*. De salientar que esta variante mais higrófila aproxima-se da associação *Frangulo alni-Prunetum lusitanicae* que ocorre no centro de Portugal Continental (Costa et al., 2015; Raposo et al., 2021). A segunda variante ocorre em zonas de maior altitude e declives acentuados, onde as comunidades de azereiro resistem a um maior período de secura estival, partilhando o seu biótopo com táxones que ocorrem mais frequentemente em posição climatófila, tais como *Paeonia coriacea* var*. maroccana, Quercus canariensis, Acer opalus* subsp*. granatense, Digitalis mauretanica*, *Satureja vulgaris* subsp*. arundana* e *Viola munbyana*. Esta última variante possui maior valor florístico e identitário, permitindo distingui-la claramente das restantes associações de *P. lusitanica* da Península Ibérica e França.

Refira-se também que não foi identificado qualquer exemplar de *P. lusitanica* em Acebo (Espanha), contrariamente ao que refere a bibliografia. A referência para este ponto isolado, poderá estar relacionada com uma identificação errónea, pela semelhança, à primeira vista, com *P. serotina* (ver diferenças no Anexo I); uma árvore originária da parte ocidental da América do Norte e Canadá Meridional, tendo sido introduzido na Europa para fins ornamentais e florestais (Blanca & Díaz de la Guardia, 1998), bem como para porta enxertos de variedades de *Prunus* cultivadas (Vázquez, com. pess.).

Cabe ainda referir a presença de *P. lusitanica* no Setor Biogeográfico Cantábrico-Bascónico, nomeadamente nas localidades de Ordunte, Montes Vascos e Baztan. Porém, com baixo número de indivíduos e uma diversidade reduzida, destacando-se Ordunte com apenas 54 táxones (J. Calleja & Ollero, 2009). Por motivos de restrição pandémica, estas áreas não foram visitadas. Porém, os inventários apresentados por Calleja (2006) nestes territórios, as plantas dominantes são *Fraxinus excelsior* e *Corylus avellana*, sendo que *P. lusitanica* raramente surge como táxone dominante. Perante este facto, assumimos que os azereiros não têm expressão para se elevarem a associação, integrando-se assim no sintáxone *Polysticho setiferi-Fraxinetum excelsioris*.

Referências

Beltran, R. S. (2006). Distribution and autoecology off Prunus lusitanica L. in Iberian Peninsula. *Forest Systems*, *15*(S1), 187–198. https://doi.org/10.5424/srf/200615S1-00991

Blanca, G., & Díaz de la Guardia, C. (1998). Prunus L. Em F. Muñoz Garmendia & C. Navarro Aranda (Eds.), *Flora Iberica—Plantas vasculares de la Península Ibérica e Islas Baleares: Vol. VI-Rosaceae*. Real Jardin Botánico, CSIC.

Calleja, J. A., Garzón, M. B., & Ollero, H. S. (2009). A Quaternary perspective on the conservation prospects of the Tertiary relict tree Prunus lusitanica L. *Journal of Biogeography*, *36*(3), 487–498. https://doi.org/10.1111/j.1365-2699.2008.01976.x

Calleja, J., & Ollero, H. (2009). Análisis e interpretación geobotánica de la estructura y composición florística de las loreras ibéricas. *Ecologia*, *22*, 45–71.

Costa, J. C., Monteiro-Henriques, T., Bingre, P., & Espírito-Santo, D. (2015). Warm-Temperate Forests of Central Portugal: A Mosaic of Syntaxa. Em E. O. Box & K. Fujiwara (Eds.), *Warm-Temperate Deciduous Forests around the Northern Hemisphere* (pp. 97–117). Springer International Publishing. https://doi.org/10.1007/978-3-319-01261-2_5

Lara, F., Garilleti, R., & Calleja, J. A. (2007). *La vegetación de ribera de la mitad norte española* (2.ª ed.). Centro de Estudios y Experimentación de Obras Públicas, CEDEX. https://dialnet.unirioja.es/servlet/libro?codigo=556929

Pulgar, I., & Manso, D. (2010). Datos sobre Prunus lusitanica L. (Rosaceae) en Galicia. *Nova Acta Científica Compostelana (Bioloxía)*, *19*, 33–47.

Pulido, F., Valladares, F., Calleja, J. A., Moreno, G., & González-Bornay, G. (2008). Tertiary relict trees in a Mediterranean climate: Abiotic constraints on the persistence of Prunus lusitanica at the eroding edge of its range. *Journal of Biogeography*, *35*(8), 1425–1435. https://doi.org/10.1111/j.1365-2699.2008.01898.x

Raposo, M., del Río, S., Pinto-Gomes, C., & Lazare, J.-J. (2021). Phytosociological analysis of Prunus lusitanica communities in the Iberian Peninsula and south of France. *Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology*, *0*(ja), 1–19. https://doi.org/10.1080/11263504.2021.1998242

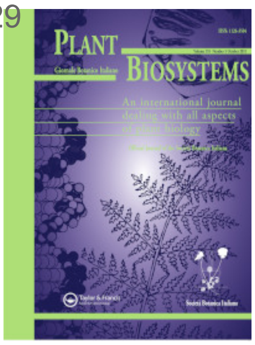
Romo, À. (2009). Contribution to the knowledge of the Moroccan mountain vegetation. *Collectanea Botanica (Barcelona)*, *28*, 111–124.

Vivero, J. L. (1998). *IUCN Red List of Threatened Species: Prunus lusitanica subsp. lusitanica*. IUCN Red List of Threatened Species. https://www.iucnredlist.org/en

II.2. Artigo: Phytosociological analysis of *Prunus lusitanica* communities in the Iberian Peninsula and South of France

CAPÍTULO II

29



Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology

Official Journal of the Societa Botanica Italiana

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tplb20

Phytosociological analysis of *Prunus lusitanica* communities in the Iberian Peninsula and South of France

Mauro Raposo, Sara del Río, Carlos Pinto-Gomes & Jean-Jacques Lazare

PLANT BIOSYSTEMS - AN INTERNATIONAL JOURNAL DEALING WITH ALL ASPECTS OF PLANT BIOLOGY
https://doi.org/10.1080/11263504.2021.1998242

Taylor & Francis
Taylor & Francis Group

Check for updates

Phytosociological analysis of *Prunus lusitanica* communities in the Iberian Peninsula and South of France

Mauro Raposo[a,b], Sara del Río[c], Carlos Pinto-Gomes[a,b,d] and Jean-Jacques Lazare[e]

[a]Department of Landscape, Environment and Development, School of Science and Technology, University of Évora, Évora, Portugal; [b]Mediterranean Institute for Agriculture, Environment and Development (MED), University of Évora, Évora, Portugal; [c]Department of Biodiversity & Environmental Management (Botany), Faculty of Biology & Environmental Sciences, Mountain Livestock Institute (CSIC-ULE), University of Leon, León, Spain; [d]Institute of Earth Sciences, University of Évora, Évora, Portugal; [e]Center for the Study and Conservation of Plant Resources (CECRV), Heugas, France

ABSTRACT

The relict communities of *Prunus lusitanica* are globally threatened, mainly by climatic and anthropic factors. Solid knowledge about floristic composition and serial dynamics provides a valuable basis for the implementation of management and conservation measures. This article focuses on peculiar communities that occur in hydric-compensated areas of the Iberian Peninsula and south of France, a submediterranean ecotonal area. A hierarchical cluster analysis allowed to identify two new syntaxa. For the first time an association of *Prunus lusitanica*, *Lonicero periclymeni-Prunetum lusitanicae ass. nova*, is reported for France, representing the mature stage of a minoriseries of vegetation, attributed to *Lonicerion periclymeni*. The discovery of populations of *P. lusitanica* in valleys embedded in the Municipality of Mação (Portugal), represent the new association *Smilaco asperae-Prunetum lusitanicae ass. nova*, enriched by thermophilous taxa. This relict association occurs in the South Beira District and corresponds to the southern limit of the natural distribution area in mainland Portugal, integrated in the suballiance *Fraxino angustifoliae-Ulmenion minoris*. Additional notes on the occurrence of *P. lusitanica* in other areas of the Iberian Peninsula are provided.

ARTICLE HISTORY
Received 6 May 2021
Accepted 22 October 2021

KEYWORDS
Chorology; laurel forest; geobotany; phytosociology; Pyrenees; relict communities; southwestern Europe; vegetation

Introduction

The Portuguese laurel, *Prunus lusitanica* L., is a plant of high conservation interest (Pardo et al. 2018) that witnessed a near tropical climate in the Iberian Peninsula during Cenozoic Era (Aguiar and Pinto 2007; Rodríguez-Sánchez and Arroyo 2008). Most paleotropical plants disappeared from Europe before the falling temperatures that happened during the Pleistocene Period (Pignatti 1978; Rodríguez-Sánchez et al. 2009, 2010), but taxa such as *Laurus nobilis* L., *Ilex aquifolium* L., *Rhododendron ponticum* L., *Prunus lusitanica* L. and *Buxus sempervirens* L. (Barrón 2003; Barrón et al. 2010) can still be found.

Currently, the Portuguese laurel occurs in the Ibero-Maghrebian region, specifically in SW France (western Pyrenees), Spain (center and north), Portugal (center and north) and Moroccan Rif mountains (Blanca and Guardia 1998). Acid substrates, e.g. schists, granites, quartzites or shale between 200 and 900 m of altitude, are its ecological optimum in the Iberian Peninsula (Franco 1964; Beltrán 2006; Calleja and Ollero 2009). In Morocco, the Portuguese laurel lives from 900 to 1700 meters of altitude and its optimum is the Rif mountains, between 1100 and 1400 m of altitude (Romo 2009). However, according to IUCN criteria, this species is globally Endangered (A2c), mainly due to threats such as fire (Lazare 1995), overcutting and forest management activity, as well as a decrease in water availability (Vivero 1998). According to Calleja and Ollero (2009), Mountains of Açor and Estrela harbour more than half of the individuals of *P. lusitanica* existing in the Iberian Peninsula. Mata da Margaraça was the place with the largest Portuguese laurel population (Calleja et al. 2009), however vegetation on this site was partly destroyed by fire in 2017 (Raposo et al. 2021) and currently is in recovery with the contribution of project Life-Relict (NAT/PT/000754).

Currently, these communities are refugees in transition zones from the Mediterranean to the temperate macrobioclimate, constituting important functions in ecosystem services (Poldini et al. 2020). The first studies about the ecological features of *P. lusitanica* referred to a hygrophilous position (Ladero 1970), but this was later changed to a temporihygrophilous and climatophilous position (Ladero 1976). In syntaxonomic terms, the communities described in Portugal are included in the temporihygrophilous woodlands of *Fraxino angustifoliae-Ulmenion minoris*, *Populion albae*, *Populetalia albae*, *Salici purpureae-Populetea nigrae* (Costa

CONTACT Mauro Raposo mraposo@uevora.pt Department of Landscape, Environment and Development, School of Science and Technology, University of Évora, 7000-671 Évora, Portugal

Published online 22 Nov 2021

et al. 2012). In the centre of Spain, this association was described as being filiated in microphanerophytes communities of *Arbuto unedonis-Laurion nobilis*, *Pistacio-Rhamnetalia alaterni*, *Quercetea ilicis*, that occupy siliceous substrates (Ladero 1976) and later passed on to *Fraxino angustifoliae-Ulmenion minoris* (Rivas-Martínez 2011). In Galicia (NW Spain), *Prunus lusitanica* occurs in associations of *Fraxino angustifoliae-Ulmenion minoris*, *Osmundo-Alnion glutinosae*, *Arbuto unedonis-Laurion nobilis*, *Quercion pyrenaicae* (Pulgar and Manso 2010).

Three associations and one subassociation characterized and named *P. lusitanica* were recognized in the Iberian Peninsula. *Frangulo alni-Prunetum lusitanicae* C. Lopes, J.C. Costa, Lousã & Capelo in J.C. Costa, C. Lopes, Capelo & Lousã 2000 is an association found in the Montemuro and Estrela Sierran sector (Costa et al. 2015). *Luzulo henriquesii-Prunetum lusitanicae* Honrado, P. Alves, Lomba, Torres & B. Caldas 2007 is an association found in the territories of the Northern Lusitanian Sierra Sector (Honrado et al. 2007). *Viburno tini-Prunetum lusitanicae* Ladero 1976 is an association of mountain ranges in the center of the Iberian Peninsula (Ladero, 1976). *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae* O. de Bolòs 1956 is an exclusive subassociation of Catalonia (Bolòs, 1956). Several *P. lusitanica* communities are not represented at the phytosociological level of association (Calleja 2006; Lara et al. 2007; Garilleti et al. 2012). The only indigenous population of *P. lusitanica* in France (Vallée des Aldudes) was discovered by J. Richter (Rouy, 1892) and later described in detail mostly by Neyraut (1910), Hibon (1927) and Allorge (1941). This species is legally protected in France (under Order of January 20th, 1982).

The main objective of this work is to improve the phytosociological knowledge of the communities of *P. lusitanica* in the Iberian Peninsula and south of France. Our study identifies and characterizes the bioclimate, the chorology and the ecology of these relict communities and their affiliations in the higher syntaxonomic units.

Materials and methods

The study area includes all biogeographic sectors where *P. lusitanica* communities are known, namely in the Iberian Peninsula (Figure 1).

Taxonomic and syntaxonomic nomenclature follows the works of Rivas-Martínez et al. (2002), Rivas-Martínez (2011), Costa et al. (2012), Foucault and Royer (2015), Mucina et al. (2016), Taleb and Fennane (2019) and 4th edition of the ICPN (Theurillat et al. 2020) is followed. For the *Querco-Fagetea* class we follow the work of Rivas-Martínez (2011), based on the reasons presented by Loidi (2020). For the identification of plants, Aizpuru et al. (2015), Castroviejo et al. (1986), Coutinho (1939), Franco (1971) and Franco and Rocha-Afonso (1994) are used. The biogeographical and bioclimatic framework follows the work of Rivas-Martínez et al. (2017a, 2017b). This work is conducted according to the the phytosociological method proposed by Braun-Blanquet (1979), Géhu and Rivas-Martínez (1981), Rivas-Martínez (2005) and updated by Biondi (2011).

For numerical analysis, we collected 12 field relevés, which were compared with another 22 relevés from literature review, in order to obtain a representative sample of communities dominated by *P. lusitanica* (Table 1). For the Portuguese territories, we followed Honrado et al. (2007), Costa et al. (2015) and we carried out two relevés in the Municipality of Mação (only known places). For the communities in the center of Spain we used data from Ladero (1976). For the Catalonian (Montseny District and Osona and Olot District), we performed three relevés, complemented by Bolòs (1956). For France, we carried out six relevés. Table 1 shows scientific names with the name of the genus and the respective subspecies when applicable.

Populations of *P. lusitanica* from north-central Spain (Ordunte, Baztán and Montes Vascos) are small and rarely dominant. For this reason, they are not significant enough to become an association, but rather a plant community that develops in the biotope of the temporihygrophilous ash of *Polysticho setiferi-Fraxinetum excelsioris* (Tüxen & Oberdorfer 1958) Rivas-Martínez ex C. Navarro 1982.

The transformation of cover-abundance values followed Van der Maarel (1979). We compiled an Excel© table with 34 relevés × 67 plants. Thirty four relevés were submitted to hierarchical cluster analysis using Ward's method with Euclidean distance to measure dissimilarity (Rodríguez-Guitián et al. 2007), using the software RStudio.

Results

Hierarchical analysis of the *P. lusitanica* communities in the Iberian Peninsula revealed a separation between the comunities with the greatest Atlantic influence in Portugal (Group A) and the central and northern Iberian Peninsula (Group B) (Figure 2).

A1. *Luzulo henriquesii-Prunetum lusitanicae* Honrado, P. Alves, Lomba, Torres & B. Caldas 2007

The A1 group brought together the *P. lusitanica* communities existing in the Serra of Peneda-Gerês, which corresponds in biogeographic terms to the North Lusitania Sierran Sector. *Luzulo henriquesii-Prunetum lusitanicae* is a mesotemperate humid to hyperhumid semihyperoceanic association, which develops in embedded valleys and slopes exposed to the north between 600 and 800 m above sea level (a.s.l.), on siliceous substrates. This syntaxon is rich in nemoral taxa such as *Ilex aquifolium*, *Saxifraga spathularis* Brot. and *Luzula sylvatica* subsp. *henriquesii* (Degen) P.Silva, but also elements of *Quertecea ilicis* such as *Erica arborea* L., *Ruscus aculeatus* L., *Arbutus unedo* L. and *Rubia peregrina* L. The temporihygrophilous character is given by the presence of taxa such as *Rubus* sp., *Frangula alnus* Mill., *Athyrium filix-femina* (L.) Roth, *Carex reuteriana* Boiss., *Osmunda regalis* L. and *Salix atrocinerea* Brot. This association appears at the edges and as the first step in the replacement of the more hygrophilic variants of the potential *Quercus robur* L. forests of the *Myrtillo-Querco roboris sigmetum*.

A2 *Frangulo alni-Prunetum lusitanicae* C. Lopes, J.C. Costa, Lousã & Capelo in J.C. Costa, C. Lopes, Capelo & Lousã 2000

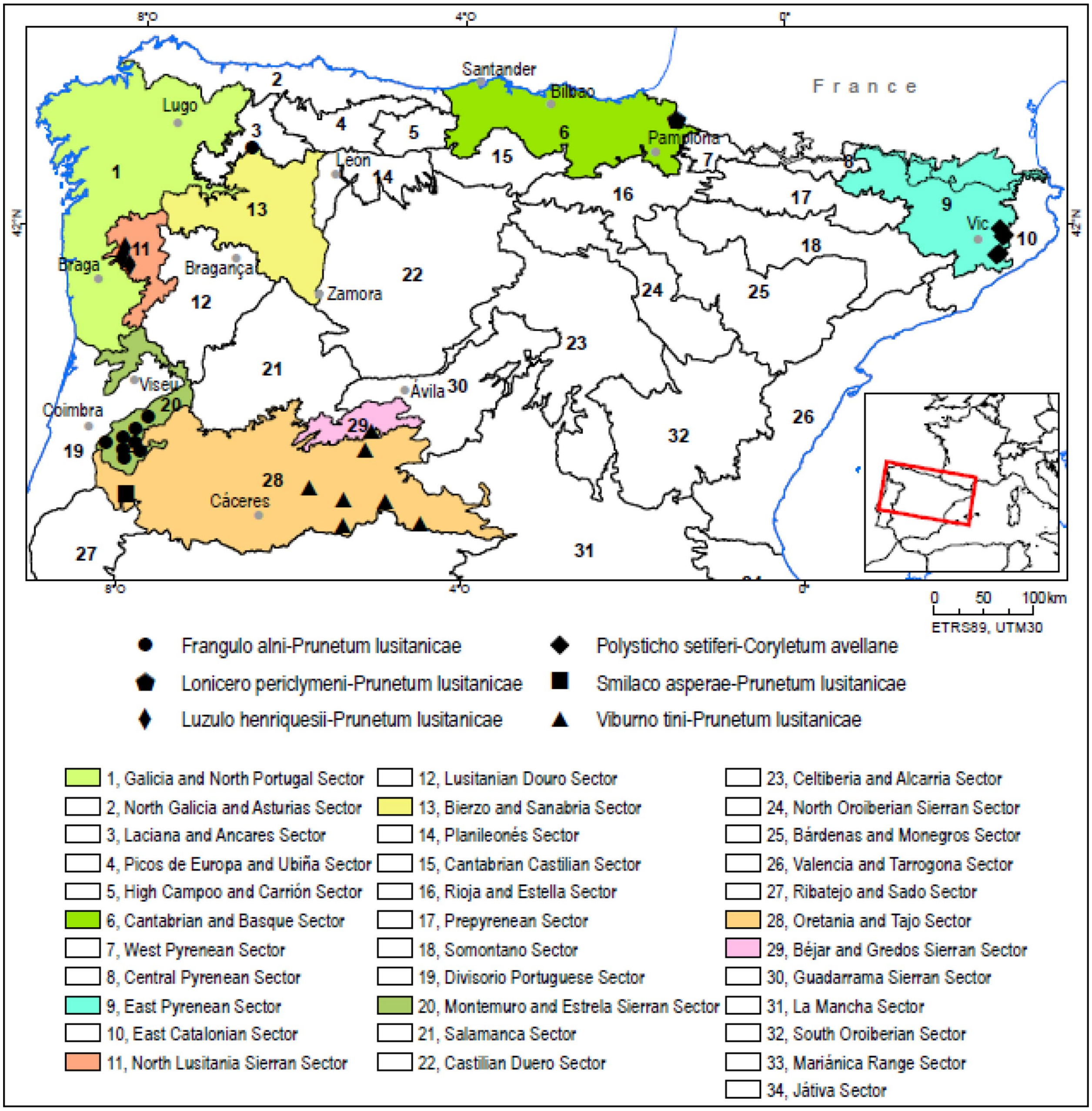


Figure 1. Study area and sampling points (adapted by Rivas-Martínez et al. 2017b).

Table 1. Origin of the used relevés.

Association	Original relevés	Bibliography relevés	Locality	Country
Frangulo alni-Prunetum lusitanicae	1	8	León and Serra da Lousã, Açor and Estrela	NW of Spain and central Portugal
Luzulo henriquesii-Prunetum lusitanicae	–	5	Serra da Penada-Gerês	NW Portugal and Spain
Viburno tini-Prunetum lusitanicae	–	7	Gredos, Las Villuercas and Montes de Toledo	Central Spain
Smilaco asperae-Prunetum lusitanicae ass. nova	2	–	Mação	Central Portugal
Lonicero periclymeni-Prunetum lusitanicae ass. nova	6	–	Vallée des Aldudes	France
Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae	3	2	Montseny and Osor	Northeastern Iberian Peninsula
	12	22		

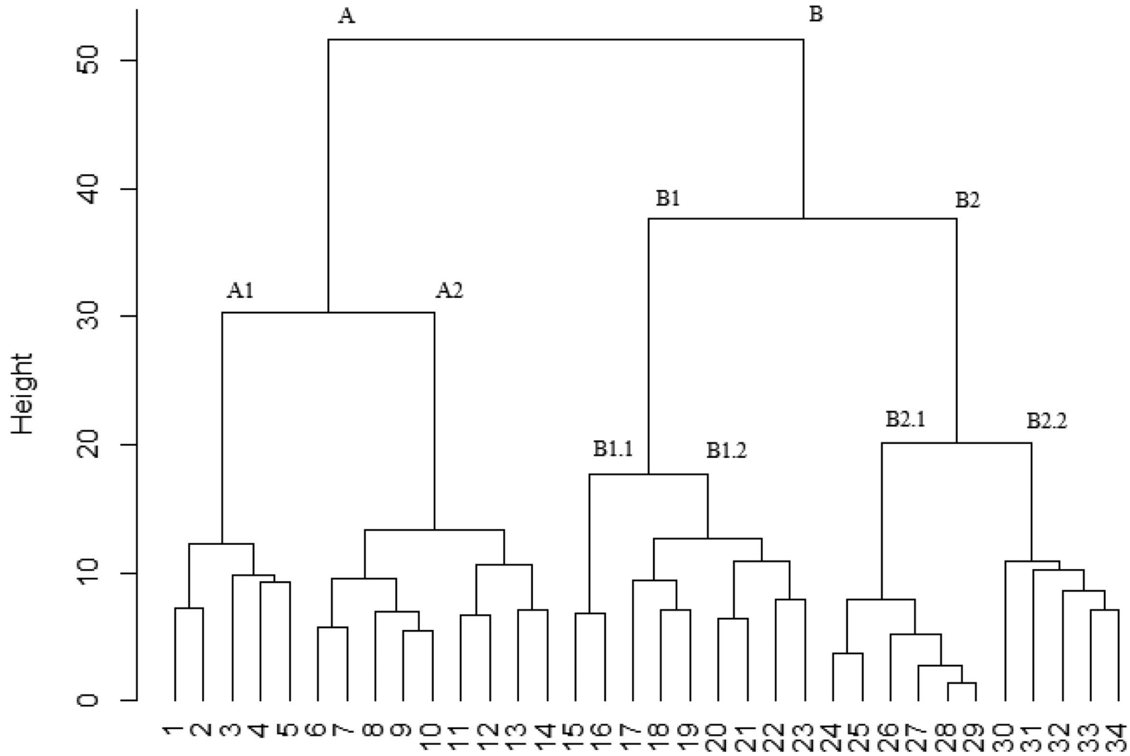


Figure 2. Dendrogram with *P. lusitanica* communities. A1 (1-5) - *Luzulo henriquesii-Prunetum lusitanicae*; A2 (6-14) – *Frangulo alni-Prunetum lusitanicae*; B1.1 (15-16) – *Smilaco asperae-Prunetum lusitanicae* ass. nova; B1.2 (17-23) – *Viburno tini-Prunetum lusitanicae*; B2.1 (24-29) - *Lonicero periclymeni-Prunetum lusitanicae* ass. nova; B2.2 (30-34) – *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae*.

The A2 group brought together the communities of the mountains of the center of mainland Portugal, namely the mountains of Lousã, Açor and Estrela, which belong, in biogeographical terms, to the Estrela Sierran District. *Frangulo alni-Prunetum lusitanicae* is a mesosubmediterranean humid to hyperhumid semihyperoceanic to euoceanic association, which presents its ecological optimum between embedded valleys and slopes exposed to the north from 350 to 800 m a.s.l., on siliceous substrates. This syntaxon is characterized by the strong presence of plants such as *Frangula alnus*, *Hedera hibernica* Bean, *Polystichum setiferum* (Forssk.) Woynar and *Lonicera periclymenum* subsp. *hispanica* (Boiss. & Reut.) Nyman. The temporihygrophilous character is given by the presence of taxa such as *Salix atrocinerea*, *Fraxinus angustifolia* Vahl, *Carex pendula* Huds., *Rubus ulmifolius*, *Oenanthe crocata* L. and *Osmunda regalis*. Sometimes this association occurs in a mesophilic position on very humid slopes with northern exposure, such as the Mata da Margaraça (Serra do Açor) and on the slope in front of the village of Cabeça (Serra da Estrela). In this ecological position, the hygrophilic taxa are absent and the domain of plants as *Ilex aquifolium*, *Arbutus unedo*, *Viburnum tinus*, *Lonicera periclymenum* subsp. *hispanica* and *Quercus robur* subsp. *broteroana* O.Schwartz. This association appears at the edges and as the first step in the replacement of the more hygrophilic variants of the potential *Quercus robur* subsp. *broteroana* forests of the *Viburno tini-Querco roboris sigmetum*.

The relevé carried out on the Fresnedelo stream (Sierra de Ancares, Spain) came close to this association due to the strong presence of *taxa* such as *Frangula alnus*, *Lonicera periclymenum* subsp. *hispanica*, *Rubus ulmifolius*, *Hedera hibernica*, *Polystichum setiferum* and *Erica arborea*. However, this territory has some original flora marked by the presence of *Quercus orocantabrica* Rivas Mart. & al. and *Agrostis durieui* Boiss. & Reuter ex Gand.

B1.1 *Smilaco asperae-Prunetum lusitanicae* *ass. nova hoc loco*

Group B1.1 brought together the low-altitude communities of the center of Portugal found in the municipality of Mação, belonging in biogeographic terms to the South Beira District, approaching the communities of *P. lusitanica* in the center of the Iberian Peninsula (Oretana Range and Tajo Sector). These communities represent the southern limit of the natural distribution area of *P. lusitanica* in mainland Portugal. *Smilaco asperae-Prunetum lusitanicae ass. nova* is a thermomediterranean subhumid to humid euoceanic association, which develops in valleys nestled between 200 and 300 meters above sea level, on siliceous substrates. This syntaxon is characterized by the presence of thermophilic plants, namely *Smilax aspera* L., *Myrtus communis* L. and *Pistacia lentiscus* L. (*Holotypus associationis hoc loco*, Tab. 2, relevé 16). The temporihygrophilous character is given by the presence of taxa such as *Frangula alnus*, *Galium broterianum* Boiss., *Salix atrocinerea*, *Carex pendula*, *Osmunda regalis* and *Rubus ulmifolius*. This association lives on the fringes of the alder woodland of the *Scrophulario scorodoniae-Alnetum glutinosae*. Unfortunately, Portuguese laurel communities were found only on the Aziral and on the Fraguedo rivers, so it was not possible to collect more relevés.

B1.2 *Viburno tini-Prunetum lusitanicae* Ladero 1976

The B1.2 group brought together the communities of the center of the Iberian Peninsula, existing in the Sierra de

Gredos, Las Villuercas and Montes de Toledo, corresponding in biogeographic terms to the Oretana Range and Tajo Sector. *Viburno tini-Prunetum lusitanicae* is a mesomediterranean humid semicontinental association, whose ecological optimum is between 600 and 900 meters of altitude, in silicic substrates (*Lectotypus associationis hoc loco*, relevé 23 in tab., pp. 216 & 217 in Ladero (1976) and in tab. 3 *hoc loco*). This syntaxon is characterized by the presence of *Quercus broteroi*, *Viburnum tinus*, *Arbutus unedo* and *Fraxinus angustifolia*. However, initially this association was described with the subassociation *fraxinetosum angustifoliae* for the same chorology. For this reason, we propose that the absence of the hygrophilic taxa *Fraxinus angustifolia*, *Vitis vinifera* subsp. *sylvestris* (C.C.Gmel) Hegi and *Tamus communis* L. is considered only a drier variation. In fact, the dissimilarity analysis did not identify significant differences between the *typus* association and the *fraxinetosum angustifoliae* subassociation (Figure 2). Thus, this association integrates the forest edges or is part of the first stage of replacement of the forests dominated by *Arbuto unedonis-Quercetum pyrenaicae* and the ash trees of *Ranunculo ficariiformis-Fraxinetum angustifoliae*.

B2.1 *Lonicero periclymeni-Prunetum lusitanicae* *ass. nova hoc loco*

The B2.1 group brought together the communities of Vallée des Aldudes (western Pyrenees – France), corresponding in biogeographic terms to the Labourd and Baztán District (Cantabrian and Basque Sector). *Lonicero periclymeni-Prunetum lusitanicae ass. nova* is a mesotemperate hyperhumid euoceanic association, whose ecologial optimum is between 400 and 600 m a.s.l., on silicic substrates (*Holotypus associationis hoc loco*: Tab. 4, relevé 26). The *P. lusitanica* communities occur in hillsides formed by sandstone conglomerates, unlike other places in the Cantabrian and Basque Sector where this species occurs along water sheds. This substrate is more xeric at the surface and presents deep hydric compensation, identified by the presence of a group of hygrophilic plants, such as *Dryopteris carthusiana* (Vill.) H.P.Fuchs and *Hypericum androsaemum* L. This hygrophilic position associated with highly frequent fogs and a hyperhumid ombrotype allows the occurrence of *P. lusitanica* northern limit range. The Portuguese laurel exceed not 6 meters in heigh, on rocky substrate and thin soil and these stands are poor in number of species, making it difficult to install large climatophilic trees, such as oaks and beech trees (Figure 3). From all Portuguese laurel communities known to date, *Lonicero periclymeni-Prunetum lusitanicae ass. nova* this is the one that shows more temperate macrobioclimate features. This community in France is surrounded by climatophilous woods of *Quercus robur* of *Hyperico pulchri-Quercetum roboris teucrietosum scorodoniae*, in the upper hillside, and by the climatophilous beechwood of *Saxifrago hirsutae-Fagetum sylvaticae* in the mountain area.

In France, this Portuguese laurel community represents the potential of a semiheliophilous, temporihygrophilous vegetation of upper hillsides. In terms of dynamics, this community has a substitution stage formed by bushwoods of the alliance *Daboecion cantabricae*, due to the presence of *Daboecia cantabrica* (Huds.) K.Koch and *Calluna vulgaris* (L.) Hull. The absence of an herbaceous substitution stage can be attributed to the rocky/gravelly character of this specific area. On the other side, high air humidity promotes the growth of a dense moss layer that frequently exceeds 75% of coverage and that also grows along tree trunks, sometimes reaching 3 meters in height (Figure 4).

B2.2 *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae* O. de Bolòs 1956

The B2.2 group brought together the communities of Sierran of Montseny and Osor, corresponding in biogeographic terms to the Montseny District and Osona and Olot District (East Pyrenean Sector). *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae* is a mesotemperate humid to hyperhumid euoceanic to semicontinental subassociation, that develops among the 350 and 900 m of altitude, in neutral-silicic substrates (Table 5). This community is always sheltered in somewhat shady areas, characterized by the high presence of ferns and lichens. *Taxa* such as *Hedera helix* L., *Corylus avellana* L., *Daphne laureola* L., *Fraxinus excelsior* L., *Buxus sempervirens* and *Euonymus europaeus* L. are frequent in this association. The presence of *Quercus canariensis* Willd. was also occasionally identified. This syntaxon appears on the edge and as the first step to replace the climatophilous beech forests of *Helleboro occidentalis-Fago sylvaticae*

Figure 3. Nebulous aspect of the relict *Lonicero periclymeni-Prunetum lusitanicae ass. nova* in Vallée des Aldudes – France (in 9/9/2018).

Figure 4. Ecological condition of the *P. lusitanica* communities in the western Pyrenees (in 9/9/2018).

Table 2. *Smilaco asperae-Prunetum lusitanicae ass. nova hoc loco* (*Salici purpureae-Populetea nigrae*, *Populetalia albae*, *Populion albae*, *Fraxino angustifoliae-Ulmenion minoris*).

No. of relevé	15	16	
Altitude (m)	274	**265**	
Surface (m^2)	90	**120**	
Cover (%)	70	**75**	
Slope (%)	5	**5**	
Average heigt (m)	6	**7**	
Exposition	W	**NW**	
N.° of taxa	23	**32**	
Characteristics			Presence
Prunus lusitanica L.	3	**4**	V
Smilax aspera L.	1	**3**	V
Myrtus communis L.	1	**2**	V
Pistacia lentiscus L.	+	**1**	V
Blechnum spicant (L.) Roth	1	**+**	V
Galium broterianum Boiss. & Reut.	1	**+**	V
Lonicera hispanica (Boiss. & Reut.) Nyman	.	**+**	III
Hedera hibernica (G.Kirchn.) Bean	.	**+**	III
Carex reuteriana (Boiss.) Luceño & Aedo	.	**+**	III
Characteristics of uni. sup.			
Frangula alnus Mill.	2	**1**	V
Polystichum setiferum (Forssk.) Woyn.	+	**+**	V
Osmunda regalis L.	+	.	III
Carex pendula Huds.	+	.	III
Salix atrocinerea Brot.	.	**+**	III
Brachypodium sylvaticum (Huds.) P.Beauv.	.	**+**	III
Companions			
Viburnum tinus L.	2	**2**	V
Arbutus unedo L.	1	**1**	V
Rubia peregrina L.	1	**+**	V
Rubus ulmifolius Schott	1	**+**	V
Pteridium aquilinum L.	1	**+**	V
Phillyrea angustifolia L.	+	**+**	V
Erica arborea L.	+	**+**	V
Holcus mollis L.	+	**+**	V
Cytisus striatus (Hill) Rothm.	+	**+**	V
Viola riviniana Rchb.	+	**+**	V

Other taxa: + *Salix salviifolia* subsp. *australis* Franco, *Athyrium filix-femina* (L.) Roth and *Asplenium billoti* F.W. Schultz in 1; + *Molinia caerulea* (L.) Moench; *Mentha suaveolens* Ehrh.; *Erica scoparia* L.; *Cystopteris viridula* (Desv.) Desv.; *Prunella vulgaris* L.; *Asplenium trichomanes* L.; *Rhamnus alaternus* L.; *Phillyrea latifolia* L. and *Asplenium onopteris* L. in 2.Locations: Relv. 15 (original) – Ribeira do Aziral (Mação – Portugal); Relv. 16 (original) – Ribeira do Fraguedo (Mação – Portugal).

sigmetum and of the temporihygrophilous ash trees of the *Doronico pardalianchis-Fraxino excelsioris sigmetum*.

Syntaxonomical scheme (Annex I shows the syntaxonomical scheme according to Mucina et al. (2016)):

QUERCO-FAGETEA SYLVATICAE Braun-Blanquet & Vlieger in Vlieger 1937

Betulo pendulae-Populetalia tremulae Rivas-Martínez & Costa 2002

Corylo avellanae-Populion tremulae (Braun-Blanquet ex O. de Bolòs 1973) Rivas-Martínez & Costa 1998

Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae O. de Bolòs 1956

RHAMNO CATHARTICII-PRUNETEA SPINOSAE Rivas Goday & Borja ex Tüxen 1962

Pyro spinosae-Rubetalia ulmifolii Biondi, Blasi & Casavecchia in Biondi et al. 2014

Lonicerion periclymeni Géhu, B. de Foucault & Delelis ex B. de Foucault & J.-M. Royer 2015

Lonicero periclymeni-Prunetum lusitanicae *ass. nova hoc loco*

SALICI PURPUREAE-POPULETEA NIGRAE (Rivas-Martínez & Cantó ex Rivas-Martínez, Bascones, T.E. Díaz, Fernández-González & Loidi) Rivas-Martínez & Cantó 2002

Populetalia albae Braun-Blanquet ex Tchou 1948

Populion albae Braun-Blanquet ex Tchou 1948

Fraxino angustifoliae-Ulmenion minoris Rivas-Martínez 1975

Frangulo alni-Prunetum lusitanicae C. Lopes, J.C. Costa, Lousã & Capelo in J.C. Costa, C. Lopes, Capelo & Lousã 2000

Luzulo henriquesii-Prunetum lusitanicae Honrado, P. Alves, Lomba, Torres & B. Caldas 2007

Smilaco asperae-Prunetum lusitanicae *ass. nova hoc loco*

Viburno tini-Prunetum lusitanicae Ladero 1976

Discussion

The *P. lusitanica* communities in the Iberian Peninsula and France live mainly in a temporihygrophilic position and in some favorable conditions in a mesophilic position. In the Iberian Peninsula, these communities live their ecological optimum in locations with a humid to hyperhumid meso-submediterranean bioclimate, enriched by plants of the *Quercetea ilicis*, such as *Erica arborea*, *Ruscus aculeatus* and *Rubia peregrina* (Costa et al. 2001; Honrado et al. 2007; Calleja and Ollero 2009; Pulgar and Manso 2010; Kondraskov et al. 2015), appearing to be absent in the rivers and streams of southern mainland Portugal (Raposo et al. 2020). In order to differentiate the characteristic plants of each syntaxon studied, a synthetic table is presented (Table 6).

Although the *P. lusitanica* communities in the municipality of Mação are geographically close to the *Frangulo alni-Prunetum lusitanicae* association, the absence of *Quercus robur* subsp. *broteroana*, *Ilex aquifolium*, *Hypericum androsaemum* and *Saxifraga spathularis* allowed a closer relationship with the communities of the center of the Iberian Peninsula of the *Viburno tini-Prunetum lusitanicae* association. Although this association is rich in *Quercetea ilicis* elements, its proximity to water gives it a temporihygrophilous character. This fact is reinforced by the presence of hygrophilic elements such as *Salix atrocinerea*, *S. salviifolia* Brot., *Molinia caerulea* (L.) Moench, *Mentha suaveolens* Ehrh., *Carex reuteriana* and *Galium broterianum*. For this reason, we have included this new syntaxon in *Fraxino angustifoliae-Ulmenion minoris*, *Populion albae*, *Populionalia albae*, *Salici purpureae-Populetea nigrae*.

The Portuguese laurel communities in France develop in irregular clusters of hydrolyzed red sandstone, thus presenting low plant diversity. The minoriseries *Lonicero periclymeni-Pruno lusitanicae minorisigmetum* does not have an arboreal climax due to the hostile edaphic environment unfavorable to colonization by pedunculated oaks and beech trees (Amigo et al. 2017). For this reason, the *P. lusitanica* communities in France correspond to a minoriseries of vegetation, according to the concept of Rivas-Martínez (2011) and Lazare (2019b). It would be

Table 3. *Viburno tini-Prunetum lusitanicae* (*Salici purpureae-Populetea nigrae*, *Populetalia albae*, *Populion albae*, *Fraxino angustifoliae-Ulmenion minoris*).

No. of relevé	17	18	19	20	21	22	23	
Altitude (m)	900	900	800	850	800	800	**600**	
Surface (m²)	50	40	50	50	50	50	**50**	
Cover (%)	95	95	90	100	100	100	**100**	
Slope (%)	4	2	4	.	.	.	**6**	
Exposition	N	NO	S	S	NO	NO	**N**	
N° of taxa	14	8	11	13	22	11	**18**	
Characteristics								Presence
Prunus lusitanica L.	4	4	4	5	4	5	**4**	V
Quercus broteroi (Cout.) Rivas Mart. & Sáenz de Rivas	2	3	2	2	4	2	**2**	V
Viburnum tinus L.	2	3	2	.	2	2	**2**	V
Arbutus unedo L.	1	.	2	2	2	2	**1**	V
Daphne gnidium L.	.	.	+	+	+	+	**+**	IV
Fraxinus angustifolia Vahl.	.	.	.	.	2	2	**2**	III
Hedera canariensis Willd.	.	.	+	.	.	2	**+**	III
Vitis sylvestris (C.C.Gmel.) Hegi	.	.	.	.	2	.	**2**	II
Ruscus aculeatus L.	2	.	.	+	.	.	.	II
Asplenium onopteris L.	+	.	.	.	1	.	.	II
Tamus communis L.	.	.	.	.	+	1	.	II
Pistacia terebinthus L.	.	.	.	.	+	.	**+**	II
Companions								
Rubus sp.	2	2	+	+	.	1	**1**	V
Lonicera hispanica (Boiss. & Reut.) Nyman	2	1	.	2	1	.	**1**	IV
Pteridium aquilinum L.	.	1	.	2	2	.	**2**	III
Erica arborea L.	.	.	2	1	+	.	**+**	III
Phillyrea angustifolia L.	.	.	2	2	2	.	.	III
Teucrium scorodonia L.	1	.	.	1	.	.	**2**	III
Viola riviniana Rchb.	+	1	.	.	.	.	**2**	III
Brachypodium sylvaticum (Huds.) P.Beauv.	1	.	+	.	+	.	.	III
Blechnum spicant L.	.	.	.	.	+	.	**2**	II
Clinopodium vulgare L.	1	.	.	.	.	.	**+**	II
Cistus psilosepalus Sweet	.	.	1	+	.	.	.	II
Frangula alnus Mill.	.	.	.	2	.	.	.	II
Helleborus foetidus L.	1	.	.	.	.	.	.	I
Cynosurus elegans Desf.	.	.	.	.	1	.	.	I

Other taxa: + *Athyrium filix-femina* (L.) Roth; *Bryonia dioica* Jacq.; *Scrophularia scorodonia* L. and *Lapsana communis* L. in 5; + *Acer monspessulanum* L. and *Juniperus oxycedrus* L. in 6; + *Quercus rotundifolia* Lam. in 7.
Locations: Relv. 17–23 (Ladero, 1976).

Table 4. *Lonicero periclymeni-Prunetum lusitanicae ass. nova* (*Rhamno catharticii-Prunetea spinosae*, *Pyro spinosae-Rubetalia ulmifolii*, *Lonicerion periclymeni*).

No. of relevé:	24	25	26	27	28	29	
Altitude (m):	515	495	**475**	410	515	530	
Surface (m²):	25	120	**200**	250	100	200	
Cover (%):	80	85	**85**	70	70	70	
Slope (%):	70	70	**60**	90	50	20	
Average heigt (m):	4-5	4-5	**<5**	<6	4-5	<6	
Exposition:	ESE	ESE	**ESE**	ESE	ESE	ESE	
N° of taxa	4	4	**5**	7	8	9	
Characteristics							**Presence**
Prunus lusitanica L.	5	5	**5**	4	4	4	V
Lonicera periclymenum L.	1	.	**2**	.	2	1	IV
Companions							
Pteridium aquilinum L.	.	2	**1**	3	2	+	V
Vaccinium myrtillus L.	.	3	**1**	.	2	2	IV
Rubus caesius L.	2	.	.	1	1	2	IV
Teucrium scorodonia L.	+	1	.	1	.	.	III
Hedera helix L.	.	.	**2**	.	+	.	II
Dryopteris carthusiana (Vill.) H.P.Fuchs	.	.	.	.	+	+	II
Polypodium interjectum Shivas	.	.	.	.	+	+	II
Hypericum androsaemum L.	.	.	.	+	.	.	I
Betula ×aurata Borkh.	.	.	.	+	.	.	I
Solanum dulcamara L.	.	.	.	+	.	.	I
Oxalis acetosella L.	.	.	.	.	.	+	I
Athyrium filix-femina (L.) Roth	.	.	.	.	.	+	I

Locations: Relv. 24–29 (original) – Banca, Vallée des Aldudes, Pyrénées-Atlantiques (France).

interesting to compare this case with the analogous case of the shrub community of *Crataegus germanica* (L.) Kuntze described by Marage and Jaccottey (2010). This Jurassic shrub community grows in pebbles surrounded by a climatophilous oakwood of *Quercus petraea* (Matt.) Liebl. that cannot colonize the pebbles. This means that the shrub community of *Crataegus germanica* represents the mature stage of an edaphophilous minoriseries. The syntaxonomical

Table 5. Relevés of the *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae* (*Querco-Fagetea sylvaticae, Betulo pendulae-Populetalia tremulae, Corylo avellanae-Populion tremulae*).

No. of relevé	30	31	32	33	34	
Altitude (m)	400	850	360	660	500	
Surface (m^2)	60	25	90	80	40	
Cover (%)	75	100	100	95	100	
Slope (%)	40	60	60	8	75	
Average height (m)	7	10	8	8	8	
Exposition	N	NE	NE	E	N	
N° of taxa	12	15	18	21	22	
Characteristics of association						Presence
Prunus lusitanica L.	3	5	5	4	3	V
Cardamine impatiens L.	.	+	.	+	+	III
Mnium affine Blandow	.	+	.	.	+	II
Athyrium filix-femina (L.) Roth	.	1	.	.	.	I
Thamnium alopecurum (Hedw.) Schimp.	.	.	.	.	+	I
Metzgeria conjugata Lindb.	.	.	.	.	+	I
Characteristics of *Querco-Fagetea sylvaticae*						
Hedera helix L.	+	5	2	2	3	V
Ilex aquifolium L.	+	.	+	2	.	III
Corylus avellana L.	.	.	1	+	+	III
Daphne laureola L.	+	.	+	+	.	III
Dryopteris filix-mas (L.) Schott	.	1	.	.	.	I
Fagus sylvatica L.	.	.	.	+	.	I
Poa nemoralis L.	.	.	.	.	+	I
Companions						
Polystichum setiferum (Forssk.) Moore ex Woynar	1	2	2	1	1	V
Rubus caesius L.	1	.	+	1	.	III
Buxus sempervirens L.	+	.	1	.	+	III
Fraxinus excelsior L.	+	.	.	1	+	III
Quercus ilex L.	+	.	+	+	.	III
Euonymus europaeus L.	+	+	+	.	.	III
Brachypodium sylvaticum (Huds.) P.Beauv.	.	+	+	.	+	III
Lonicera periclymenum L.	.	.	+	+	+	III
Castanea sativa L.	.	.	1	1	.	II
Ruscus aculeatus L.	.	.	2	.	+	II
Alnus glutinosa (L.) Gaertn.	.	+	.	.	+	II
Sambucus nigra L.	.	+	+	.	.	II
Hypericum androsaemum L.	.	.	.	+	+	II
Smilax aspera L.	.	.	.	1	.	I
*Geranium robertianum*L.	.	.	.	.	1	I
Clinopodium vulgare L.	.	.	.	.	1	I

Other taxa: + *Ficus carica* L., *Pteridium aquilinum* L. and *Phillyrea latifolia* L. in 1; + *Rubia peregrina* L., *Melica uniflora* Retz, *Viola reichenbachiana* Jord. ex Boreau and *Emerus major* Mill. in 2; + *Phyllitis scolopendrium* (L.) Newman, *Crataegus monogyna* Jacq.; *Acer monspessulanum* L. in 3; + *Prunus avium* L., *Asplenium onopteris* L., *Viburnum tinus* L., *Quercus canariensis* Willd. and *Laurus nobilis* L. in 4; + *Mnium undulatum* Hedw., *Prunus spinosa* L., *Moehringia trinervia* (L.) Clairv. and *Fragaria vesca* L. in 5.
Locations: Relevé 30 – Fot Fredu (original); Relevé 31 – Montseny (Bolòs 1956); Relevé 32 – Osor (original); Relevé 33 – Riells (original); Relevé 34 – Osor (Bolòs 1956).

position of the shrub associations that constitute the mature stage of these minoriseries deserves some attention. Given the lack of tree strata and as suggested by Marage and Jaccottey (2010) for the shrub community of *Crataegus germanica*, we propose that the association *Lonicero periclymeni-Prunetum lusitanicae* be affiliated to the *Lonicerion periclymeni*.

These examples support the concept that when a woody community belongs to several dynamic series, it is generally represented there by different syntaxa (Lazare 2019a).

In order to differentiate the main biogeographic, bioclimatic, soil characteristics and the type of vegetation, Table 7 presents a comparative table with all the studied associations.

Conclusions

This study allowed the integration of *P. lusitanica* communities from the Iberian Peninsula and southwestern France into phytosociological associations. The classification of these relict communities will allow inclusion and recognition through the Natura 2000 Network (92/43/EEC). In an upcoming habitats review, these communities are expected to be part of habitat 5230, called Arborescent matorral with *Laurus nobilis*.

The lauroid forests are concentrated in southwestern Europe, taking refuge in areas of transition between the temperate and mediterranean subhumid to hyperhumid macrobioclima. Thus, like the laurisilva forest of Macaronesia and alluvial forests in southern Europe, they deserve special conservation measures (Osorio et al. 2011; Gennai et al. 2021). In order to promote the communities of *P. lusitanica*, the selective control of heliophilous shrubs and of invasive exotic species is recommended, as well as management of grazing in these areas, in order to allow the natural regeneration of these communities. In France, where this plant is a legally protected species, it is necessary to control pastoral fires and the exploitation of inert materials. In order to increase the resilience of these communities in a scenario of drier climate change (Escriva-Bou et al. 2017), we suggest to control the use of water and conserve the upstream forests, in order to guarantee a correct infiltration of water

Table 6. Synthesis of the presence of characteristic and differentials plants of the associations of *P. lusitanica* (1 – L.h.-P.l.: *Luzulo henriquesii-Prunetum lusitanicae*; 2 – F.a.-P.l.: *Frangulo alni-Prunetum lusitanicae*; 3 – S.a.-P.l.: *Smilaco asperae-Prunetum lusitanicae*; 4 – V.t.-P.l.: *Viburno tini-Prunetum lusitanicae*; 5 – L.p.-P.l.: *Lonicero periclymeni-Prunetum lusitanicae ass. nova*; 6 – P.-C.p.l.: *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae.*

No. of association	1	2	3	4	5	6
Acronym	L.h.-P.l.	F.a.-P.l.	S.a.-P.l.	V.t.-P-l.	L.p.-P.l.	P.-C.p.l.
Differentials of association						
Dryopteris borreri (Newman) Fraser-Jenk.	V	.	.	.	.	.
Luzula henriquesii (Degen) P.Silva	IV	.	.	.	.	.
Omphalodes nitida Hoffmanns. & Link	IV	.	.	.	.	.
Pyrus cordata Desv.	IV	.	.	.	.	.
Sanicula europaea L.	III	.	.	.	.	.
Betula celtiberica Rothmal. & Vasc.	II	.	.	.	.	.
Eryngium juresianum (Laínz) Laínz	II	.	.	.	.	.
Taxus baccata L.	II	.	.	.	.	.
Quercus robur L.	II	.	.	.	.	.
Osyris alba L.	.	II	.	.	.	.
Luzula forsteri (Sm.) DC. in Lam. & DC.	.	II	.	.	.	.
Laurus nobilis L.	.	II	.	.	.	.
Scilla monophyllos Link	.	II	.	.	.	.
Quercus rotundifolia Lam.	.	I	.	.	.	.
Selaginella denticulata (L.) Spring	.	I	.	.	.	.
Quercus suber L.	.	I	.	.	.	.
Myrtus commmunis L.	.	.	V	.	.	.
Pistacia lentiscus L.	.	.	V	.	.	.
Galium broterianum Boiss. & Reut.	.	.	V	.	.	.
Carex reuteriana (Boiss.) Luceño & Aedo	.	.	III	.	.	.
Quercus broteroi Rivas-Mart. et al.	.	.	.	V	.	.
Hedera canariensis Willd.	.	.	.	III	.	.
Tamus communis L.	.	.	.	II	.	.
Pistacia terebinthus L.	.	.	.	II	.	.
Vitis sylvestris (C.C.Gmel.) Hegi	.	.	.	II	.	.
Fraxinus excelsior L.	.	.	.	.	.	IV
Euonymus europaeus L.	.	.	.	.	.	IV
Buxus sempervirens L.	.	.	.	.	.	IV
Corylus avellana L.	.	.	.	.	.	IV
Daphne laureola L.	.	.	.	.	.	IV
Mnium affine Blandow	.	.	.	.	.	II
Cardamine impatiens L.	.	.	.	.	.	II
Thamnium alopecurum (Hedw.) Schimp.	.	.	.	.	.	I
Metzgeria conjugata Lindb.	.	.	.	.	.	I
Characteristics of association						
Prunus lusitanica L.	V	V	V	V	V	V
Blechnum spicant (L.) Roth	V	IV	V	II	.	.
Ilex aquifolium L.	V	III	.	.	.	IV
Erica arborea L.	V	IV	V	IV	.	.
Hedera hibernica (G.Kirchn.) Bean	V	V	III	.	.	.
Lonicera periclymenum L.	V	.	.	.	IV	IV
Teucrium scorodonia L.	V	IV	.	III	III	.
Ruscus aculeatus L.	V	IV	.	II	.	.
Saxifraga spathularis Brot.	V	III	.	.	.	.
Vaccinium myrtillus L.	IV	.	.	.	V	.
Arbutus unedo L.	III	IV	V	V	.	.
Primula acaulis (L.) L.	III	II	.	.	.	.
Rubia peregrina L.	II	III	V	.	.	II
Hypericum androsaemum L.	II	II	.	.	I	II
Viola riviniana Rchb.	II	IV	V	IV	.	.
Asplenium onopeteris L.	.	V	III	II	.	I
Lonicera hispanica (Boiss. & Reut.) Nyman	.	V	III	IV	.	.
Polystichum setiferum (Forssk.) Woyn.	I	IV	V	.	.	V
Viburnum tinus L.	.	IV	V	V	.	.
Frangula alnus Mill.	III	IV	V	.	.	.
Brachypodium sylvaticum (Huds.) P.Beauv.	III	IV	V	.	.	III
Carex pendula Huds.	.	III	III	.	.	.
Phillyrea angustifolia L.	.	III	V	III	.	.
Daphne gnidium L.	.	II	.	IV	.	.
Fraxinus angustifolia Vahl.	I	II	.	III	.	.
Athyrium filix-femina (L.) Roth	.	II	.	.	.	I
Smilax aspera L.	.	.	V	.	.	I

into the soil and consequently greater water flow to the plants.

The Portuguese laurel communities are of great conservation importance, as they are currently out of their optimal ecological conditions. In view of climate change, there is a possibility that these areas present the first indications of the impact of concrete changes in the habitat, acting as reference areas for the regression or advancement of the chorology of *P. lusitanica*, especially in its chorological limits, such as in Mação (Portugal) or Vallée des Aldudes (France).

Table 7. Ecological framework of *Prunus lusitanica* communities in Iberian Peninsula and south of France (L.h.-P.l.: *Luzulo henriquesii-Prunetum lusitanicae*; F.a.-P.l.: *Frangulo alni-Prunetum lusitanicae*; S.a.-P.l.: *Smilaco asperae-Prunetum lusitanicae*; V.t.-P.l.: *Viburno tini-Prunetum lusitanicae*; L.p.-P.l.: *Lonicero periclymeni-Prunetum lusitanicae ass. nova*; P.-C.p.l.: *Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae*).

Sintaxa	Biogeography	Bioclime	Substrate	Type of vegetation
L.h.-P.l.	North Lusitania Sierran Sector	Mesotemperate humid to hyperhumid	Granites and granodiorites	Temporihygrophilous
F.a.-P.l.	Estrela Sierran District	Mesosubmediterranean subhumid to humid	Schists and sandstone	Mesophilous and temporihygrophilous
S.a.-P.l.	South Beira District	Termomediterranean subhumid	Schist and slate	Temporihygrophilous
V.t.-P.l.	Oretana Range and Tajo Sector	Mesomediterranean humid	Granite, schist, slate, quartzite and sandstone	Mesophilous and temporihygrophilous
L.p.-P.l.	Labourd and Baztán District	Mesotemperate hyperhumid	Sandstone and schists	Temporihygrophilous
P.-C.p.l.	East Pyrenean Sector	Termo to mesotemperate humid	Granite, granodiorites, quartzites, gneisses, slate and sandstones	Temporihygrophilous

Disclosure statement

No potential conflict of interest was reported by the author(s).

Annex I

Syntaxonomical scheme (according to Mucina et al., 2016):
CRATAEGO-PRUNETEA Tüxen 1962

Prunetalia spinosae Tüxen 1952

Astrantio-Corylion avellanae Passarge 1978

Polysticho setiferi-Coryletum avellanae prunetosum lusitanicae O. de Bolòs 1956

Pruno-Rubion radulae Weber 1974
Lonicero periclymeni-Prunetum lusitanicae *ass. nova hoc locoALNO GLUTINOSAE-POPULETEA ALBAE* P. Fukarek et Fabijanic 1968

Alno-Fraxinetalia excelsioris Passarge 1968

Fraxino-Quercion roboris Passarge 1968

Frangulo alni-Prunetum lusitanicae C. Lopes, J.C. Costa, Lousã & Capelo in J.C. Costa, C. Lopes, Capelo & Lousã 2000

Luzulo henriquesii-Prunetum lusitanicae Honrado, P. Alves, Lomba, Torres & B. Caldas 2007

Smilaco asperae-Prunetum lusitanicae *ass. nova hoc loco*

Viburno tini-Prunetum lusitanicae Ladero 1976

Funding

This work is funded by National Funds through FCT - Foundation for Science and Technology under the Project UIDB/05183/2020. We acknowledge of the European Commission's LIFE program, through the Life-Relict Project – Preserving Continental Laurissilva Relicts (NAT/PT/000754).

References

Aguiar C, Pinto B. 2007. Paleo-história e história antiga das florestas de Portugal continental: até à Idade Média. In: Silva J, editor. Árvores e Florestas de Portugal: floresta e Sociedade, Uma História Comum; Lisboa: Jornal Público, Fundação Luso-Americana para o Desenvolvimento, Liga para a Protecção da Natureza; p. 15–53.

Aizpuru I, Aseginolaza C, Uribe-Echebarría PM, Urrutia P, Zorrakin I. 2015. Claves ilustradas de la flora del País Vasco y territorios limítrofes. Zamudio: Printek, S.A.L..

Allorge P. 1941. A propos du *Prunus lusitanica* L. de la vallée de la Hayra (Basses-Pyrénées). Bull Soc Bot Fr. 88(1):61–69.

Amigo J, Rodríguez-Guitián MA, Honrado J, Alves P. 2017. The Lowlands and Midlands of Northwestern Atlantic Iberia. In: Loidi J., editor. The vegetation of the Iberian Peninsula. Cham: Springer International Publishing; p. 250.

Barrón E. 2003. Evolución de las floras terciarias en la Península Ibérica. Mongrafías del Real Jardín Botánico de Córdoba. 11:63–74.

Barrón E, Rivas-Carballo R, Postigo-Mijarra JM, Alcalde-Olivares C, Vieira M, Castro L, Pais J, Valle-Hernández M. 2010. The Cenozoic vegetation of the Iberian Peninsula: a synthesis. Rev Palaeobot Palynol. 162:382–402.

Beltrán R. 2006. Distribución y autoecología de "*Prunus lusitanica*" L. en la Península Ibérica. Investigación agraria. Sist Recur For. 15(1):187–198.

Biondi E. 2011. Phytosociology today: methodological and conceptual evolution. Plant Biosyst. 145(sup1):19–29.

Bolòs O. d. 1956. De vegetatione notulae, II. Collect Bot. V:244–252.

Braun-Blanquet J. 1979. Fitosociología. Bases para el estudio de las comunidades vegetales. Madrid: Ed. Blume.

Calleja JA. 2006. Geobotánica, estructura demográfica, consevación y biología predispersiva de Prunus lusitanica L. (loro) en la Península Ibérica. [Memoria de Tesis doctoral]. Madrid: Universidad Autónoma de Madrid.

Calleja JA, Garzón MB, Ollero HS. 2009. A Quaternary perspective on the conservation prospects of the Tertiary relict tree *Prunus lusitanica* L. J Biogeogr. 36(3):487–498.

Calleja J, Ollero H. 2009. Análisis e interpretación geobotánica de la estructura y composición florística de las loreras ibéricas. Ecologia. 22:45–71.

Castroviejo S, al. (coord.). 1986. Flora Ibérica. Plantas vasculares da Península Ibérica e Ilhas Baleares. Madrid: Real Jardín Botánico, CSIC.

Costa JC, Lopes C, Capelo J, Lousã M. 2001. Sintaxonomia das comunidades de *Prunus lusitanica* L. subsp. *lusitanica* no ocidente da Península Ibérica. Silva Lusitana. 8 (2):253–263.

Costa JC, Monteiro-Henriques T, Bingre P, Espírito-Santo D. 2015. Warm-temperate forests of Central Portugal: a mosaic of syntaxa. In: Box EO, Fujiwara K, editors. Warm-temperate deciduous forests around the northern hemisphere, geobotany studies. Cham: Springer International Publishing; p. 97–117.

Costa JC, Neto C, Aguiar C, Capelo J, Espírito Santo MD, Honrado JJ, Gomes CP, Monteiro-Henriques T, Sequeira M, Lousã M. 2012. Vascular plant communities in Portugal (continental, the Azores and Madeira). Glob Geobot. 2:1–180.

Coutinho AXP. 1939. Flora de Portugal (plantas vasculares). Lisboa: Bertrand.

Escriva-Bou A, Pulido-Velazquez M, Pulido-Velazquez D. 2017. Economic value of climate change adaptation strategies for water management in Spain's Jucar Basin. J Water Resour Plann Manage. 143(5):04017005.

Foucault B, Royer JM. 2015. Contribution au prodrome des végétations de France: les *Rhamno catharticae-Prunetea spinosae* Rivas Goday & Borja ex Tüxen 1962. Documents Phytosociologiques, Série 3. 2:152–345.

Franco JA. 1964. O azereiro e as ginjeiras bravas, Coimbra, 1964 - Biblioteca Nacional Digital. Boletim da Sociedade Portuguesa de Ciências Naturais, 2ª Série. 10:66–90.

Franco JA. 1971. Nova Flora de Portugal (Continente e Açores). Ed. Escolar. ed.

Franco JA, Rocha-Afonso ML. 1994. Nova Flora de Portugal (Continente e Açores). Ed. Escolar.

Garilleti R, Alarcón JAC, García FL. 2012. Vegetación ribereña de los ríos y ramblas de la España Meridional (peninsula y archipiélagos). Madrid: Ministério da Agricultura, Alimentação e Meio Ambiente. ed. Secretaría General Técnica.

Géhu JM, Rivas-Martínez S. 1981. Notions fondamentales de phytosociologia. In: Dierschke H, editor. IV-V. Ber. Int. Symp. Int. Vereinigung Vegetationsk, Vaduz.

Gennai M, Gabellini A, Viciani D, Venanzoni R, Dell'Olmo L, Giunti M, Lucchesi F, Monacci F, Mugnai M, Foggi B. 2021. The floodplain woods of Tuscany: towards a phytosociological synthesis. Plant Sociol. 58(1):1–28.

Hibon J. 1927. Note sur le "*Prunus lusitanica*" L. des environs de Banca (Basses-Pyrénées). Bull Soc Dendrol France. 61:5–6.

Honrado J, Alves P, Lomba Â, Torres J, Caldas FB. 2007. Ecology, diversity and conservation of relict laurel-leaved mesophytic scrublands in mainland Portugal. Acta Bot Gall. 154(1):63–77.

Kondraskov P, Schütz N, Schüßler C, Sequeira MM, Guerra AS, Caujapé-Castells J, Jaén-Molina R, Marrero-Rodríguez Á, Koch MA, Linder P, et al. 2015. Biogeography of Mediterranean hotspot biodiversity: re-evaluating the "Tertiary relict" hypothesis of Macaronesian laurel forests. PLos One. 10(7):e0132091.

Ladero M. 1970. Contribución al estúdio de la flora y vegetation de las comarcas de La Jara, Serranías de Ibor y Las Villuercas en la Oretana Central [Tesis doctoral]. Universidad Complutense de Madrid.

Ladero M. 1976. *Prunus lusitanica* L. (Rosaceae) en la Península Ibérica. Anales Inst. Bot. A.J. Cavanilles. 33:207–218.

Lara F, Garilleti R, Calleja JA. 2007. La vegetación de ribera de la mitad norte española. 2nd ed. Madrid: Centro de Estudios y Experimentación de Obras Públicas, CEDEX.

Lazare JJ. 1995. *Prunus lusitanica* L. In: Olivier L, Galland J-P, Maurin H, editors. Livre rouge de la flore menacée de France, Tome I: Espèces prioritaires. Paris: Secrétariat faune-flore; p. 372.

Lazare JJ. 2019a. Comment la symphytosociologie permet d'exercer un rétrocontrôle de la phytosociologie. Botanique. 5:101–108.

Lazare JJ. 2019b. La phytosociologie paysagère: vers une gestion intégrée de la biodiversité. Actes du colloque international "La Phytosociologie paysagère, des concepts aux applications", Brest, septembre 2014. Documents Phytosociologiques, Série 3. 9:33–47.

Loidi J. 2020. The concept of vegetation class and order in phytosociological syntaxonomy. Veg Classif Surv. 1:163–167.

Marage D, Jaccottey L. 2010. Un nouveau groupement à néflier (*Mespilus germanica* L.) dans le domaine continental français. J Bot Soc Bot France. 50:27–32.

Mucina L, Bültmann H, Dierßen K, Theurillat J-P, Raus T, Čarni A, Šumberová K, Willner W, Dengler J, García RG, et al. 2016. Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. Appl Veg Sci. 19(S1):3–264.

Blanca G, Guardia D. 1998. *Prunus*. In: Muñoz Garmendia F, Navarro C, editors. Flora Ibérica. Plantas Vasculares Da Península Ibérica e Ilhas Baleares, Vol. 6. Madrid: Real Jardín Botanico, CSIC; p. 444–466.

Neyraut ME-J. 1910. La station du *Prunus lusitanica* L. dans les Basses-Pyrénées. Bull Soc Bot France. 57(4):275–276.

Osorio VEM, Torre WWD, Scholz S. 2011. Relict ecosystems of thermophilous and laurel forest as biodiversity hotspots in Fuerteventura, Canary Islands. Plant Biosyst. 145(sup1):180–185.

Pardo A, Cáceres Y, Pulido F. 2018. Rangewide determinants of population performance in *Prunus lusitanica*: Lessons for the contemporary conservation of a Tertiary relict tree. Acta Oecol. 86:42–48.

Pignatti S. 1978. Evolutionary trends in Mediterranean flora and vegetation. Vegetatio. 37(3):175–185.

Poldini L, Vidali M, Castello M, Sburlino G. 2020. A novel insight into the remnants of hygrophilous forests and scrubs of the Po Plain biogeographical transition area (Northern Italy. Plant Sociol. 57(2):17–69.).

Pulgar , Manso, D. 2010. Datos sobre *Prunus lusitanica* L. (Rosaceae) en Galicia. Nova Acta Científica Compostelana. 19:33–47.

Raposo M, Nunes LJR, Quinto-Canas R, del Río S, Pardo FMV, Galveias A, Pinto-Gomes C. 2021. *Prunus lusitanica* L.: an endangered plant species relict in the central region of mainland Portugal. Diversity. 13(8):359.

Raposo M, Quinto-Canas R, Cano-Ortiz A, Spampinato G, Pinto Gomes C. 2020. Originalities of Willow of *Salix atrocinerea* Brot. in Europe Mediterranean. Sustainability. 12(19):8019.

Rivas-Martínez S. 2005. Notions on dynamic-catenal phytosociology as a basis of landscape science. Plant Biosyst. 139(2):135–144.

Rivas-Martínez S. 2011. Mapa de series, geoseries y geopermaseries de vegetación de España. Itinera Geobot II. 18:384.

Rivas-Martínez S, Díaz TE, Fernández-González F, Izco J, Loidi J, Lousã M, Penas A. 2002. Vascular plant communities of Spain and Portugal. Addenda to the syntaxonomical checklist of 2001. Part II. Itinera Geobot. 15:433–922.

Rivas-Martínez S, Penas Á, del Río S, Díaz González TE, Rivas-Sáenz S. 2017a. Bioclimatology of the Iberian Peninsula and the Balearic Islands. In: Loidi J, editor. The vegetation of the Iberian Peninsula: Volume 1. Plant and vegetation. Cham: Springer International Publishing; p. 29–80.

Rivas-Martínez S, Penas Á, Díaz González TE, Cantó P, del Río S, Costa JC, Herrero L, Molero J. 2017b. Biogeographic units of the Iberian Peninsula and Baelaric Islands to district level. A concise synopsis. In: Loidi J, editor. The vegetation of the Iberian Peninsula: Volume 1. Plant and vegetation. Cham: Springer International Publishing; p. 131–188.

Rodríguez-Guitián MA, Franco RR, Rego PR. 2007. Caracterização ecológica y florística de las comunidades lauroides del occidente de la Cornisa Cantábrica (Noroeste ibérica). Lazaroa. 28:35–65.

Rodríguez-Sánchez F, Arroyo J. 2008. Reconstructing the demise of Tethyan plants: climate-driven range dynamics of *Laurus* since the Pliocene. Glob Ecol Biogeogr. 17(6):685–695.

Rodríguez-Sánchez F, Guzmán B, Valido A, Vargas P, Arroyo J. 2009. Late Neogene history of the laurel tree (*Laurus* L., Lauraceae) based on phylogeographical analyses of Mediterranean and Macaronesian populations. J Biogeogr. 36(7):1270–1281.

Rodríguez-Sánchez F, Hampe A, Jordano P, Arroyo J. 2010. Past tree range dynamics in the Iberian Peninsula inferred through phylogeography and palaeodistribution modelling: a review. Rev Palaeobot Palynol. 162:507–521.

Romo À. 2009. Contribution to the knowledge of the Moroccan mountain vegetation. Collect Bot. 28:111–124.

Rouy MG. 1892. Plantes des Basses-Pyrénées, rares ou nouvelles pour la Flore Française. Bull Soc Bot France. 39(6):230–232.

Taleb MS, Fennane M. 2019. Vascular plant communities of Morocco: phytosociology, ecology and geography, geobotany studies. Cham: Springer International Publishing.

Theurillat J-P, Willner W, Fernández-González F, Bültmann H, Čarni A, Gigante D, Mucina L, Weber H. 2020. International Code of Phytosociological Nomenclature. 4th edition. Appl Veg Sci. Vol. 24; p. 1–62.

Van der Maarel E. 1979. Transformation of coverabundance values in phytosociology and its effects on community similarity. Vegetation. 39:97–114.

Vivero JL. 1998. IUCN Red List of Threatened Species: *Prunus lusitanica* subsp. *lusitanica*. IUCN Red List of Threatened Species.

CAPÍTULO III

AVALIAÇÃO DO ESTADO DE CONSERVAÇÃO DE *PRUNUS LUSITANICA* NO CENTRO DE PORTUGAL CONTINENTAL

Publicado como:

Raposo, M., Nunes, L.J., Quinto-Canas, R., del Río, S., Vázquez Pardo, F.M., Galveias, A., & Pinto-Gomes, C. (2021). *Prunus lusitanica* L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal. *Diversity* 13, (8): 359. https://doi.org/10.3390/d13080359

CAPÍTULO III. AVALIAÇÃO DO ESTADO DE CONSERVAÇÃO DE *PRUNUS LUSITANICA* NO CENTRO DE PORTUGAL CONTINENTAL

III.1. Intróito

Este Capítulo analisa o estado de conservação da maior subpopulação de *Prunus lusitanica* de toda a sua área de distribuição – o centro de Portugal Continental. A primeira seção deste artigo contextualiza a origem e a importância desta planta relíqua no contexto mediterrâneo, bem como as principais ameaças ao seu estado de conservação. A segunda seção é subdividida em três partes. A primeira apresenta um enquadramento geográfico e as principais características biofísicas da área de estudo. A segunda parte apresenta as metodologias adotadas para a recolha de dados no campo. A terceira parte aborda os critérios utilizados para realizar a modelação ecológica através do programa Maxent (Phillips et al., 2006). A quarta seção apresenta os resultados obtidos sobre os núcleos de *P. lusitanica* observados e comparam-se com os dados publicados no trabalho de Calleja (2006). Apresentam-se ainda algumas considerações sobre a regeneração natural do azereiro e pela primeira vez publicam-se imagens SEM (Scanning Electron Microscope) do seu pólen, acompanhadas com uma descrição morfológica. Análises de solos foram realizadas para determinar a quantidade de matéria orgânica presente em vários graus de conservação. A quinta e última parte destaca a redução do número de indivíduos de *P. lusitanica* nos últimos anos e a forte necessidade de intervenção, de modo a reduzir as principais ameaças à conservação desta relíquia paleotropical.

Calleja (2006) contabilizou todos os núcleos de *P. lusitanica* existentes na Península Ibérica conhecidos até à data, tendo reconhecido 16 232 indivíduos nas serras do centro de Portugal. Devido à importância patrimonial deste táxone, passados quinze anos da sua publicação, decidimos no âmbito desta Tese de Doutoramento verificar o seu estado populacional. Na verdade, sabendo à priori que as ações de conservação dedicadas ao azereiro em território nacional foram diminutas, que a sua regeneração natural é pouco relevante e que várias ameaças continuam a impactar sobre estas comunidades, pretendeu-se saber quantitativamente qual o verdadeiro grau de redução dos núcleos de azereiro neste território (Vivero, 1998). Embora a forte prospeção dos trabalhos de campo tenha resultado na identificação de novos núcleos populacionais, como são exemplo os azereiros de Mação e do Orvalho, observa-se uma redução geral no número de indivíduos e na qualidade do seu biótopo, sobretudo pela perda de solo, matéria orgânica e consequentemente menor retenção de água no solo (Gimeno-García et al., 2000).

A principal ameaça atual são os incêndios florestais, que para além de lavrarem grandes extensões de território, são cada vez mais recorrentes (Figura 1). Aliado a isso, estão as alterações climáticas que parecem favorecer os eventos de fogo no sul da Europa (Dupuy et al., 2020).

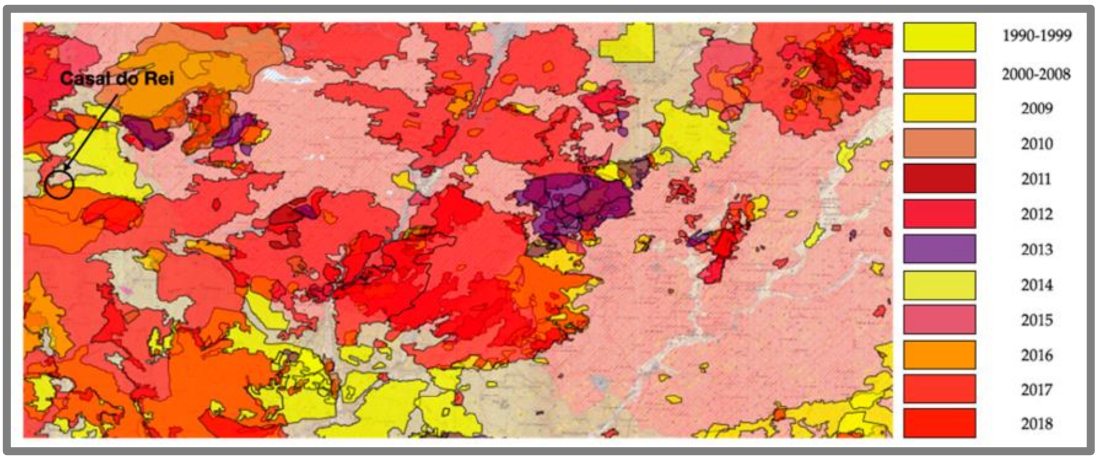


Figura S1. Sobreposição das áreas ardidas entre 1990 e 2018 na zona da Serra da Estrela (adaptado de (Nunes et al., 2020)).

De facto, tendo em conta as observações de campo, os indivíduos de azereiro mais afastados das linhas de água apresentam menor resiliência, enquanto os azereiros com maior disponibilidade hídrica têm capacidade para rebentar de toiça após os incêndios (Figura 2).

A segunda ameaça está relacionada com o fogo, uma vez que é incrementada por ele (Nunes et al., 2020). Dentro da área de estudo foram identificadas oito espécies vegetais invasoras que ocorrem dentro do biótopo do azereiro, as quais se apresentam as principais áreas de ocorrência, bem como os métodos de controlo mais adequados (Marchante et al., 2014).

Figura S2. Comportamento do azereiro após incêndio. (a) Situação mais seca sem regeneração de toiça. (b) Situação húmida com regeneração de toiça (fotografias: Mauro Raposo, 7 de agosto de 2019).

Realiza-se também uma modelação ecológica com base no programa Maxent, onde se incluíram oito fatores climáticos, nomeadamente a temperatura mínima, temperatura média, temperatura máxima, precipitação média anual, radiação solar, velocidade do vento e pressão de vapor de água (Fick & Hijmans, 2017). Os fatores edáficos não foram incluídos neste trabalho porque toda a área de estudo apresenta boa aptidão para a ocorrência do azereiro, nomeadamente solos siliciosos de origem xistosa ou granítica (Marques et al., 2005).

Referências

Calleja J. (2006). Geobotánica, estructura demográfica, conservación y biología predispersiva de *Prunus lusitanica* L. (loro) en la Península Ibérica. Memoria de Tesis Doctoral. Universidad Autónoma de Madrid.

Dupuy, J., Fargeon, H., Martin-StPaul, N., Pimont, F., Ruffault, J., Guijarro, M., Hernando, C., Madrigal, J., & Fernandes, P. (2020). Climate change impact on future wildfire danger and activity in southern Europe: A review. *Annals of Forest Science*, *77*(2), 35. https://doi.org/10.1007/s13595-020-00933-5

Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*, *37*(12), 4302–4315. https://doi.org/10.1002/joc.5086

Gimeno-García, E., Andreu, V., & Rubio, J. L. (2000). Changes in organic matter, nitrogen, phosphorus and cations in soil as a result of fire and water erosion in a Mediterranean landscape. *European Journal of Soil Science*, *51*(2), 201–210. https://doi.org/10.1046/j.1365-2389.2000.00310.x

Marchante, H., Morais, M., Freitas, H., & Marchante, E. (2014). *Guia prático para a identificação de plantas invasoras em Portugal*. Imprensa da Universidade de Coimbra. http://dx.doi.org/10.14195/978-989-26-0786-3

Marques, J. M. E., Marques, J. M. V. B., Chaminé, H. I., Afonso, M. J., Carreira, P. M., Fonseca, P. E., Cabral, J., Santos, F. A. M., Vieira, G. B. G. T., Mora, C., Gomes, A. A., Teixeira, J., Samper, J., Pisani, B. J., Aguiar, C., Gonçalves, J. A. A. P., Almeida, P. G., Cavaleiro, V., Carvalho, J. M., …

Rocha, F. T. (2005). Hydrogeological study of A High Mountain Area (Serra da Estrela, Central Portugal): A multidisciplinary approach. *Cadernos Del Laboratorio Xeológico de Laxe*, *30*, 145–166.

Nunes, L. J. R., Raposo, M. A. M., Meireles, C. I. R., Pinto Gomes, C. J., & Ribeiro, N. M. C. A. (2020). Fire as a Selection Agent for the Dissemination of Invasive Species: Case Study on the Evolution of Forest Coverage. *Environments*, *7*(8), 57. https://doi.org/10.3390/environments7080057

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*(3), 231–259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Vivero, J. L. (1998). *IUCN Red List of Threatened Species: Prunus lusitanica subsp. lusitanica*. IUCN Red List of Threatened Species. https://www.iucnredlist.org/en

CAPÍTULO III

III.2. Artigo: *Prunus lusitanica* L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal

diversity

MDPI

Article

Prunus lusitanica L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal

Mauro A. M. Raposo [1,2,*], Leonel J. R. Nunes [3], Ricardo Quinto-Canas [4], Sara del Río [5], Francisco M. Vázquez Pardo [6], Ana Galveias [7] and Carlos J. Pinto-Gomes [1,2]

[1] Department of Landscape, Environment and Planning, School of Science and Technology, University of Évora, 7000-671 Évora, Portugal; cpgomes@uevora.pt
[2] Mediterranean Institute for Agriculture, Environment and Development (MED), University of Évora, 7000-671 Évora, Portugal
[3] PROMETHEUS—Unidade de Investigação em Materiais, Energia e Ambiente para a Sustentabilidade, Escola Superior Agrária, Instituto Politécnico de Viana do Castelo, Rua da Escola Industrial e Comercial de Nun'Alvares, 4900-347 Viana do Castelo, Portugal; leonelnunes@esa.ipvc.pt
[4] Centre of Marine Sciences (CCMAR), Faculty of Sciences and Technology, Campus de Gambelas, University of Algarve, 8005-139 Faro, Portugal; rjcanas@ualg.pt
[5] Departamento de Biodiversidad y Gestión Ambiental (Área de Botánica), Instituto de Ganadería de Montaña (CSIC-ULE), Facultad de Ciencias Biológicas y Ambientales, Campus de Vegazana s/n, Universidad de León, E-24071 León, Spain; sara.delrio@unileon.es
[6] Departamento de Producción Florestal y Pastos, Centro de Investigación Finca La Orden-Valdesequera (CICYTEX), 06187 Guadajira, Spain; francisco.vazquezp@juntaex.es
[7] Department of Chemistry, ICT—Institute of Earth Sciences, School of Sciences and Technology & IIFA, University of Évora, 7000-671 Évora, Portugal; acgjorge@uevora.pt
* Correspondence: mraposo@uevora.pt

check for updates

Citation: Raposo, M.A.M.; Nunes, L.J.R.; Quinto-Canas, R.; del Río, S.; Pardo, F.M.V.; Galveias, A.; Pinto-Gomes, C.J. *Prunus lusitanica* L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal. *Diversity* **2021**, *13*, 359. https://doi.org/10.3390/d13080359

Academic Editors: Michael Wink and Mario A. Pagnotta

Received: 5 July 2021
Accepted: 31 July 2021
Published: 4 August 2021

Abstract: *Prunus lusitanica* L. is a paleotropical relic species with an Ibero-Maghrebian distribution, which is presently considered as an endangered species, recognized by the Natura 2000 Network (92/43/EEC) as a priority habitat for conservation in Europe. The mountains in the Portuguese mainland central region offer the best location for this species to occur. The main objective of this study is to measure the current conservation status of the communities of *P. lusitanica*, through the collection of field data, such as the number of existing individuals of each population and their location, which will then be comparatively analyzed based on the previous literature, published at least 15 years ago. Soil characterization analysis was carried out and the main threats to conservation were identified. As a result, a decline of approximately 40% was observed in the number of individuals and in the quality of their habitat. The main threats to their conservation were found to be the seasonal occurrence of rural fires and the expansion of invasive species, such as *Acacia dealbata* Link and *Ailanthus altissima* (Mill.) Swingle. Finally, we present the main management methodologies that should be considered for the valorization of this important vegetational relic in the central region of mainland Portugal.

Keywords: forest relic; habitat 5230*pt2; laurissilva; Natura 2000; red list

1. Introduction

The communities of *Prunus lusitanica* L. are true paleotropical relics that had their optimal ecological apogee during the Paleogene period [1,2]. Since then, with the evolution of the Mediterranean climate conditions to actual standards in the Iberian Peninsula, characterized mainly by the accentuation of a summer drought period, the Laurissilva forest has undergone a sharp reduction in its occupation area throughout southern Europe and, particularly, in the Mediterranean basin [3–5]. For this reason, the communities of *P. lusitanica* are currently refugees in certain specific locations with very particular conditions, where the orography allows for a greater atmospheric humidity and mild temperatures to occur [6,7]. This forest can be characterized by exhibiting persistent leafy vegetation, similar to what happens today in some well-preserved slopes in the north of the Island of Madeira (Portugal) and in the Canary Islands (Spain) [8]. Although much of the typical Laurissilva flora has disappeared from the European continent, several other species, such as *Rhododendron ponticum* L., *Laurus nobilis* L., *Ilex aquifolium* L. and *Myrica faya* Aiton, still persist as relic vegetation [1,9].

Evaluated as an Endangered species using the IUCN criteria established in 1998 [10], it is in Portugal that the most well-preserved and extensive communities of *P. lusitanica* still persist throughout its entire distribution area, with more than 19,000 individuals registered at a national level in 2005, corresponding to approximately 62% of the total global population [11]. Their communities are also recognized as a priority habitat for conservation in Europe through the Sectoral Plan of the Natura 2000 Network (92/43/EEC), called *Laurus nobilis* arborescent shrubs, of the Azereirais subtype (5230*pt2). However, due to the permanent threats that menace these habitats, a significant reduction in the number of individuals occurred [6]. Among all the threats identified in the Habitat File, the invasion of exotic plants that progressively colonize new areas and the recurrence and severity of rural fires can be highlighted [12–14]. In fact, at this moment, the impact of fires is, probably, the major concern for the reduction in the number of individuals and loss of the area occupied by this habitat, particularly in the central region of mainland Portugal [15]. An example of this is the rural fire that occurred in October 2017 and destroyed a significant part of the largest population of *P. lusitanica*, located in Mata da Margaraça (Arganil, Portugal). As can be seen in Figure 1, the entire area that surrounds the habitat was burnt and is slowly recovering 1 year after the rural fire.

Figure 1. Mata da Margaraça (Arganil, Portugal) after the rural fire that occurred in October 2017 (picture taken in 2018).

Thus, it is necessary to study and monitor, in detail, the evolution of *P. lusitanica* nuclei to reverse this situation of decline. The analysis of the edaphoclimatic conditions, as well as the anthropic action, allows us to understand and facilitate the adoption of adequate management methodologies for the valorization of the remaining populations of the continental Laurissilva. Based on these concerns, the main objectives of the present article are to update the population census of *P. lusitanica* in Serra da Estrela; to identify the main threats to its conservation; to identify management strategies to value this relict habitat.

2. Materials and Methods

2.1. Characterization of the Area under Study

The area under study is located on the reliefs of the central region of mainland Portugal, covering the area occupied by Serra da Estrela, Serra da Lousã, Serra de Alvéolos, Serra

Vermelha and Serra do Açor. The lower altitude found in the region is around 220 m and the highest altitude is around 1300 m (Figure 2). In biogeographic terms, the areas under study belong to the Montemuro and Estrela Sierran Sector and the Oretania and Tejo Sector [16]. The geology of the region is mostly formed by Precambrian and Cambrian metasediments that form the schist–greywacke complex, which is intercepted by a set of granitic rocks of hercynian origin [17]. Although a varied mineralogical composition can be found from granodiorites to leucogranites [18], the areas of occurrence of *P. lusitanica* are dominated by the schist soils, as well as fluvial sedimentary deposits with wavy and pronounced reliefs. These schists are part of the Malpica do Tejo formation and are dated from 500 to 650 million years ago [19]. Most of the soils in the area under study are lithosols, while some of which have evolved into cambisols over the years [20].

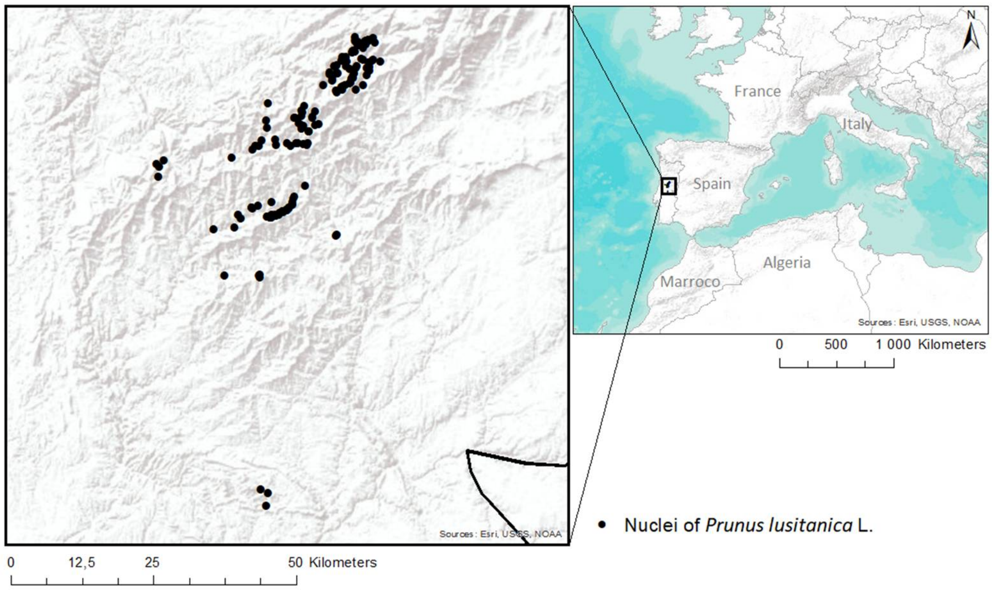


Figure 2. Location of the areas under study.

At the bioclimatic level, the area is located in the transition from the mediterranean to the temperate macrobioclimate (Table 1). The municipality of Mação represents the southern limit of the natural distribution area of *P. lusitanica* in mainland Portugal and is under the influence of a humid thermomediterranean bioclimate [21]. The northern limit of the area is part of the municipality of Seia and is influenced by a humid mesotemperate bioclimate (Figure 3).

Table 1. Bioclimatic data of the area under study: T—annual average temperature in Celsius degrees; P—average annual rainfall in millimeters; Tp—positive annual temperature in Celsius degrees; Pp—positive rainfall in millimeters; Io—annual ombrothermic index; It—thermicity index; Ic—simple continentality index (index based on Rivas-Martínez et al. [21]).

Location	T	P	Tp	Pp	Io	It	Ic
Mação	14.87	816.30	178.40	816.30	4.58	316.67	14.00
Lousã	14.03	1270.00	168.40	1270.00	7.54	324.33	9.10
Mata da Margaraça	13.53	1157.50	162.40	1157.50	7.13	277.33	13.90
Seia	13.03	906.90	156.40	906.90	5.80	264.33	14.00
Average	13.87	1037.68	166.40	1037.68	6.26	295.67	12.75

These conditions are favorable for the presence of *Quercus robur* subsp. *broteroana* O. Schwartz that constituted the potential climatophilic vegetation of much of the area under study, of the association *Viburno tini-Quercetum broteroanae* (Br.Bl., P. Silva, and Rozeira,

1955) J.C. Costa, Capelo, Honrado, Aguiar and Lousã 2002 corr. J.C. Costa and Monteiro-Henriques 2012. The communities of *Alnus lusitanica* Vít, Douda and Mandák, from the association *Scrophulario scorodoniae-Alnetum glutinosae* Br.-Bl., P. Silva and Rozeira 1955, appear in an edafo-hygrophilic position. In a secondary position, or as an edaphoxerophilous vegetation, are communities of *Quercus pyrenaica* Willd., *Q. suber* L. and *Q. rotundifolia* Lam., from the associations *Arbuto unedonis-Quercetum pyrenaicae* (Rivas-Goday in Rivas-Goday, Esteve, Galiano, Rigual and Rivas-Martínez, 1960) Rivas-Martínez 1987, *Sanguisorbo hybridae-Quercetum suberis* Rivas-Goday in Rivas-Goday, Borja, Esteve, Galiano, Rigual and Rivas-Martínez 1960 and *Teucrium salviastri-Quercetum rotundifoliae* Pinto-Gomes, Ladero, Cano, Meireles, Aguiar and P. Ferreira 2010, respectively [22].

However, the landscape is quite altered, dominating the stands of maritime pine (*Pinus pinaster* Aiton) and eucalyptus (*Eucalyptus globulus* Labill.). The communities of *P. lusitanica* in the Portuguese central region are ecologically positioned between the amyals of *Scrophulario scorodoniae-Alnetum glutinosae* and the oak trees of *Viburno tini-Quercetum broteroanae*, integrating with the slopes or as the first stage of replacement of these forests. Thus, the association *Frangulo alni-Prunetum lusitanicae* C. Lopes, J.C. Costa, Lousã and Capelo in J.C. Costa, C. Lopes, Capelo and Lousã 2000 often occupies a tempori-hygrophilic position or a climatophilic position, with water being compensated at a ground level or at an atmospheric level by the fog.

2.2. Data Collection

The interpretation of plant communities followed the phytosociological information based on the landscape and sigmatist approach presented by the Zurich-Montpellier Phytosociology School, as proposed by Braun-Blanquet [23], Géhu and Rivas-Martínez [24] and updated by Rivas-Martínez [25]. Taxonomic and sintaxonomic nomenclature followed the work of Rivas-Martínez et al. [26] and was complemented by more recent works, namely those by Costa et al. [22], Mucina et al. [27] and Taleb and Fennane [28]. For the identification of plant material, the works presented by Castroviejo et al. [29], Coutinho [30], Franco [31] and Franco and Rocha Afonso [32] were used. The biogeographical and bioclimatic framework followed the work presented by Rivas-Martínez et al. [16] and Rivas-Martínez et al. [21].

To count the number of individuals of *P. lusitanica*, field trips were conducted from 2018 to 2020, during which their geographical coordinates were recorded using GPS equipment with a precision of 1 m, as well as the number of individuals observed in each nucleus. These individuals were separated into two groups: more than 1.5 m and less than 1.5 m height. Regeneration over the year itself was not taken into account due to its small size. Although pollen crossing between individuals can occur at a distance of several kilometers, in this study, each population nuclei was differentiated when any specimen was more than 100 m away.

For the characterization of the pollen, scanning electron microscopy was carried out on a Phenom Pro X instrument. The *P. lusitanica* L. pollen was deposited on carbon adhesive tabs with a diameter of 12 mm. For the hydration of pollen grains, the carbon adhesive was placed in a humid chamber overnight. The pollen samples were photographed in high resolution (10 kV).

In order to understand the different existing soil conditions, five sampling points were randomly selected in four different zones: P1—habitat in good condition; P2—degraded habitat; P3—areas surrounding the habitat; P4—areas dominated by acacias. This approach resulted in the selection and collection of composite samples, separated into three depth horizons: 0–5 cm; 5–15 cm; 15–30 cm. In the sampling points with shallow soil, it was possible to collect only the first two most superficial horizons. The determination of the organic matter (OM) content was achieved using the muffle method following the procedure established by Goldin [33], with some modifications: beforehand, the samples were dried in an oven at 105 °C for a period of 24 h to eliminate all the water present in the samples [34]. After this period, the ceramic crucibles with the samples were placed in a muffle furnace and incinerated at a temperature of 550 °C for 3 h. Subsequently, the set (crucible + waste) was placed in a desiccator and then weighed. The organic matter content was determined due to the mass loss of the incinerated residue, considering the material lost by burning in the temperature range of from 105 °C to 550 °C, according to the formula (*P* = weight of the sample (g) after heating to 105 °C; *C* = tare of the crucible (g); *T* = weight of ash + crucible (g)), as presented in Equation (1):

$$\text{OM } (\%) = \frac{(P - (T - C)) \times 100}{P}, \tag{1}$$

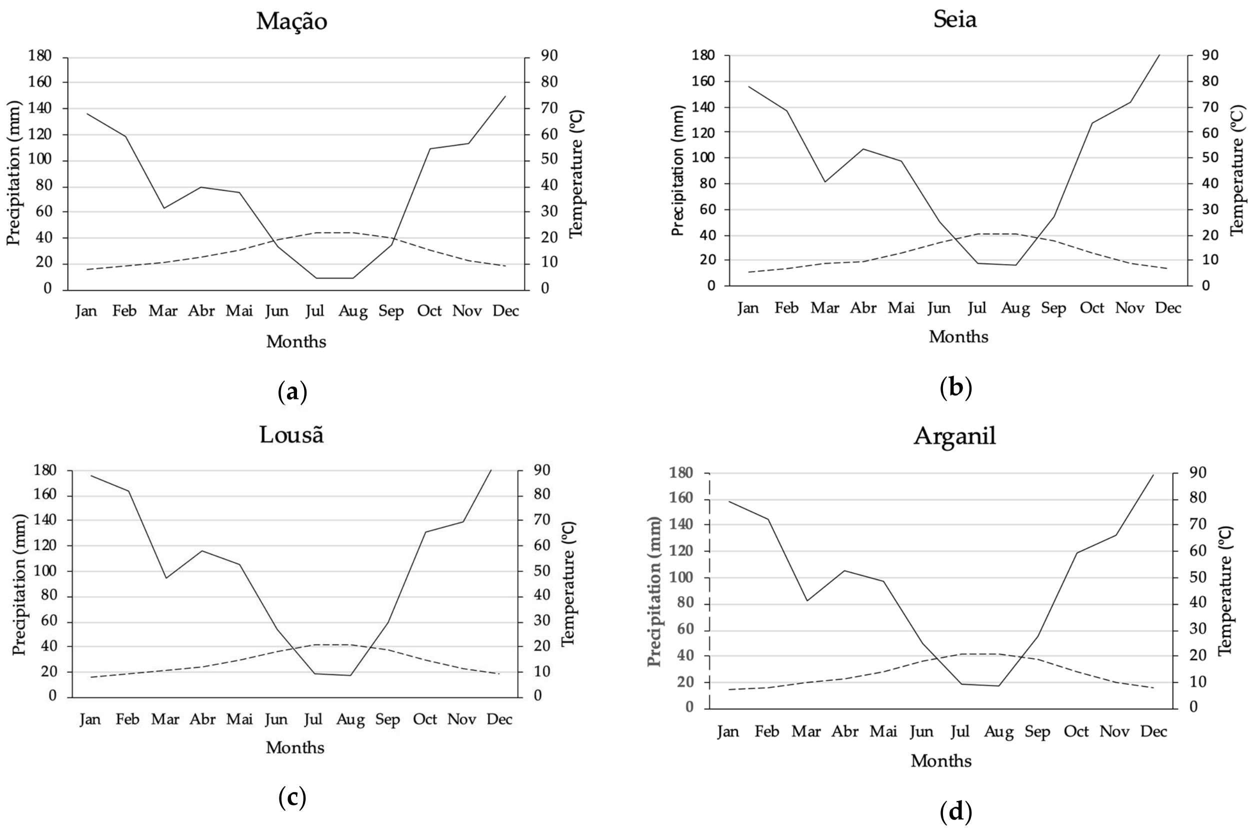


Figure 3. Thermopluviometric graphics of the areas under study: (**a**) Mação; (**b**) Seia; (**c**) Lousã; (**d**) Arganil (data acquired at Portal do Clima web platform, available at www.portaldoclima.pt, accessed on 14 June 2021, in accordance with the methodology presented by Walter and Lieth (1967) and Walter (2012) [34,35]).

2.3. Ecological Modeling

Based on prior knowledge of the ecological conditions of *P. lusitanica*, modeling was carried out using the Maxent 3.4.4 program for the area under study [11,35]. This information was complemented with field data collected during the period from 2018 to 2020. Eight climate variables from WorldClim (version 2.1) were used for ecological modeling: Tavg—average temperature; Tmax—maximum temperature; Tmin—minimum temperature; elev—elevation; prec—precipitation; srad—solar radiation; vapr—water vapor pressure; wind—wind speed [36]. The bioclimatic variables (1970–2000) used to calculate the current distribution have a spatial resolution of 30 s (~1 km^2).

3. Results and Discussion

The fieldwork resulted in the observation of almost 10,000 individuals of *P. lusitanica* in the central region of mainland Portugal (Table 2). Despite the rural fire that occurred in October 2017, Serra do Açor continues to have the greatest representativeness of this species, corresponding to approximately 50% of the individuals in the area under study. With almost

3000 individuals, the União de Freguesias de Vide e Cabeça faces serious problems with the invasion of exotic species, such as *Acacia dealbata* Link., *Acacia melanoxylon* R. Br. and *Ailanthus altissima* (Mill.) Swingle. In the municipality of Mação, which includes the lowest number of cherry trees, with around 70 individuals, constitutes the southernmost territory in Portugal, where the presence of thermophilic elements can still be detected, such as *Pistacia lentiscus*, *Myrtus communis* and *Smilax aspera* in the Ribeira do Aziral and Ribeira do Fraguedo.

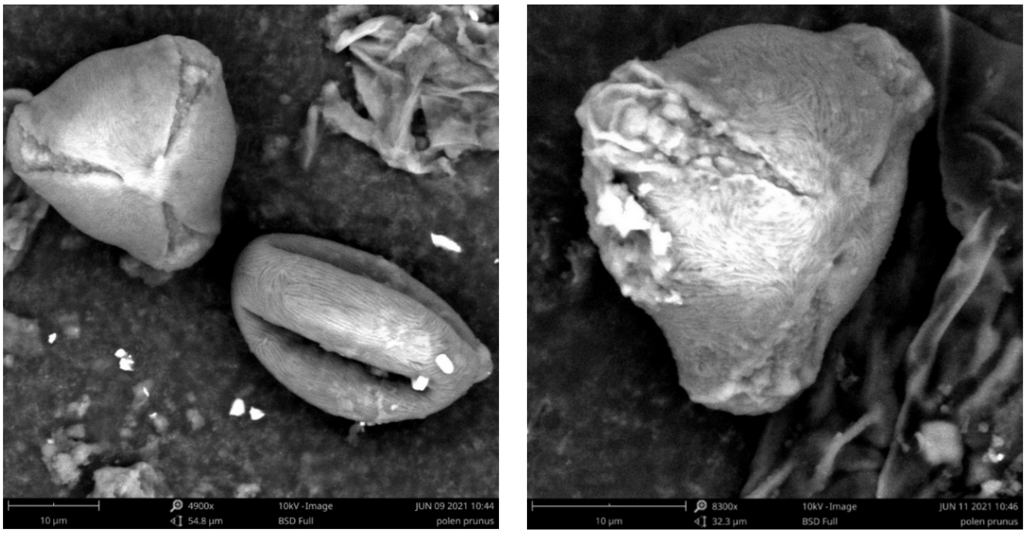
Table 2. Size of the population nuclei of *P. lusitanica*.

Geographical Area	Adult Individuals (>1.5 m)	Young Individuals (<1.5 m)	Total Individuals	Natural Regeneration (%)	Total Population (%)
Vide and Cabeça (Seia)	2494	469	2963	18.81	30.3
Serra da Lousã	216	28	244	12.96	2.49
Serra do Açor	3905	831	4736	21.28	48.40
Pampilhosa da Serra	1229	162	1391	13.18	14.22
Ribeira do Aziral (Mação)	67	2	69	2.99	0.71
Serra dos Alvéolos	245	14	259	5.71	2.65
Orvalho (Oleiros)	114	9	123	7.89	1.26
Total	8270	1515	9785	11.83	100

These data show a reduction of approximately 6500 individuals in the area under study, corresponding to a loss of approximately 40% in comparison with the results published by Calleja [11]. In general, in the well-preserved areas, there were no problems with the pollination of flowers, or with the seed production, or with the natural germination (Figure 4). However, we verified a low survival of young plants. Occasionally, there were problems with the presence of herbivorous animals, such as deer, namely in Ribeira do Gondufo (Seia), where it is possible to observe some of the oldest cherry trees in Portugal, although the natural regeneration is practically nil.

Figure 4. Details of *P. lusitanica*. From left to right: flowering; fruiting; natural regeneration.

At the infraspecific and even specific levels, the pollen of the genus *Prunus* is one of the most difficult to differentiate due to its morphological similarities [11,37]. According to the present research, pollen from *P. lusitanica* is rarely studied, and there is only one database with its typification [38]. Through our analyzes we confirm that *Prunus lusitanica* L. pollen is monad, tricolporate (three apertures furrows, pores indistinct or obscure) and isopolar. In polar view is circular or triangular and subprolate in equatorial view (Figure 5). In equatorial view the apertures are visible. The exine is strongly striate with some puncta between the striae. Furrows are wide, with irregular margins, granulate ornamentation with saliente intine. The size of this pollen type is average, around 36-40 µm. The pollen of several taxa of the genus *Prunus* is heavy, which is why pollination by the honeybee (*Apis mellifera* Linneus) is important for the development of a high number of fruits, as is the case with the cultivation of the cherry trees [39,40].



(**a**) (**b**)

Figure 5. *P. lusitanica* pollen grains under the Scanning Electron Microscope (SEM), collected in Mata da Margaraça. (**a**) Tricolpate pollen in polar view on the left side and equatorial view on the right side. (**b**) Tricolpate pollen in polar view—detail of the exine sculpturing with some puncta between the striae.

The strong mortality of young plants may be associated with climatic or edaphic factors. In the different sampled areas, the horizon A (0–5 cm) of the soil showed a high organic matter content, while the second sampled horizon (5–15 cm) showed a significant reduction in organic matter content (Figure 6). Although some samples from the third horizon (15–30 cm) were not taken due to the weak thickness of the soil, this was the horizon that showed the lowest accumulated values. Although the areas P2 and P3 were sometimes presented as clearings between the shrub cover, the areas dominated by *A. dealbata* showed an even lower organic matter content in horizon A. This fact is mainly due to the lack of other flora, kept away by the physical and allelopathic competition effect of the acacias, as well as the reduced amount of organic matter produced by *A. dealbata* stands [41].

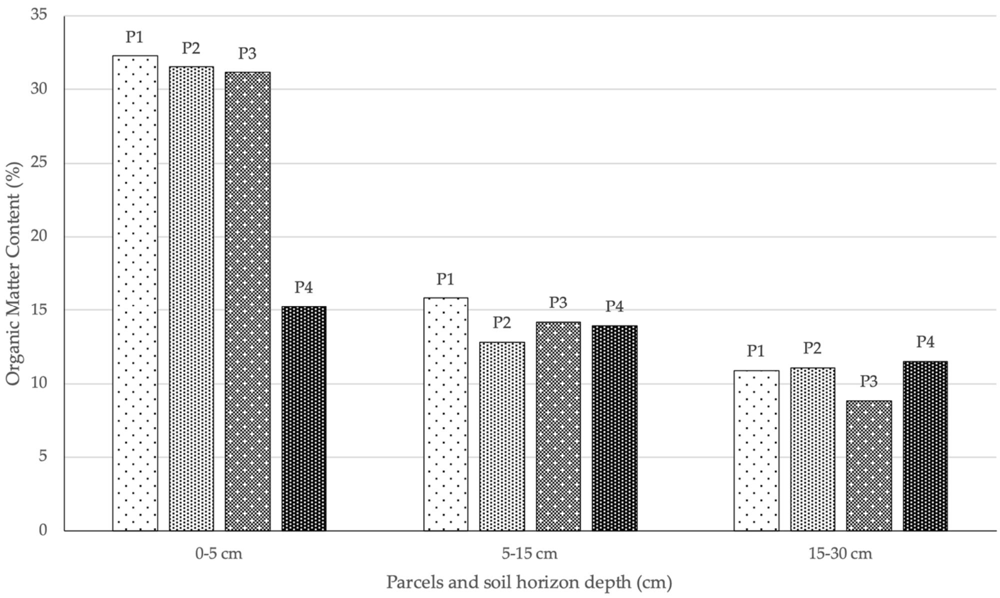


Figure 6. Percentage of organic matter per plot and depth of sampling (P1—habitat with good conservation status; P2—habitat with poor conservation status; P3—periphery of habitat 5230*pt2; P4—areas dominated by *A. dealbata*).

Several nuclei of *P. lusitanica* from the central region of mainland Portugal are currently in regression due to the strong expansion of exotic plants with an invasive character. Table 3 presents the main species identified in the area under study, as well as the most appropriate control method for each species [42]. Of all species, *A. dealbata* can be highlighted, which occurs inside or in the vicinity of all the areas under study, occupying the slopes and margins of the water lines (Figure 7a). Another identified aspect was the formation of seeds in *Hakea sericea* Schrader from plants that germinated 1 year after the occurrence of a rural fire (Figure 7b). On the other hand, although *E. globulus* does not have an invasive behavior in much of the national territory, in territories with high humidity and after the passage of fire, it presents a high dispersion and germination of seeds, resulting in plant densities which sometimes completely cover the soil (Figure 7c).

Table 3. Main exotic plants with invasive behavior identified in the areas under study.

Scientific Name	Family	Occurrences	Control Method
Acacia dealbata Link.	FABACEAE	Açor, Estrela, Lousã, Mação, Oleiros, Orvalho, Pampilhosa da Serra	To peel
Acacia melanoxylon R. Br.	FABACEAE	Lousã, Estrela, Pampilhosa da Serra	To peel
Hakea sericea Schrader	PROTEACEAE	Estrela, Lousã, Mação, Orvalho, Pampilhosa da Serra	Cut + burn
Ailanthus altissima (Miller) Swingle	SIMAROUBACEAE	Estrela, Lousã, Pampilhosa da Serra	To peel
Robinia pseudoacacia L.	FABACEAE	Lousã, estrela	To peel
Eucalyptus globulus Labill.	MYRTACEAE	Açor, Lousã, Estrela	To peel
Paulownia tomentosa (Thunb.) Steud.	PAULOWNIACEAE	Estrela	To peel
Arundo donax L.	POACEAE	Estrela, Lousã	Cut + grazing

Figure 7. Exotic plants with invasive behavior in the areas under study. (**a**) Invasion of the banks of the River Alvôco with *A. dealbata*; (**b**) *H. sericea* fruiting near Ribeira do Aziral (Mação); (**c**) aggressive seminal regeneration of *E. globulus* in Serra da Estrela. (These photographs are by Mauro Raposo).

In addition to the urgent need to control invasive plants in the region under study, it is necessary to avoid the introduction of other species that could invade new areas, as has happened in other areas of Europe [43,44]. Rural fires promote the appearance of heliophilous shrubs, which increases the risk of rural fires recurring in short time periods [45]. In this sense, selective control with vegetation cover is proposed, in order to promote the growth of the characteristic species of habitat 5230, such as *Laurus nobilis*, *Rhododendron ponticum*, *Myrica faya*, *Arbutus unedo*, *Viburnum tinus*, *Ilex aquifolium*, *Rosa sempervirens* and *Smilax aspera*, among others, avoiding the negative impacts of chemical control [46].

On the other hand, to create buffer zones and fire breaks in a landscape marked by forest production stands, discontinuities must be created through the promotion of native forest species, such as *Q. robur* subsp. *broteroana*, *Q. pyrenaica*, *Q. suber* or even *Castanea sativa*, *Prunus avium* and *Arbutus unedo*. The landscape mosaic contributes not only to lowering the risk of fires but also to the greater sustainability and resilience of the landscape. Thus, planting native forests in the areas surrounding habitat 5230 will contribute significantly to reducing the risk of fire, when compared to the high rates of flammability of resinous species and species with high essential oil content, such as

P. pinaster and *E. globulus*, respectively [47,48]. Although the strong contribution of the analyzed threats to the decrease in the number of individuals of *P. lusitanica*, recolonization through plantations is an effective method and has already been tested and used with other species [49,50]. To meet the potential area of occurrence of the species, a model was created using current ecological data, presented in Figure 8.

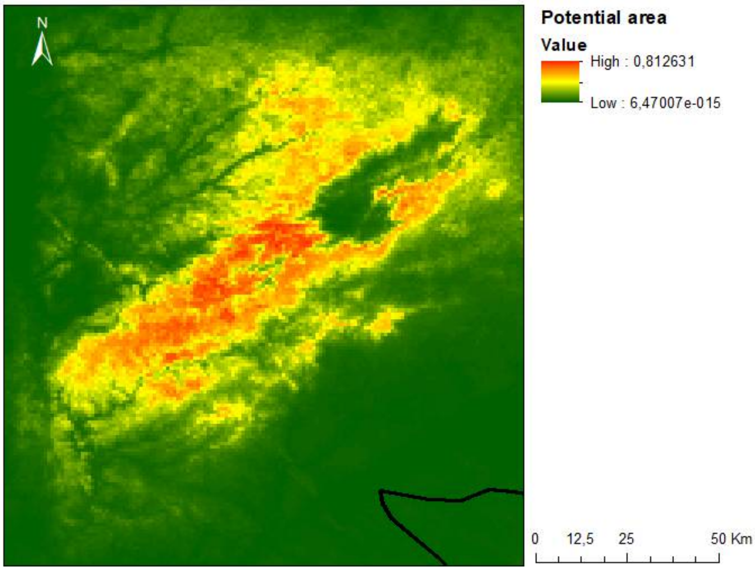


Figure 8. Map of the potential occurrence area of *P. lusitanica* in the central region of mainland Portugal.

According to the results obtained, the most determining factor in the geographic distribution of *P. lusitanica* in the central region of mainland Portugal is precipitation. Other noteworthy factors are solar radiation and the average annual temperature (Figure 9). These results are in accordance with the ecological characterizations carried out in previous works, namely on the north-facing slopes, with mild temperatures and higher humidity [51–54]. Following the achievements of the present research, however, the aim is to identify integrative policies with local communities instead of on a restrictive basis, as is the case in other places in the Mediterranean basin with lush vegetation [55].

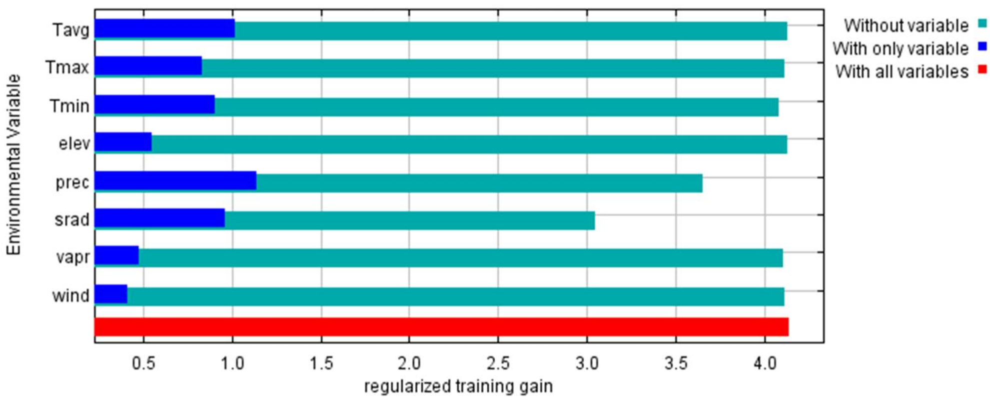


Figure 9. Importance of ecological factors in modeling the potential occurrence area of *P. lusitanica* in Serra da Estrela (Tavg—average temperature; Tmax—maximum temperature; Tmin—minimum temperature; elev—elevation; prec—precipitation; srad—solar radiation; vapr—water vapor pressure; wind—wind speed).

4. Conclusions

The communities of *P. lusitanica* in the central region of mainland Portugal are in sharp decline, with the loss of approximately 40% of individuals in 15 years. Several conservation projects have contributed to recovering this species and avoiding aggravating the evaluation criteria to Critically Endangered. Thus, it is expected that, in the near future, the assessment of Endangered will be maintained due to the adequacy of the A2c criterion. However, stricter conservation policies and replication actions are needed based on the experiences that were already carried out, such as the Life-Relict Project (NAT/PT/000754). Thus, it is not enough to conserve the species, but instead, its habitat and the surrounding areas must be conserved, allowing better flow between plants and animals. This study shows the need for the rapid integration of *P. lusitanica* in the Red List of Vascular Plants of Mainland Portugal, thus allowing a better transmission of the value of this species to the instruments of territorial management.

Author Contributions: Conceptualization, M.A.M.R. and C.J.P.-G.; methodology, M.A.M.R., A.G. and L.J.R.N.; software, S.d.R. and R.Q.-C.; validation, S.d.R., F.M.V.P. and C.J.P.-G.; formal analysis, M.A.M.R. and A.G.; investigation, M.A.M.R., L.J.R.N. and R.Q.-C.; data curation, M.A.M.R., S.d.R., R.Q.-C., L.J.R.N. and C.J.P.-G.; writing—original draft preparation, M.A.M.R.; writing—review and editing, S.d.R. and F.M.V.P.; visualization, A.G. and M.A.M.R.; supervision, S.d.R., F.M.V.P. and C.J.P.-G. All authors have read and agreed to the published version of the manuscript.

Funding: This work is funded by National Funds through the Foundation for Science and Technology (FCT) under the Project UIDB/05183/2020. L.J.R.N. was supported by Prometheus—Research Unit on Energy, Materials and Environment for Sustainability, UIDP/05975/2020, funded by national funds through FCT.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request to the corresponding author.

Acknowledgments: This research received a contribution from the European Commission's LIFE program, through the Life-Relict Project (NAT/PT/000754), to the municipalities of Mação, Pampilhosa da Serra and Freguesia de Vide e Cabeça for their collaboration in the fieldwork. We would like to thank researcher Helena Ribeiro from the Department of Geosciences, Environment and Spatial Plannings of the Faculty of Sciences University of Porto for her contributions to pollen characterization.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Aguiar, C.; Pinto, B. *Paleo-História e História Antiga das Florestas de PORTUGAL Continental: Até à IDADE Média*; Público: Lisbon, Portugal, 2007; pp. 15–53.
2. Barrón, E. Evolución de las floras terciarias en la península ibérica. *Mongr. Jard. Bot. Córdoba* **2003**, *11*, 63–74.
3. Barrón, E.; Rivas-Carballo, R.; Postigo-Mijarra, J.M.; Alcalde-Olivares, C.; Vieira, M.; Castro, L.; Pais, J.; Valle-Hernández, M. The cenozoic vegetation of the Iberian Peninsula: A synthesis. *Rev. Palaeobot. Palynol.* **2010**, *162*, 382–402. [CrossRef]
4. Juaristi, C.M. El paisaje vegetal ibérico durante el quaternario. *Monogr. Jard. Bot. Córdoba* **2003**, *11*, 75–93.
5. Pignatti, S. Evolutionary trends in mediterranean flora and vegetation. *Vegetatio* **1978**, *37*, 175–185. [CrossRef]
6. Calleja, J.; Ollero, H. Análisis e interpretación geobotánica de la estructura y composición florística de las loreras ibéricas. *Ecologia* **2009**, *22*, 45–71.
7. Pulido, F.; Valladares, F.; Calleja, J.A.; Moreno, G.; González-Bornay, G. Tertiary relict trees in a mediterranean climate: Abiotic constraints on the persistence of Prunus lusitanica at the eroding edge of its range. *J. Biogeogr.* **2008**, *35*, 1425–1435. [CrossRef]
8. Rodríguez-Sánchez, F.; Guzmán, B.; Valido, A.; Vargas, P.; Arroyo, J. Late neogene history of the laurel tree (Laurus L., Lauraceae) based on phylogeographical analyses of mediterranean and macaronesian populations. *J. Biogeogr.* **2009**, *36*, 1270–1281. [CrossRef]
9. Kondraskov, P.; Schütz, N.; Schüßler, C.; de Sequeira, M.M.; Guerra, A.S.; Caujapé-Castells, J.; Jaén-Molina, R.; Marrero-Rodríguez, Á.; Koch, M.A.; Linder, P.; et al. Biogeography of mediterranean hotspot biodiversity: Re-evaluating the "Tertiary Relict" hypothesis of macaronesian laurel forests. *PLoS ONE* **2015**, *10*, e0132091. [CrossRef] [PubMed]

10. Vivero, J.L. IUCN Red List of Threatened Species: Prunus lusitanica Subsp. Lusitanica. Available online: https://www.iucnredlist.org/en (accessed on 6 June 2020).
11. Calleja, J.A. Geobotánica, Estructura Demográfica, Consevación Y Biología Predispersiva de Prunus lusitanica L. (Loro) en La Península Ibérica. Ph.D. Thesis, Universidad Autónoma de Madrid, Madrid, Spain, 2006.
12. Monteiro, A.T.; Gonçalves, J.; Fernandes, R.F.; Alves, S.; Marcos, B.; Lucas, R.; Teodoro, A.C.; Honrado, J.P. Estimating invasion success by non-native trees in a national park combining worldview-2 very high resolution satellite data and species distribution models. *Diversity* **2017**, *9*, 6. [CrossRef]
13. Nunes, L.J.R.; Raposo, M.A.M.; Meireles, C.I.R.; Gomes, C.J.P.; Ribeiro, N.M.C.A. The impact of rural fires on the development of invasive species: Analysis of a case study with acacia dealbata link, in Casal Do Rei (Seia, Portugal). *Environments* **2021**, *8*, 44. [CrossRef]
14. Nunes, L.J.R.; Raposo, M.A.M.; Meireles, C.I.R.; Pinto Gomes, C.J.; Ribeiro, N.M.C.A. Fire as a selection agent for the dissemination of invasive species: Case study on the evolution of forest coverage. *Environments* **2020**, *7*, 57. [CrossRef]
15. Turco, M.; Jerez, S.; Augusto, S.; Tarín-Carrasco, P.; Ratola, N.; Jiménez-Guerrero, P.; Trigo, R.M. Climate drivers of the 2017 devastating fires in portugal. *Sci. Rep.* **2019**, *9*, 13886. [CrossRef] [PubMed]
16. Rivas-Martínez, S.; Penas, Á.; Díaz González, T.E.; Cantó, P.; del Río, S.; Costa, J.C.; Herrero, L.; Molero, J. Biogeographic units of the Iberian Peninsula and Baelaric Islands to district level. A concise synopsis. In *The Vegetation of the Iberian Peninsula: Volume 1*; Loidi, J., Ed.; Springer: Cham, Switzerland, 2017; pp. 131–188. ISBN 978-3-319-54784-8.
17. Marques, J.E.; Marques, J.M.; Chaminé, H.I.; Carreira, P.M.; Fonseca, P.E.; Monteiro Santos, F.A.; Moura, R.; Samper, J.; Pisani, B.; Teixeira, J.; et al. Conceptualizing a mountain hydrogeologic system by using an integrated groundwater assessment (Serra Da Estrela, Central Portugal): A Review. *Geosci. J.* **2013**, *17*, 371–386. [CrossRef]
18. Sant'Ovaia, H.; Olivier, P.; Ferreira, N.; Noronha, F.; Leblanc, D. Magmatic structures and kinematics emplacement of the variscan granites from Central Portugal (Serra Da Estrela and Castro Daire Areas). *J. Struct. Geol.* **2010**, *32*, 1450–1465. [CrossRef]
19. Sá, A.A.; Gutiérrez-Marco, J.C.; Meireles, C.; García-Bellido, D.C.; Rábano, I. A revised correlation of lower ordovician sedimentary rocks in the Central Iberian Zone, Portugal and Spain. In *STRATI 2013: First International Congress on Stratigraphy: On the Cutting Edge of Stratigraphy*; Springer: Berlin, Germany, 2013.
20. Connor, S.E.; Araújo, J.; van der Knaap, W.O.; van Leeuwen, J.F.N. A long-term perspective on biomass burning in the Serra Da Estrela, Portugal. *Quat. Sci. Rev.* **2012**, *55*, 114–124. [CrossRef]
21. Rivas-Martínez, S.; Penas, Á.; del Río, S.; Díaz González, T.E.; Rivas-Sáenz, S. Bioclimatology of the Iberian Peninsula and the Balearic Islands. In *The Vegetation of the Iberian Peninsula: Volume 1*; Loidi, J., Ed.; Springer: Cham, Switzerland, 2017; pp. 29–80. ISBN 978-3-319-54784-8.
22. Costa, J.C.; Neto, C.; Aguiar, C.; Capelo, J.; Espírito Santo, M.D.; Honrado, J.J.; Gomes, C.P.; Monteiro-Henriques, T.; Sequeira, M.; Lousã, M. Vascular plant communities in Portugal (continental, the Azores and Madeira). *Glob. Geobot.* **2012**, *2*, 1–180.
23. Braun-Blanquet, J. *Fitosociología. Bases Para El Estudio de Las Comunidades Vegetales*; Blume: Madrid, Spain, 1979.
24. Géhu, J.M.; Rivas-Martínez, S. Notions fondamentales de phytosociologia. *Ber. Int. Symp. Int.* **1981**, *4–5*, 5–33.
25. Rivas-Martínez, S. *Avances En Geobotánica. Discurso de Apertura Del Curso 2005*; Real Academia Farmacia: Madrid, Spain, 2005.
26. Rivas-Martínez, S.; Díaz, T.E.; Fernández-González, F.; Izco, J.; Loidi, J.; Lousã, M.; Penas, A. Vascular plant communities of Spain and Portugal. Addenda to the syntaxonomical checklist of 2001, part II. *Itinera Geobot.* **2002**, *15*, 433–922.
27. Mucina, L.; Bültmann, H.; Dierßen, K.; Theurillat, J.-P.; Raus, T.; Čarni, A.; Šumberová, K.; Willner, W.; Dengler, J.; García, R.G.; et al. Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. *Appl. Veg. Sci.* **2016**, *19*, 3–264. [CrossRef]
28. Taleb, M.S.; Fennane, M. *Vascular Plant Communities of Morocco: Phytosociology, Ecology and Geography*; Springer: Berlin, Germany, 2019; ISBN 978-3-319-93703-8.
29. Castroviejo, S. *Flora Ibérica. Plantas Vasculares Da Península Ibérica e Ilhas Baleares*; CSIC: Madrid, Spain, 1986.
30. Coutinho, A.X.P. *Flora de Portugal (Plantas vasculares)*; Bertrand: Lisbon, Portugal, 1939.
31. Franco, J.A. *Nova Flora de Portugal (Continente e Açores) Volume 1-Fascículos 2*; Escolar Editora: Vila Franca de Xira, Portugal, 1971.
32. Franco, J.A.; Rocha-Afonso, M.L. *Nova Flora de Portugal (Continente e Açores) Volume III Fascísculo I*; Escolar Editora: Vila Franca de Xira, Portugal, 1994.
33. Goldin, A. Reassessing the use of loss-on-ignition for estimating organic matter content in noncalcareous soils. *Commun. Soil Sci. Plant Anal.* **1987**, *18*, 1111–1116. [CrossRef]
34. Rodella, A.A.; Alcarde, J.C. Avaliação de materiais orgânicos empregados como fertilizantes. *Sci. Agric.* **1994**, *51*, 556–562. [CrossRef]
35. Phillips, S.J.; Anderson, R.P.; Schapire, R.E. Maximum entropy modeling of species geographic distributions. *Ecol. Model.* **2006**, *190*, 231–259. [CrossRef]
36. Fick, S.E.; Hijmans, R.J. Worldclim 2: New 1-Km spatial resolution climate surfaces for global land areas. *Int. J. Climatol.* **2017**, *37*, 4302–4315. [CrossRef]
37. Li, W.; Wang, Y.; Liu, L.; Niu, Y.; Zhao, S.; Zhang, S.; Wang, Y.; Liao, K. Pollen morphology of selected apricot (prunus) taxa. *Palynology* **2021**, *45*, 95–102. [CrossRef]
38. Auer, W.; Prunus lusitanica. In PalDat—A Palynological Database. Available online: https://www.paldat.org/pub/Prunus_lusitanica/304059;jsessionid=EA915573AE592ED5F577CE42A8223CC6 (accessed on 26 May 2021).

39. Chauvin, J.-E. *Etude de Quatre Familles de Demi-Frères Issues de Croisements Intraspécifiques Chez le Prunier Domestique*; Ecole Nationale Supérieure Agronomique: Alger, Algeria, 1985.
40. Guitián, J.; Guitián, P.; Sánchez, J.M. Reproductive biology of twoprunus species (rosaceae) in the Northwest Iberian Peninsula. *Plant Syst. Evol.* **1993**, *185*, 153–165. [CrossRef]
41. Lorenzo, P.; Pereira, C.S.; Rodríguez-Echeverría, S. Differential impact on soil microbes of allelopathic compounds released by the invasive acacia dealbata link. *Soil Biol. Biochem.* **2013**, *57*, 156–163. [CrossRef]
42. Marchante, H.; Morais, M.; Freitas, H.; Marchante, E. *Guia Prático Para a Identificação de Plantas Invasoras Em Portugal*; Imprensa da Universidade de Coimbra: Coimbra, Portugal, 2014; ISBN 978-989-26-0786-3.
43. Laface, V.L.A.; Musarella, C.M.; Cano Ortiz, A.; Quinto Canas, R.; Cannavò, S.; Spampinato, G. Three new alien taxa for Europe and a chorological update on the alien vascular flora of Calabria (Southern Italy). *Plants* **2020**, *9*, 1181. [CrossRef] [PubMed]
44. Osborne, B.; Gioria, M. Plant invasions. *J. Plant Ecol.* **2018**, *11*, 1–3. [CrossRef]
45. Raposo, M.A.M.; Gomes, C.J.P.; Nunes, L.J.R. Selective shrub management to preserve mediterranean forests and reduce the risk of fire: The case of Mainland Portugal. *Fire* **2020**, *3*, 65. [CrossRef]
46. Piñar Fuentes, J.C.; Leiva, F.; Cano-Ortiz, A.; Musarella, C.M.; Quinto-Canas, R.; Pinto-Gomes, C.J.; Cano, E. Impact of grass cover management with herbicides on biodiversity, soil cover and humidity in olive groves in the Southern Iberian. *Agronomy* **2021**, *11*, 412. [CrossRef]
47. Fernandes, P.M.; Guiomar, N.; Rossa, C.G. Analysing eucalypt expansion in Portugal as a fire-regime modifier. *Sci. Total Environ.* **2019**, *666*, 79–88. [CrossRef] [PubMed]
48. Niccoli, F.; Esposito, A.; Altieri, S.; Battipaglia, G. Fire severity influences ecophysiological responses of pinus pinaster ait. *Front. Plant Sci.* **2019**, *10*, 539. [CrossRef]
49. Rumpf, S.B.; Hülber, K.; Wessely, J.; Willner, W.; Moser, D.; Gattringer, A.; Klonner, G.; Zimmermann, N.E.; Dullinger, S. Extinction debts and colonization credits of non-forest plants in the European Alps. *Nat. Commun.* **2019**, *10*, 4293. [CrossRef] [PubMed]
50. Whittaker, R.J.; Bush, M.B.; Richards, K. Plant recolonization and vegetation succession on the Krakatau Islands, Indonesia. *Ecol. Monogr.* **1989**, *59*, 59–123. [CrossRef]
51. Lara, F.; Garilleti, R.; Calleja, J.A. *La Vegetación de Ribera de la Mitad Norte Española*, 2nd ed.; Centro de Estudios y Experimentación de Obras Públicas: Madrid, Spain, 2007; ISBN 978-84-7790-440-3.
52. Franco, J.A. O Azereiro e as Ginjeiras Bravas, Coimbra, 1964—Biblioteca nacional digital. *Bol. Soc. Port. Ciênc. Nat.* **1964**, *10*, 66–90.
53. Ladero, M. Prunus lusitanica L. (rosaceae) en la Península Ibérica. *Anal. Inst. Bot. A. J. Cavanilles* **1976**, *33*, 207–218.
54. Calleja, J.A.; Garzón, M.B.; Ollero, H.S. A quaternary perspective on the conservation prospects of the tertiary relict tree *Prunus lusitanica* L. *J. Biogeogr.* **2009**, *36*, 487–498. [CrossRef]
55. Sattout, E.; Caligari, P.D.S. Forest biodiversity assessment in relic ecosystem: Monitoring and management practice implications. *Diversity* **2011**, *3*, 531–546. [CrossRef]

CAPÍTULO IV

ORIGINALIDADES EDAFO-HIGRÓFILAS IDENTIFICADAS NO SUL DE PORTUGAL

Publicado como:

Raposo, M., Quinto-Canas R., Cano-Ortiz A., Spampinato G. & Pinto-Gomes C. (2020). Originalities of Willow of *Salix atrocinerea* Brot. in Mediterranean Europe. *Sustainability* 12, (19): 8019. https://doi.org/10.3390/su12198019.

CAPÍTULO IV. ORIGINALIDADES EDAFO-HIGRÓFILAS IDENTIFICADAS NO SUL DE PORTUGAL

IV.1. Intróito

Este Capítulo descreve duas novas comunidades de *Salix atrocinerea* para Portugal Continental e um novo arrelvado vivaz dominado por *Molinia caerulea* subsp*. arundinacea*. A primeira seção enquadra a importância da conservação das galerias ripícolas como refúgio de biodiversidade e contextualiza-as do ponto de vista fitossociológico. A segunda seção apresenta a metodologia adotada e um tópico sobre a recolha de dados no campo. A terceira seção apresenta os resultados da análise estatística às comunidades de *S. atrocinerea*, através de um dendrograma, onde representa a dissimilaridade das associações de salgueiro estudadas, acompanhado com um quadro que diferencia as principais plantas características. Dentro desta parte, apresenta-se ainda uma descrição detalhada de cada sintáxone, onde se caracterizam os principais aspetos ecológicos, biogeográficos e as principais plantas características de associação e unidades superiores. A quarta seção refere-se a importância do conhecimento fitossociológico para conservar estes habitats, servindo de refúgio para um conjunto de táxones raros com elevado valor patrimonial.

Este artigo surge na sequência da recolha de informação durante as saídas de campo realizadas para prospetar a área de distribuição atual de *P. lusitanica*. Tendo por base a área de distribuição conhecida do azereiro, bem como uma referência antiga da sua presença para a Serra de Monchique (Antunes & Ribeiro, 2007), decidimos prospetar algumas linhas de água no sul de Portugal. Nestes territórios, focamos a prospeção somente nas linhas de água, porque as plantas que ocorrem naturalmente em ombrótipos elevados, apenas têm possibilidade de sobreviver em situações compensadas edaficamente quando o ombrótipo é menor, como são as margens das linhas de água (Rivas-Martínez, 2005). Na verdade, atualmente muitos dos núcleos de azereiro vivem nas margens das linhas de água, face à intensa e continuada ação antrópica na paisagem (Pardo et al., 2018).

Embora os resultados da prospeção à Serra de Monchique tenham dado negativo, não seria descabida a sua presença neste território, uma vez que o ponto mais elevado, a Foia, situa-se a cerca de 902 metros de altitude, apresenta precipitações perto dos 2 mil milímetros anuais e em termos de substrato dominam os solos siliciosos, destacando-se os xistos nas altitudes menos elevadas e os sienitos nefelínicos nas mais elevadas (Malato-Beliz, 1982). Para além disso, atualmente ainda é possível observar em algumas linhas de água melhor conservadas elementos que testemunham a presença de uma flora paleotropical, cujo expoente máximo é o raro *Rhododendron ponticum* subsp. *baeticum*, bem como outros elementos singulares como é *Myrica faya, Ilex aquifolium, Laurus nobilis*, entre outros (Aguiar & Pinto, 2007; Pinto-Gomes et al., 2019).

Assim, de forma a validar as novas associações de salgueiro, realizou-se uma análise estatística abrangendo todas as comunidades de salgueiro mediterrânicas da Europa. A análise aos 84 inventários resultou na identificação de sete associações vegetais, propondo-se como novidades a *Frangulo baeticae-Salicetum atrocinereae* e a *Clematido flammulae-Salicetum australis*.

IV.1.1. Referências

Aguiar, C., & Pinto, B. (2007). Paleo-história e história antiga das florestas de Portugal continental: Até à Idade Média. *Árvores e florestas de Portugal: floresta e sociedade, uma história comum*, 15–53.

Antunes, J., & Ribeiro, M. M. A. (2007). O Azereiro (Prunus lusitanica L.): Uma monografia. *Agroforum : Revista da Escola Superior Agrária de Castelo Branco*, 33–36.

Malato-Beliz, J. (1982). *A Serra de Monchique – Flora e Vegetação. Coleção de Parques Naturais Nº 10.* Serviço Nacional de Parques, Reservas e Património Paisagístico.

Pardo, A., Cáceres, Y., & Pulido, F. (2018). Rangewide determinants of population performance in Prunus lusitanica: Lessons for the contemporary conservation of a Tertiary relict tree. *Acta Oecologica*, *86*, 42–48. https://doi.org/10.1016/j.actao.2017.12.001

Pinto-Gomes, C., Meireles, C., Raposo, M., Castro, C., Matos, R., & Santos, P. (2019). *Guia da excursão geobotânica do XIII Seminário Internacional de Gestão e Conservação da Biodiversidade-Vale do Lobo, Loulé (Algarve-Portugal)*. https://dspace.uevora.pt/rdpc/handle/10174/26867

Rivas-Martínez, S. (2005). *Avances en Geobotánica. Discurso de Apertura del Curso 2005*. Real Acad. Farmacia.

IV.2. Originalities of Willow of *Salix atrocinerea* Brot. in Europe Mediterranean

CAPÍTULO IV

sustainability

MDPI

Article

Originalities of Willow of *Salix atrocinerea* Brot. in Europe Mediterranean

Mauro Raposo [1,*], Ricardo Quinto-Canas [2,3], Ana Cano-Ortiz [4], Giovanni Sampinato [5] and Carlos Pinto Gomes [1]

1 Department of Landscape, Environment and Planning, Mediterranean Institute for Agriculture, Environment and Development (MED), School of Science and Technology—Universidade de Évora, Rua Romão Ramalho, n° 59, P-7000-671 Évora, Portugal; cpgomes@uevora.pt
2 Faculty of Sciences and Technology, Campus de Gambelas, University of Algarve, P-8005-139 Faro, Portugal; rjcanas@ualg.pt
3 CCMAR—Centre of Marine Sciences (CCMAR), Campus de Gambelas, University of Algarve, P-8005-139 Faro, Portugal
4 Department of Animal and Plant Biology and Ecology, Section of Botany, University of Jaén, Campus Universitario Las Lagunillas s/n., 23071 Jaén, Spain; anacanor@hotmail.com
5 Department of Agraria, "Mediterranea" University of Reggio Calabria, Loc. Feo di Vito, 89122 Reggio Calabria, Italy; gspampinato@unirc.it
* Correspondence: mraposo@uevora.pt

Received: 21 July 2020; Accepted: 27 September 2020; Published: 28 September 2020

Abstract: Willow communities (genus *Salix*) occurring in Mediterranean Europe are presented, showing, through statistical treatment with multivariate cluster analysis, the separation of the different plant communities and their sintaxonomic affiliation. Six willow communities have been identified, whose formations include a set of plants with high heritage value. We highlight plants with legal protection status (Annex IV and II of the Habitats Directive-92/43/EEC), endemic, rare, and endangered species such as *Salix salviifolia* subsp. *australis*, *Cheirolophus uliginosus*, *Euphorbia uliginosa* and *Leuzea longifolia*. Therefore, two new willow communities are proposed for the southwest of the Iberian Peninsula. The first dominated by *Salix atrocinerea*, *Frangulo baticae-Salicetum atrocinereae ass. nova* of ribatagan distribution, under acid substrates, thermomediterranean to lower mesomediterranean, dry to sub-humid. The second, dominated by the endemic *Salix salviifolia* subsp. *australis*, *Clematis flammulae-Salicetum australis* distributed in the Algarve, developing on neutral-basic substrates, exclusively thermomediterranous, dry to sub-humid. In both cases, there are presented on their own floristic serial, ecology, and substitution steps. A new hygrophytic meadows was also identified dominated by *Molinia caerulea* subsp. *arundinaceae*, *Cheirolopho uliginosii-Molinietum arundinaceae ass. new hoc loco*, which lives on substrates rich in organic matter, exclusive to the Ribatagano Sector. Through the deepening of knowledge about the composition and dynamics of riparian vegetation, it is possible to adapt management methods to sustain and protect these important edafo-hygrophilic systems in the Mediterranean.

Keywords: cluster analysis; geobotany; peatland; phytosociology; willow forest; Sardinia; southwest of Iberian Peninsula

1. Introduction

Riparian zones are highly heterogeneous and disturbed environments. They are composed of a wide variety of physical habitats in terms of their size of substrate sediment, moisture, and nutrient conditions, inundation duration and frequency, and also susceptibility to drought [1]. The southern Iberian small rivers and torrential streams are characterized by extreme flow irregularity (floods and droughts), leading to decreased soil cohesion and high eroded sediment discharge.

As a consequence, it is necessary to increase knowledge on Mediterranean riverside vegetation, in order to contribute to select methods of management and conservation of these highly important systems, especially in territories with a torrential character [2]. This importance is related to ecosystem services, guaranteeing environmental sustainability, through the regulation of the hydrological cycle, erosion control, and refuge of a large number of floristic and fauna species. A territory to be successful at the environmental, social, and economic level must have a balanced landscape [3]. The willow forests comprise the potential natural vegetation in torrential intermittent streams of the Southwestern part of the Iberian Peninsula [4].

According to Rivas-Martínez [5], Costa et al. [6] and Mucina et al. [7], two vegetation classes of riparian woodlands can be recognized in southwestern Europe: *Alnetea glutinosae* and *Salici purpureae-Populetea nigrae*. The first encompasses swamp and fens forests of *Alnus glutinosa* and *Salix atrocinerea*, in margins frequently inundated by dystrophic lentic waters of the Coastal Lusitania and West Andalusia Province [5,6], which are included in the *Salici atrocinereae-Alnenion glutinosae* suballiance (*Alnion glutinosae* alliance). The second includes willow communities of *Salix salviifolia subsp. australis* linked to the *Salicion salviifoliae* alliance, found in riparian, hygrophilous, deciduous forests growing on alluvial soils in the Mediterranean, sub-Mediterranean, and Thermo Atlantic Regions.

This paper provides a phytosociological and syntaxonomical analysis of the riparian woodlands communities dominated by *Salix salviifolia* subsp. *australis* (included in the *Salicion salviifoliae* alliance) and *Salix atrocinerea* (included in the *Alnion glutinosae* alliance), which occur in the southwest of the Iberian Peninsula and in Sardinia. In Iberian Peninsula *Salix atrocinerea* grows in some in riparian communities or in humid depressions that fall within the *Salici atrocinereae-Alnenion glutinosae* sub-alliance of the *Alnion glutinosae* [5]. Costa et al. [6] consider it characteristic *Carici lusitanicae-Salicetum atrocinereae*. This association is exclusive to the Sado river basin [8]. It is also recognized as *Viti sylvestris-Salicetum atrocinereae* occurring from the south of Spain [9] to the center of Portugal [4].

The communities of *Salix salviifolia* subsp. *australis* fall within *Salicion salviifoliae*, represented by the association *Salicetum atrocinereae-australis*, to the Alentejo territories [2].

In Sardinia, *Salix atrocinerea* grows in some in riparian communities or in humid depressions that fall within the *Hyperico hircini-Alnenion glutinosae* sub-alliance of the *Osmundo Alnion* [10]. In particular, Angius and Bacchetta [11] consider it characteristic of *Carici microcarpae-Salicetum atrocinereae* willow woodlands. Biondi and Bagella [12] described the *Myrto communis-Salicetum atrocinereae* for the marshy area of the island of Maddalena (Nord East Sardinia). As a subordinate species, it is also found in other riparian plant communities such as of the riparian woods of the *Eupatorio corsici-Alnetum glutinosae* were differentiate the sub-association *salicetosum atrocinereae*.

2. Materials and Methods

The sampling was carried out according to the school of Zürich-Montpellier (also known as Sigmatist) approach [13–18]. Taxonomic nomenclature followed the work of Coutinho [19], Franco [20,21], Franco and Rocha Afonso [22], Castroviejo et al. [23], and Valdés et al. [24]. The identification of *Salix* genus followed Portela-Pereira et al. [25]. Seventy-one relevés collected from bibliography along with thirteen relevés carried out by us were submitted to hierarchical cluster analysis using Ward's method with Euclidean distance to measure dissimilarity [26], using the software R. The transformation of cover-abundance values follows Van der Maarel [27]. The relevés performed in data matrix include our field sampling and relevés taken from literature: Costa [2], Cano and Valle [28], Rivas-Martínez [9], Biondi and Bagella [12], and Angius and Bacchetta [11]. For biogeographical and bioclimatological information we follow Rivas-Martínez [29], Rivas-Martínez et al. [30,31], and Fenu et al. [32].

Data Collection

For the confirmation of the new associations we carry out a set of relevés (Figure 1). In each relevé, all existing plants were recorded and assigned a quantitative index according to the abundance-dominance scale, with according by Braun-Blanquet [33]. This scale combines an estimative between the number of individuals of each existing specie and the respective area within the inventory. For each index (in bold), there is a coverage range, namely: + few individuals with very poor coverage (0.1% to 1%); 1 very abundant individuals with low coverage (from 1% to 10%); 2 individuals very abundant or covering at least 1/20 of the surface (from 10% to 25%); 3 any number of individuals covering $\frac{1}{4}$ to $\frac{1}{2}$ of the surface (from 25% to 50%); 4 any number of individuals covering $\frac{1}{2}$ to $\frac{3}{4}$ of the surface (from 50% to 75%); 5 any number of individuals covering more than $\frac{3}{4}$ of the surface (from 75% to 100%). We compiled an Excel© table with 84 relevés, where 13 were made by the authors and the rest supported by bibliography [2,9,11,12].

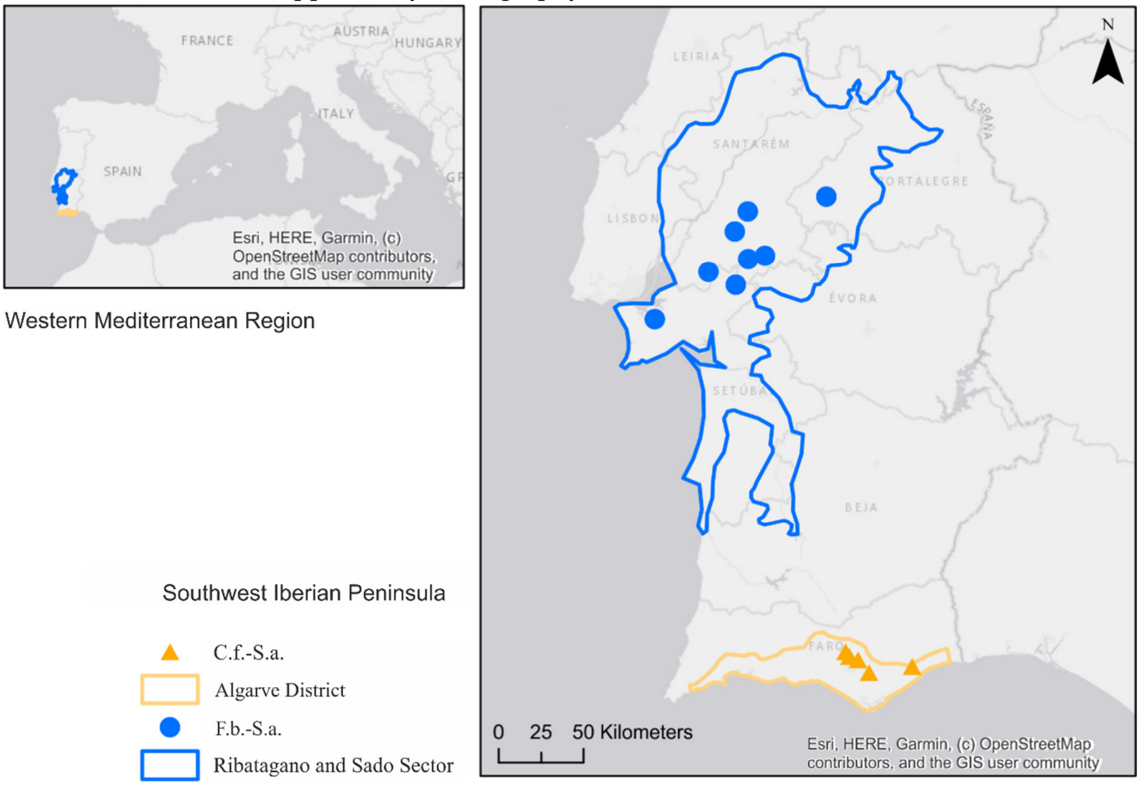


Figure 1. Sampling sites in the southwest of the Iberian Peninsula.

3. Results and Discussion

The cluster analysis (Figure 2) of 84 riparian relevés result in two main clusters with high dissimilarity levels, which are organized into two different groups. Group A has a high dissimilarity in relation to the other associations, and includes communities dominated by *Salix salviifolia* subsp. *australis* (*Salicion salviifoliae* alliance), which spreads across the southwestern areas of the Iberian Peninsula: (Subgroup A1) *Clematido flammulae-Salicetum australis* (plot 14–18) and (Subgroup A2) *Salicetum atrocinereo-australis* (plot 1–11). The samples ascribed to the communities dominated by *Salix atrocinerea*, occurring throughout the southwest of the Iberian Peninsula and the island of Sardinia, are included in the cluster Group B, divided into two subgroups. The relevé cluster subgroup B1 corresponds to the association *Myrto communis-Salicetum atrocinerea* (plot 39–46), which occurs in thermomediterranean bioclimatic areas, mainly of the islands Caprera and Santo Stefano. The subgroup B2 comprises two block communities: The first block (B21) encompasses plot (54–84) contained within the association *Carici microcarpae-Salicetum atrocinereae* described for the thermomediterranean to mesomediterranean, dry to sub-humid belts of the island of Sardinia, which are included in the *Salici purpureae-Populetea nigrae* class. The second block (B22) encompasses samples ascribed to the associations included in the *Alnetea glutinosae* vegetation class: *Carici lusitanicae-Salicetum atrocinereae* (plot 27–38), suggested by Neto [8] for the Sadese District; *Viti sylvestris-Salicetum atrocinerea* (plot 47–53), described by Rivas-Martínez [9] for the thermomediterranean belt of the Cádiz and Litoral Huelva Sector, extending over the Coastal Lusitania and West Andalusia Province, and; *Frangulo baeticae-Salicetum atrocinereae* (plot 19–26), which is proposed here as a new association for the Ribatejo and Sado Sector. In Table 1, the characteristics and differentials species of each association studied is highlighted.

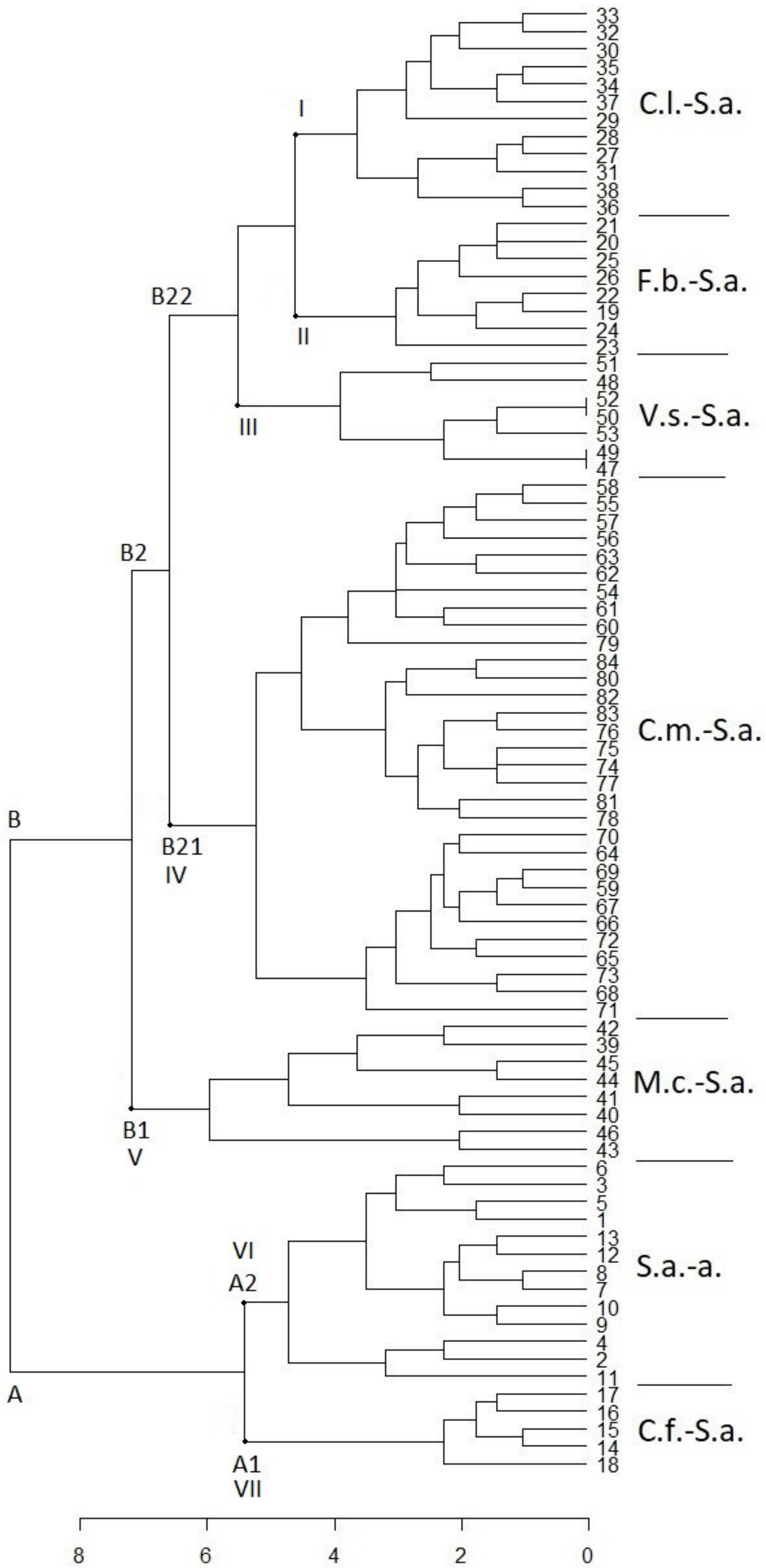


Figure 2. Dendrogram with the communities dominated by *Salix atrocinerea* and *Salix salviifolia* subsp. *australis*, occurring throughout the southwest of the Iberian Peninsula and the island of Sardinia. B22 (27–38)—C.l.-S.a.: *Carici lusitanicae-Salicetum atrocinereae*; B22 (19–26)—F.b.-S.a.: *Frangulo baeticae-Salicetum atrocinereae ass. nova hoc. loco*; B22 (47–53)—v.s.-S.a.: *Viti sylvestris-Salicetum atrocinereae*; B21 (54–84)—C.m.-S.a.: *Carici microcarpae-Salicetum atrocinerea*; B1 (39–46)—M.c.-S.a.: *Myrto communis-*

Salicetum atrocinerea; A2 (1–13)—S.a.-a.: *Salicetum atrocinereo-australis*; A1 (14–18)—C.f.-S.a.: *Clematido flammulae-Salicetum australis ass. nova hoc. loco*.

Table 1. Synoptic table with the communities of *Salix atrocinerea* and *Salix salviifolia* subsp. *australis* in south-west Europe.

Numerical order	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Number of relevées	12	8	7	31	8	13	5
Acronym	C.l.-S.a.	F.b.-S.a.	V.s.-S.a.	C.m.-S.a.	M.c.-S.a.	S.a.-a.	C.f.-S.a.
Characteristics and differentials							
Salix atrocinerea	V	V	V	V	V	IV	.
Carex lusitanica	V	.	.	.	.	.	.
Thelypteris palustris	V	.	V	.	.	.	.
Myrica gale	V	.	.	.	.	.	.
Frangula alnus subsp. *baetica*	IV	V	.	.	.	.	.
Salix salviifolia subsp. *australis*	II	II	.	.	.	V	V
Cheirolophus uliginosus	.	III	.	.	.	.	.
Leuzea longifolia	.	II	.	.	.	.	.
Euphorbia uliginosa	.	II	.	.	.	.	.
Vitis sylvestris	.	.	V	.	.	III	.
Rubus ulmifolius	.	.	IV	V	V	V	.
Fraxinus angustifolia	.	.	II	.	.	II	III
Dioscorea communis	.	.	.	V	.	II	.
Carex microcarpa	.	.	.	V	.	.	.
Smilax aspera	.	.	.	V	.	.	.
Quercus ilex	.	.	.	V	.	.	.
Brachypodium sylvaticum	.	.	.	IV	.	.	II
Oenanthe crocata	.	.	.	III	IV	.	.
Hypericum hircinum subsp. *hircinum*	.	.	.	III	.	.	.
Euphorbia meuselii	.	.	.	III	.	.	.
Nerium oleander	.	.	.	III	.	.	.
Bellium bellidioides	.	.	.	III	.	.	.
Bryonia dioica	.	.	.	.	.	II	.
Securinega tinctorea	.	.	.	.	.	+	.
Salix neotricha	.	.	.	.	.	III	V
Clematis flammula	.	.	.	.	.	.	V
Vinca difformis	.	.	.	.	.	.	IV
Equisetum ramosissimum	.	.	.	.	.	.	IV
Aristolochia paucinervis	.	.	.	.	.	.	I
Equisetum telmateia	.	.	.	.	.	.	I
Hedera canariensis	.	.	.	.	.	II	.
Myrtus communis	.	.	.	.	V	.	.
Carex hispida	.	.	.	.	III	.	.
Tamarix africana	.	.	.	.	III	.	.

Other taxa: + Alnus lusitanica, + Populus alba in A; + Arum italicum, + Vincetoxum nigrum in C; + Populus nigra, + Securigena tinctoria in F. Note: A—Carici lusitanicae-Salicetum atrocinereae; B—Frangulo baeticae-Salicetum atrocinereae ass. nova hoc. loco; C—Viti sylvestris-Salicetum atrocinereae; D—Carici microcarpae-Salicetum atrocinerea; E—Myrto communis-Salicetum atrocinerea; F—Salicetum atrocinereo-australis; G—Clematido flammulae-Salicetum australis ass. nova hoc. loco.

Description of Willow Communities

I—*Carici lusitanicae-Salicetum atrocinereae* (clusters 27–38, Figure 1)

According to Neto [8], this association is dominated by *Salix atrocinerea* and occupies swamps, lagoons, and margins of rivers and streams with water flowing over sandy soils subjected to fluctuations in its flow (although they present a high humidity content during the dry season). This association tends to be located in hygrophilous environments in a dry to subhumid ombroclimate in the thermomediterranean belt of the Sadese District.

II—*Frangulo baeticae-Salicetum atrocinereae ass. nova hoc. loco* (clusters 19–26, Figure 1; holotypus relevé: 08, Table 2)

Table 2. *Frangulo baeticae-Salicetum atrocinereae ass. nova hoc. loco* (*Salici atrocinereae-Alnenion glutinosae, Alnion glutinosae, Alnetalia glutinosae, Alnetea glutinosae*).

Ordinal Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Surface (m²)	150	100	150	300	200	250	200	100
Altitude (m)	48	64	43	86	65	27	45	50
Cover rate (%)	85	80	80	95	85	80	85	90
Orientation	W	W	N	S	NW	W	N	N
Slope (%)	12	18	12	6	10	8	7	15
Average heigth (m)	4	5	4	4	5	3	4	3
Number of species	24	22	23	22	28	32	36	36
Association characteristics								
Salix atrocinerea	4	3	4	4	3	4	4	4
Frangula alnus subsp. *baetica*	+	1	.	2	1	1	+	3
Cheirolophus uliginosus	.	.	+	.	1	.	2	+
Leuzea longifolia	.	.	.	+	+	1	.	.
Salix salviifolia subsp. *australis*	.	.	.	.	.	+	.	+
Euphorbia uliginosa	.	.	.	.	.	.	+	+
Companions								
Molinia caerulea subsp. *arundinacea*	+	1	1	1	2	2	3	3
Rubus ulmifolius	+	+	1	+	+	+	+	+
Quercus suber	+	+	+	+	+	+	+	+
Erica ciliaris	1	.	2	1	1	1	1	1
Ulex australis subsp. *welwitschianus*	+	+	+	+	+	.	+	+
Brachypodium phoenicoides	1	+	.	1	1	+	+	1
Ulex minor var. *lusitanicus*	.	+	1	1	1	1	1	1
Erica erigena	1	+	1	.	.	1	1	2
Lonicera hispanica	.	+	1	.	2	1	+	+
Schoenus nigricans	.	.	+	+	1	1	+	1
Calluna vulgaris	+	+	.	.	+	+	+	+
Asparagus aphyllus	+	+	.	+	+	.	+	+
Schirpus holoschoenus	+	+	+	.	.	+	+	+
Daphne gnidium	+	.	.	+	+	+	.	+
Agrostis castellana	+	+	.	+	.	+	+	.
Pteridium aquilinum	.	.	1	+	.	+	+	+
Lepidophorum repandum	.	.	.	+	+	+	+	+
Prunella vulgaris	.	+	.	+	+	+	+	.
Holcus lanatus	+	+	+	.	.	.	+	+
Juncus rugosus	+	.	+	+	.	.	.	+
Crataegus monogyna	.	.	+	+	+	+	.	.
Erica scoparia	+	.	+	.	.	.	+	+
Panicum repens	+	+	+	.	.	.	+	.
Quercus lusitanica	.	+	.	.	+	.	+	+
Juncus effusus	1	+	.	.	.	+	.	.
Erica arborea	.	.	.	.	+	+	.	+
Arbutus unedo	.	.	.	.	+	+	+	.
Pseudarrhenatherum longifolium	.	.	.	.	+	+	.	+
Genista triacanthos	+	.	.	.	+	.	.	+

Euphorbia transtagana	.	.	+	.	.	.	+	+
Agrostis stolonifera	.	.	+	.	+	+	.	.
Halimium calycinum	.	+	.	.	+	.	.	+
Fuirena pubescens	.	+	+	+	.	.	.	.
Stachys officinalis	.	.	.	.	+	+	+	.
Halimium lasianthum	+	.	.	.	.	.	+	+
Erica lusitanica	.	.	1	.	.	+	.	.
Lavandula lusitanica	.	.	.	.	+	.	.	+
Danthonia decumbens	.	.	.	.	+	.	+	+
Narcissus bulbocodium	.	.	.	.	.	+	.	+
Holcus mollis	+	.	.	.	.	.	.	+
Hyacinthoides transtagana	.	.	.	.	.	+	.	+
Laurus nobilis	+	.	.	.	.	.	+	.
Lobela urens	.	.	.	.	.	+	+	.
Potentilla erecta	.	.	.	.	.	+	+	.

Other taxa: + *Myrtus communis* in 1; *Dactylis hispanica* subsp. *lusitanica* in 2; + *Carex riparia* in 4; + *Carex flacca* in 5; + *Cyperus longus*, + *Juncus inflexus*, + *Juncus conglomeratus* in 7; + *Lavandula luisieri* in 8. Localities (Coordinate Reference System Datum WGS84): 1—Fajarda (lat 38°58′30.8″N, long 8°36′47.3″W); 2—Malhada Alta (lat 38°52′00.2″N, long 8°32′36.9″W); 3—Canha (lat 38°45′01.1″N, long 8°34′28.2″W); 4—Montargil (lat 39°08′13.9″N, long 8°08′11.8″W); 5—Foros do Rebocho (Monte da Barca; lat 38°52′48.6″N, long 8°28′39.6″W); 6—Infantado (lat 38°50′34.6″N, long 8°44′07.5″W); 7—Coina (lat 38°36′43.4″N, long 9°02′21.2″W); 8—Venda (lat 39°03′43.4″N, long 8°32′50.8″W).

The *Frangulo baeticae-Salicetum atrocinereae ass. nova hoc. loco* occurs in thermomediterranean and warmer mesomediterranean areas, dry to sub-humid belts of the Ribatejo and Sado Sector, over hydromorphic sandy soils rich in organic matter, with some degree of peat formation, and are found on unusual position, since these willow woodlands are strictly linked to slopes of hills with a supplementary supply of springs. This is because the surface water infiltrates through the permeable pliocene-pleistocene sandy soils and feed the upwelling of subterranean water in many isolated springs, often in positions where the impermeable miocene substrates emerge. Thus, *Frangulo baeticae-Salicetum atrocinereae* is an silicicolous association developed close to springs, supporting a long period of waterlogging and represents an obvious discontinuities (island) with the surrounding zonal forests of cork oak (*Quercus suber*): *Aro neglecti–Querco suberis sigmetum*, which represent the climatophilous vegetation series. In addition to their distinct ecology, this new acidophilous community are physiognomically characterized by vegetation that is markedly different from the willow forests most often associated with the banks of water courses of the valleys from the nearby areas. The new *Salix atrocinerea* willow forest proposed here is frequently accompanied by *Frangula alnus* subsp. *baetica* and other differential species from the *Genistion micrantho-anglicae* alliance, such as *Cheirolophus uliginosus*, *Leuzea longifolia* and *Euphorbia uliginosa*.

Sinecologically, these willow woodlands fit in the *Salici atrocinereae-Alnenion glutinosae* sub-alliance (*Alnion glutinosae, Alnetalia glutinosae, Alnetea glutinosae*) and represent the mature stage of the edaphohygrophilous series: *Frangulo baeticae-Salico atrocinereae sigmentum*. The *Cirsio welwitschii-Ericetum ciliaris*, a hydromorphic heathland dominated by *Erica ciliaris* and *Ulex minor* var. *lusitanicus*, represents the first seral stage.

With the destruction of these hygrophyllous formation occurs a new association dominated by *Molinia caerulea* subsp. *arundinaca*, accompaneid by *Cheirolophus uliginosus*: *Cheirolopho uliginosii-Molinietum arundinaceae ass. nova hoc loco* (*holotypus* relevé: 07, Table 3). This perennial grassland grows on peaty areas of the Ribatejo and Sado Sector, colonizing sandy soils with a water-table near the surface. We include the phytocoenoses within the *Brizo minoris-Holoschoenenion vulgaris* sub-alliance (*Molinio arundinacea-Holoschoenion vulgaris, Holoschoenetalia vulgaris, Molinio-Arrhenatheretea*), which also differs from the other association already described by a pool of rare or endemic species, such as *Cheirolophus uliginosus*, *Leuzea longifolia* and *Euphorbia uliginosa*.

Table 3. Cheirolopho uliginosii-Molinietum arundinaceae ass. nova hoc loco (Brizo minoris-Holoschoenenion vulgaris, Molinio arundinacea-Holoschoenion vulgaris, Holoschoenetalia vulgaris, Molinio-Arrhenatheretea).

Ordinal Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Surface (m²)	30	25	20	20	20	20	25
Altitude (m)	84	49	26	66	61	42	46
Cover rate (%)	95	95	85	80	85	90	95
Orientation	S	N	W	NW	NE	N	N
Slope (%)	6	12	5	3	8	10	8
Average heigth (m)	0.7	0.8	0.7	0.6	0.7	0.6	0.8
Number of species	25	26	33	21	26	27	31
Association characteristics							
Molinia caerulea subsp. *arundinacea*	5	5	5	4	5	5	5
Schoenus nigricans	1	2	2	+	+	1	+
Schirpus holoschoenus	+	+	+	+	+	+	+
Cheirolophus uliginosus	+	.	+	1	+	+	2
Prunella vulgaris	+	.	+	.	+	+	+
Erica erigena	.	+	+	+	.	+	1
Holcus lanatus	.	+	.	+	+	1	+
Euphorbia uliginosa	.	+	.	.	.	.	+
Leuzea longifolia	.	.	+	+	.	.	.
Fuirena pubescens	.	.	.	.	+	+	.
Companions							
Erica ciliaris	1	1	+	1	+	+	+
Ulex minor var. *lusitanicus*	+	1	+	+	+	1	+
Brachypodium phoenicoides	+	+	1	+	+	+	+
Salix atrocinerea	+	+	+	+	+	+	.
Ulex australis subsp. *welwitschianus*	.	+	+	+	+	+	+
Pteridium aquilinum	1	.	.	+	2	+	+
Calluna vulgaris	+	+	+	+	.	.	1
Daphne gnidium	+	+	+	.	.	+	+
Holcus mollis	+	+	+	.	+	.	+
Erica scoparia	.	+	+	.	+	+	+
Euphorbia transtagana	+	.	+	.	.	+	1
Crataegus monogyna	+	+	.	+	+	.	.
Agrostis castellana	+	.	.	.	+	+	+
Asparagus aphyllus	+	+	+	.	.	.	+
Lepidophorum repandum	.	+	+	.	+	.	+
Juncus rugosus	.	.	+	.	+	+	.
Ditrichia viscosa	+	.	+	.	+	.	.
Juncus effusus	+	.	.	.	.	+	+
Potentilla erecta	+	.	+	.	.	.	+
Frangula alnus subsp. *baetica*	+	+	+	.	.	.	.
Halimium calycinum	.	+	+	.	+	.	.
Stachys officinalis	.	.	+	+	.	.	+
Halimium lasianthum	.	.	+	.	.	+	+
Lobelia urens	.	.	+	+	.	.	+
Hyacinthoides transtagana	.	.	+	+	.	.	+
Cistus psilosepalus	.	+	.	.	.	+	+
Panicum repens	.	.	.	.	+	+	+
Erica lusitanica	+	.	.	.	1	.	.
Narcissus bulbocodium	+	.	+	.	.	.	.

Lonicera hispanica	+	+	.	.	.	.	.
Erica arborea	.	.	+	.	.	+	.
Carex riparia	.	.	.	1	.	+	.
Agrostis stolonifera	.	+	.	.	+	.	.
Euphorbia boetica	.	+	.	.	+	.	.

Other taxa: + Salix salviifolia subsp. australis in 1; + Dactylis hispanica subsp. lusitanica; + Hypericum perforatum in 2; + Carex lusitanica; + Pinguicula lusitanica, + Scutellaria minor; in 3; + Hypericum elodes, + Myrtus communis in 4; + Agrostis juressi in 5; + Asphodelus aestivus; + Cynodon dactylon in 6; + Danthonia decumbens; + Potentilla erecta in 7. Localities (Coordinate Reference System Datum WGS84): 1—Montargil (lat 39°07′29.2″N, long 8°07′45.8″W); 2—Venda (lat 39°03′42.7″N, long 8°32′51.7″W); 3—Samora Correia (Infantado, lat 38°49′11.8″N, long 8°45′24.8″W); 4—Foros do Rebocho (Monte da Barca; lat 38°52′34.0″N, long 8°27′43.5″W); 5—Coruche (lat 38°52′43.7″N, long 8°28′42.5″W); 6—Canha (lat 38°45′01.4″N, long 8°34′26.7″W); 7—Palhais (Mata da Machada; lat 38°36′43.4″N, long 9°01′56.0″W).

III—*Viti sylvestris-Salicetum atrocinereae* (clusters 47–53, Figure 1)

This is a community that was described as belonging to the gleyed sandy soils of the Doñana area, in Cádiz and Littoral Huelva Sector [9], extending towards the Coastal Lusitania and West Andalusia Province, and reaching the Atlantic Orolusitania Subprovince and western areas of the Lusitania and Extremadura Subprovince. It occurs in dry to sub-humid thermomediterranean belt, and grows on ologotrophic soils, subjected to temporary flooding. According to Rivas-Martínez [9], this community is dominated by *Salix atrocinerea* and is characterized by the frequency of *Vitis vinifera* subsp. *sylvestris*, *Thelypteris palustris*, among others.

IV—*Carici microcarpae-Salicetum atrocinereae* (clusters 54–84, Figure 1)

The Carici microcarpae-Salicetum atrocinereae, linked to the Hyperico hircini-Alnenion glutinosae suballiance (Osmundo-Alnion, Populetalia albae, Salici purpureae-Populetea nigrae), encompasses willow forests dominated by Salix atrocinerea usually accompained by Carex microcarpa, supporting longer flooding periods of both oligotrophic and oligo-eutrophic waters, and widely distributed throughout the thermomediterranean to mesomediterranean, dry to sub-humid belts of the Sardinian–Corsican province [32]. According to Angius and Bacchetta [11], this association has a wide representation of endemic species characteristics of Hyperico hircini-Alnenion glutinosae suballiance, such as Mentha suaveolens subsp. insularis, Eupatorium cannabium subsp. corsicum, Euphorbia meuselii.

V—*Myrto communis-Salicetum atrocinerea* (clusters 39–46, Figure 1)

For La Madalena archipelago, located between north-eastern Sardinia and southern Corsica (Maddalenino Subscector, Campidanese-Turritano Sector, Sardinian–Corsican province), Biondi and Bagella [12] published the willow forest *Myrto communis-Salicetum atrocinerea*, dominated by *Salix atrocinerea*, often accompanied by *Rubus ulmifolius*, *Carex hispida*, *Myrtus communis* and *Oenanthe crocata*. This association is located in hydromorphic soils on swampy depressions, where the water table is almost permanent or close to the soil surface, within the thermomediterranean dry bioclimatic belt. On more dry soils of riverbeds, occurs a variant of this association, the subass. *tamaricetosum africanae*, characterized by the presence of *Tamarix africana* [12]. Following Bacchetta [34], in river and streams with permanent flow, on oligo-miocene deposits located in upper thermomediterranean or lower mesomediterranean belts under upper dry to lower subhumid areas of the western-central Sardinia, the communities enriched with *Laurus nobilis* are classified as subass. *lauretosum nobilis*.

VI—*Salicetum atrocinereo-australis* (clusters 1–13, Figure 1)

This association colonizes siliceous soils of the thermomediterranean to mesomediterranean, dry to humid belts of the southwestern part of the Cádiz and Sado Suprovince and Lusitania and Extremadura Subprovince [2,4]. According to Dalila [35] and Quinto-Canas [36], the *Salicetum atrocinereo-australis* occurs in periodically flooded margins of temporary watercourses, characterized by torrential flows during the wet season and is distinguished by the abundance of *Salix salviifolia* subsp. *australis* and the absence or scarcity of nemoral species in the shady understory, due to the substratum instability and strong sediment carriage.

VII—*Clematido flammulae-Salicetum australis ass. nova hoc loco* (clusters 14–18, Figure 1; *holotypus* relevé: 04, Table 4)

In the southern Portuguese territories included in the biogeographical unit of Algarve District, occurs the association *Clematido flammulae-Salicetum australis*, which is proposed here as a new willow forest association, exclusive from the limestone substrates of Barrocal algarvio, under thermomediterranean dry to subhumid belts. These riparian forests develop along banks of torrential Algarve's streams, where the hydrographical basin substrata are mostly basic [37]. It is found on oligotrophic soils, with sandy-limey texture, that are periodically flooded, and resisting to prolonged drought periods. The new willow forest is dominated by *Salix salviifolia* subp. *australis*, constantly accompanied by *Salix neotricha* and *Clematis flammula*. The presence of Fraxinus angustifolia and *Nerium oleander*, reveals the catenal relationship of this association, with the ash woodlands (*Ranunculo ficariiformis-Fraxinetum angustifoliae*) and oleander micro-woodlands (*Oenantho crocatae-Nerietum oleandri*). Out of the trees and shrub observed, the climbing plant species are well represented, with *Aristolochia baetica*, *Lonicera implexa*, *Rubus ulmifolius*, *Smilax aspera* var. *altissima,* and *Calystegia sepium*. In the understory, we can highlight the presence of *Brachypodium sylvaticum, Vinca difformis, Equisetum ramosissimum,* and *Festuca ampla,* as well as hygrophilous plants from *Molinio caeruleae-Arrhenatheretea elatioris* and *Magnocarici elatae-Phragmitetea australis* such as *Oenanthe crocata, Carex hispida, Lythrum salicaria, Cyperus longus* subsp. *badius, Schoenoplectus lacustris, Typha domingensis, Scirpoides holoschoenus, Mentha suaveolens, Agrostis stolonifera, Dorycnium rectum*, among others, associated to environments affected by temporary flooding. The presence of nemoral-thermophile species *Aristolochia baetica, Bupleurum fruticosum*, and *Cheirolophus sempervirens*, must be emphasized.

Table 4. Clematido flammulae-Salicetum australis ass. nova hoc loco (Salicion salviifoliae, Salicetalia purpureae, Salici purpureae-Populetea nigrae).

Ordinal Number	1	2	3	4	5
Surface (m2)	200	100	250	300	200
Altitude (m)	160	30	130	185	155
Cover rate (%)	85	85	95	90	85
Orientation	NE	N	O	O	S
Slope (%)	3	2	15	3	2
Average height (m)	6	6	6	7	6
Number of species	18	16	14	31	29
Association characteristics					
Salix salviifolia subp. *australis*	4	4	4	4	4
Salix neotricha	3	3	3	3	3
Clematis flammula	+	+	+	1	+
Vinca difformis	.	1	1	1	1
Equisetum ramosissimum	+	1	.	+	1
Fraxinus angustifolia	.	.	+	1	+
Brachypodium sylvaticum	.	.	.	1	+
Aristolochia paucinervis	.	.	.	.	+
Equisetum telmateia	.	.	.	.	+
Companions					
Rubus ulmifolius	1	2	1	1	2
Ceratonia siliqua	+	+	1	+	+
Smilax aspera var. *altissima*	1	.	2	1	2
Scirpoides holoschoenus	+	+	.	1	1

Nerium oleander	1	.	+	1	+
Arundo donax	+	1	1	.	+
Lythrum salicaria	+	1	.	+	+
Mentha suaveolens	+	+	.	+	+
Dorycnium rectum	.	+	.	+	2
Carex hispida	+	.	.	+	+
Rosa pouzinii	.	1	.	+	.
Calystegia sepium	.	1	.	.	+
Viburnum tinus	+	.	.	+	.
Aristolochia baetica	.	+	.	.	+
Paspalum dilatatum	.	+	.	+	.
Dittrichia viscosa subsp. *revoluta*	.	.	+	.	+
Samolus valerandi	.	.	.	+	+
Cyperus longus subsp. *badius*	.	.	.	+	+

Other taxa: + Euphorbia hirsuta, + Festuca ampla, + Oenanthe crocata, + Rosa canina in 1; + Lonicera implexa, + Arbutus unedo, + Rhamnus alaternus in 3; + Adiantum capillus-veneris, + Agrostis stolonifera, + Holcus lanatus, + Plantago major, + Prunella vulgaris, + Sanguisorba hybrida, + Rumex crispus, + Tamarix africana, + Typha domingensis, + Verbena officinalis, in 4; + Bupleurum fruticosum, + Dactylis hispanica subsp. glomerata, + Cheirolophus sempervirens, + Myrtus communis, + Schoenoplectus lacustris in 5. Localities (Coordinate Reference System Datum WGS84): 1—Fonte Filipe (lat 37°10′52.95″N, long 7°57′46.71″W); 2—Rib.ª da Fonte da Benémola (lat 37°12′32.69″N, long 8°00′33.95″W); 3—Amendoeiras (São Brás de Alportel e Estoi lat 37°07′24.21″N, long 7°53′58.50″W); 4—Rio Séqua (Asseca; lat 37°09′08.91″N, long 7°40′21.63″W); 5—Rib.ª da Fonte da Benémola (lat 37°11′50.11″N, long 8°00′22.79″W).

Its fringe and first substitution step belongs to the bramble shrublands of *Rubus ulmifolius* from *Lonicero hispanicae-Rubetum ulmifolii*. Accordingly, the removal of tree and shrub cover leads to the hygro-nitrophilous reed beds belong to the association *Holoschoeno vulgaris-Juncetum acuti*. Lastly occurs the perennial grasslands from *Narcisso willkommii-Festucetum amplae*, dominated by *Festuca ampla*, growing on neutro basic deep soils, with sandy-limey texture, along torrential streams running through calcareous deposits of the Jurassic and Cretaceous age, always in the Algarve's streams basin [38].

We place the Clematido flammulae-Salicetum australis ass. nova hoc loco, at the syntaxonomic level, in the Salicion salviifoliae alliance (Salicetalia purpureae, Salici purpureae-Populetea nigrae) and we propose changing its diagnosis to encompass both neutro-calcicolous and silicicolous communities.

4. Conclusions

With the information collected from 84 phytosociological relevés, we conducted a comparative and synthetic analysis of riparian woodlands communities dominated by *Salix atrocinerea* and *Salix salviifolia* subsp. *australis*, occurring in Southwestern part of the Iberian Peninsula and Sardinia. This study allowed us to identify the ecological position of *Salix atrocinerea* next to springs located hills sploes on psamophilic soils. Accordingly, we propose a new association namely *Frangulo baeticae-Salicetum atrocinereae*, for the acid pliocene-pleistocene sandy soils, in the Ribatejo and Sado Sector. Furthermore, for neutro-basophilous torrentail streams and watercourses of the Algarvese District (Algarve and Monchique biogeographic Sector) we propose the association *Clematido flammulae-Salicetum australis*.

At sub-serial level we identified a new perennial grassland association dominated by *Molinia caerulea* subsp. *arundinacae*, namely *Cheirolopho uliginosii-Molinietum arundinaceae*, for the thermomediterranean dry to sub-humid areas of the Ribatejo and Sado Sector, and represents a regression stage of *Frangulo baeticae-Salicetum atrocinereae*.

Such willow forests and perennial grasslands are important for biodiversity conservation, since they constitute a refuge to endemic or protected species, such as *Salix salviifolia* subsp. *australis*, *Euphorbia uliginosa, Cheirolophus uliginosus, Leuzea longifolia, Agrostis juressi, Euphorbia transtagana, Hyacinthoides transtagana*, among others. Therefore, it is important to guarantee the sustainability of these habitats, through conservation measures to avoid the disturbance on riparian woodlands across the Mediterranean, as reported by Fenu et al. [39]. In this sense, it would be necessary to create joint policies for these areas of high biodiversity, through the enhancement of ecosystem services.

Species conservation should give priority to places with a high number of plants threatened by IUCN (International Union for Conservation of Nature) criteria, such as Mediterranean waterways. Set as priorities, these areas should be subject to overgrazing control (mainly cattle grazing), develop programs to eradicate invasive plants (focusing on several species of the genus *Acacia* and *Arundo*), and seed harvest for germination and conservation studies in germplasm banks.

Attempt to their high conservational value, the willow woodlands associations should incorporate the habitat 92A0-*Salix alba* and *Populus alba* galleries, besides the perennial grasslands of *Cheirolopho uliginosii-Molinietum arundinaceae*, incorporate the habitat 6410-*Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*), both from Annex I of Council Directive 92/43/EEC.

Syntaxonomical Scheme

ALNETEA GLUTINOSAE Br.-Bl. and Tüxen *ex* Westhoff, Dijk, and Passchier 1946

ALNETALIA GLUTINOSAE Tüxen 1937

Alnion glutinosae Malcuit 1929

Salici atrocinereae-Alnenion glutinosae Rivas-Martínez, T.E. Díaz and F. Prieto 2011

Carici lusitanicae-Salicetum atrocinereae Neto, Capelo, J.C. Costa and M. Lousã 1996

Frangulo baeticae-Salicetum atrocinerea *ass. nova hoc loco*

Viti sylvestris-Salicetum atrocinereae Rivas-Martínez and Costa *in* Rivas-Martínez, Costa, Castroviejo and E. Valdés 1980

SALICI PURPUREAE-POPULETEA NIGRAE (Rivas-Martínez and Cantó *ex* Rivas-Martínez, Báscones, T.E. Díaz, Fernández-González and Loidi 1991) Rivas-Martínez and Cantó 2002

POPULETALIA ALBAE Br.-Bl. Ex Tchou 1948

OSMUNDO-ALNION (Br.-Bl., P. Silva et Rozeira 1956) Dierschke et Rivas-Martínez in Rivas-Martínez 1975

Hyperico hircini-Alnenion glutinosae Dierschke 1975

Carici microcarpae-Salicetum atrocinereae Angius and Bacchetta 2009

Myrto communis-Salicetum atrocinereae Biondi and Bagella 2005

SALICETALIA PURPUREAE Moor 1958

Salicion salviifoliae Rivas-Martínez, T.E. Díaz, F. Prieto, Loidi and Penas 1984

Clematido flammulae-Salicetum australis *ass. nova hoc loco*

Salicetum atrocinereo-australis J.C. Costa & Lousã *in* J.C. Costa, Lousã and Paes 1998

MOLINIO-ARRHENATHERETEA Tüxen 1937

HOLOSCHOENETALIA VULGARIS Br.Bl. ex Tchou 1948

Molinio arundinacea-Holoschoenion vulgaris Br.Bl. ex Tchou 1948

Brizo minoris-Holoschoenenion vulgaris (Rivas Goday 1964) Rivas-Martínez in Rivas-Martínez, Costa, Castroviejo and E. Valdés 1980

Cheirolopho uliginosii-Molinietum arundinaceae *ass. nova hoc loco*

Author Contributions: Conceptualization, M.R. and R.Q.-C.; methodology, C.P.G.; software, M.R.; validation, C.P.G., G.S.; formal analysis, M.R., A.C.-O.; investigation, M.R., A.C.-O.; resources, M.R., R.Q.-C.; data curation, M.R., R.Q.-C., C.P.G.; writing—original draft preparation, M.R.; writing—review and editing, R.Q.-C., G.S.; visualization, A.C.-O.; supervision, C.P.G., G.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: With the contribution of the European Commission's LIFE program, through the Life-Relict Project—Preserving Continental Laurissilva Relicts (NAT/PT/000754).

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Camporeale, C.; Perucca, E.; Ridolfi, L.; Gurnell, A.M. Modeling the Interactions between River Morphodynamics and Riparian Vegetation. *Rev. Geophys.* **2013**, *51*, 379–414, doi:10.1002/rog.20014.
2. Costa, J.; Lousã, M.; Oliveira Paes, A.P. As comunidades ribeirinhas da bacia hidrográfica do rio Sado (Alentejo, Portugal). *Actas Colóquio Int. Ecol.* **1996**, *I*, 291–320.
3. Raposo, M.; Castro, M.C.; Pinto-Gomes, C. The application of symphytosociology in landscape architecture in the Western Mediterranean. *Botanique* **2016**, *1*, 103–112.
4. Portela-Pereira, E. Análise Geobotânica dos Bosques e Galerias Ripícolas da Bacia Hidrográfica do Tejo em Portugal. Ph.D. Thesis, Universidade de Lisboa, Lisboa, Portugal, 2013.
5. Rivas-Martínez, S. Mapa de series, geosséries y geopermaseries de vegetación de España. (Memoria del mapa de vegetatión potencial de España). *Itinera Geobot.* **2011**, *18*.
6. Costa, J.C.; Neto, C.; Aguiar, C.; Capelo, J.; Espírito Santo, M.D.; Honrado, J.J.; Gomes, C.P.; Monteiro-Henriques, T.; Sequeira, M.; Lousã, M. Vascular plant communities in Portugal (continental, the Azores and Madeira). *Glob. Geobot.* **2012**, *2*, 1–180.
7. Mucina, L.; Bültmann, H.; Dierßen, K.; Theurillat, J.-P.; Raus, T.; Čarni, A.; Šumberová, K.; Willner, W.; Dengler, J.; García, R.G.; et al. Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. *Appl. Veg. Sci.* **2016**, *19*, 3–264, doi:10.1111/avsc.12257.
8. Neto, C. A Flora e a Vegetação do superdistrito Sadense (Portugal). *Guineana* **2002**, *8*, 178–186.
9. Rivas-Martínez, S.; Valdés, E.; Costa, M.; Castroviejo, S. Vegetación de Doñana (Huelva, España). *Lazaroa* **1980**, *2*, 5–190.
10. Bacchetta, G.; Bagella, S.; Biondi, E.; Farris, E.; Filigheddu, R.; Mossa, L. Vegetazione forestale e serie di vegetazione della Sardegna (con rappresentazione cartografica. *Fitosociologia* **2009**, *46*, 82.
11. Angius, R.; Bacchetta, G. Boschi e boscaglie ripariali del Sulcis-Iglesiente (Sardegna Sud-Occidentale, Italia). *UNICA IRIS* **2009**, *45*, 1–68.
12. Biondi, E.; Bagella, S. Vegetazione e paesaggio vegetale dell`arcipelago di La Maddalena (Sardegna nord-orientale). *Fitosociologia* **2005**, *42*, 63.
13. Braun-Blanquet, J.; Pavillard, J. *Vocabulaire de Sociologie Végétale*, 3rd ed.; Roumégous et Déhan: Montpellier, France, 1928.
14. Tüxen, R. *Die Pflanzengesellschaften Nordwestdeutschlands*; Mitt. Flor.-Soz. Arbeitsgem: Hannover, Germany, 1937; Volume 3.
15. Géhu, J.M.; Rivas-Martínez, S. Notions fondamentales de phytosociologie. In *Syntaxonomie. Vaduz: Berichte Internationalen Symposien der Internationalen Vereinigung fur Vegetationskunde*; J. Cramer.: Vaduz, Liechtenstein, 1981; pp. 5–33.
16. Rivas-Martinez, S. Notions on dynamic-catenal phytosociology as a basis of landscape science. *Plant Biosyst. Int. J. Deal. All Asp. Plant Biol.* **2005**, *139*, 135–144, doi:10.1080/11263500500193790.
17. Lazare, J.J. Phytosociologie dynamico-caténale et gestion de la biodiversité. *Acta Bot. Gall.* **2009**, *156*, 49–62.
18. Biondi, E. Phytosociology today: Methodological and conceptual evolution. *Plant Biosyst.* **2011**, *145*, 19–29.
19. Coutinho, A.X.P. *Flora de Portugal*, 2nd ed.; Bertrand: Lisboa, Portugal, 1939.
20. Franco, J.A. *Nova Flora de Portugal (Continente e Açores)*; Escolar Editora: Lisboa, Portugal, 1971; Volume I.
21. Franco, J.A. *Nova Flora de Portugal (Continente e Açores)*; Escolar Editora: Lisboa, Portugal, 1984; Volume II.
22. Franco, J.; Rocha Afonso, M. *Nova Flora de Portugal (Continente e Açores)*; Escolar Editora: Lisboa, Portugal, 1984; Volume III.

23. Castroviejo, S. *Flora Ibérica. Plantas Vasculares da Península Ibérica e Ilhas Baleares*; Real Jardín Botánico; CSIC: Madrid, Spain, 1986.
24. Valdés, B.; Talavera, S.; Fernández-Galiano, E. *Flora Vascular de Andalucía Occidental*; Ketres Editora, S.A.: Barcelona, Spain, 1987; Volume 1–3.
25. Portela-Pereira, E.; Capelo, J.; Neto, C.; Costa, J.C. Síntese do Conhecimento Taxonómico do Género Salix L. em Portugal Continental. *Silva Lusit.* **2013**, *21*, 103–133.
26. Ward, J.R. Hierarchical Grouping to Optimize an Objective Function. *J. Am. Stat. Assoc.* **1963**, *58*, 236–244, doi:10.1080/01621459.1963.10500845.
27. Van der Maarel, E. Transformation of cover-abundance values in phytosociology and its effects on community similarity. *Vegetatio* **1979**, *39*, 97–114, doi:10.1007/BF00052021.
28. Cano, E.; Valle, F. Aportaciones fitosociologicas sobre sierra morena oriental (Andalucia, España). *Monogr. Flora Veg. Béticas* **1990**, *4*, 45–51.
29. Rivas-Martínez, S. Mapas de series, geoseries y geopermaseries de vegetación de España [Memoria del mapa de vegetación potencial de España]. Parte I. *Itinera Geobot.* **2007**, *17*, 5–436.
30. Rivas-Martínez, S.; Penas, Á.; Díaz González, T.E.; Cantó, P.; del Río, S.; Costa, J.C.; Herrero, L.; Molero, J. Biogeographic Units of the Iberian Peninsula and Baelaric Islands to District Level. A Concise Synopsis. In *The Vegetation of the Iberian Peninsula: Volume 1*; Loidi, J., Ed.; Plant and Vegetation; Springer International Publishing: Cham, Switzerland, 2017; pp. 131–188. ISBN 978-3-319-54784-8.
31. Rivas-Martínez, S.; Penas, Á.; del Río, S.; Díaz González, T.E.; Rivas-Sáenz, S. Bioclimatology of the Iberian Peninsula and the Balearic Islands. In *The Vegetation of the Iberian Peninsula: Volume 1*; Loidi, J., Ed.; Plant and Vegetation; Springer International Publishing: Cham, Switzerland, 2017; pp. 29–80. ISBN 978-3-319-54784-8.
32. Fenu, G.; Fois, M.; Cañadas, E.M.; Bacchetta, G. Using endemic-plant distribution, geology and geomorphology in biogeography: The case of Sardinia (Mediterranean Basin). *Syst. Biodivers.* **2014**, *12*, 181–193, doi:10.1080/14772000.2014.894592.
33. Braun-Blanquet, J. *Fitosociología. Bases Para el Estudio de las Comunidades Vegetales*; H. Blume: Madrid, Spain, 1979.
34. Bacchetta, G. Contributo alla conoscenza dei boschi a Laurus nobilis L. della Sardegna, habitat prioritario ai sensi della Direttiva 92/43/CEE. *Fitosociologia* **2007**, *44*, 249–244.
35. Espírito-Santo, D.; Capelo, J.; Neto, C.; Pinto-Gomes, C.; Ribeiro, S.; Quinto Canas, R.; Costa, J.C. Lusitania. In *The Vegetation of the Iberian Peninsula. Plant and Vegetation*; Springer: Berlin/Heidelberg, Germany, 2017; Volume 13, pp. 35–82.
36. Quinto-Canas, R. Flora y Vegetación de la Serra do Caldeirão—Aproximación Fitosociológica. Ph.D. Thesis, Universidad de Jaén, Jaén, Spain, 2014.
37. Pinto-Gomes, C.; Paiva-Ferreira, R. *Flora e Vegetação Barrocal Algarvio, Tavira—Portimão*; CCDR Algarve: Faro, Portugal, 2005; ISBN 972-95734-9-2.
38. Quinto-Canas, R.; Mendes, P.; Meireles, C.; Musarella, C.; Pinto-Gomes, C. The Agrostion castellanae Rivas Goday 1957 corr. Rivas Goday & Rivas- Martínez 1963 alliance in the southwestern Iberian Peninsula. *Plant Sociol.* **2018**, *55*, 21–29, doi:10.7338/pls2018551/02.
39. Fenu, G.; Bacchetta, G.; Christodoulou, C.S.; Cogoni, D.; Fournaraki, C.; Gian Pietro, G.G.; Gotsiou, P.; Kyratzis, A.; Piazza, C.; Vicens, M.; et al. A Common Approach to the Conservation of Threatened Island Vascular Plants: First Results in the Mediterranean Basin. *Diversity* **2020**, *12*, 157, doi:10.3390/d12040157.

CAPÍTULO V

PRINCIPAIS AMEAÇAS AO ESTADO DE CONSERVAÇÃO DAS COMUNIDADES DE *PRUNUS LUSITANICA*

Publicado como:

Raposo, M., Pinto-Gomes, C., & Nunes L.J. (2020). Selective Shrub Management to Preserve Mediterranean Forests and Reduce the Risk of Fire: The Case of Mainland Portugal. *Fire* 3, (4): 65. https://doi.org/10.3390/fire3040065

Raposo, M., Pinto-Gomes, C., & Nunes, L.J. (2021). Evaluation of Species Invasiveness: A Case Study with *Acacia dealbata* Link. on the Slopes of Cabeça (Seia-Portugal). *Sustainability* 13, 20: 11233. https://doi.org/10.3390/su132011233

CAPÍTULO V. PRINCIPAIS AMEAÇAS AO ESTADO DE CONSERVAÇÃO DAS COMUNIDADES DE *PRUNUS LUSITANICA*

V.1. Intróito

Este Capítulo aborda a importância do controlo seletivo do coberto vegetal na diminuição do risco de incêndio e concomitantemente, a sua contribuição no melhoramento do estado de conservação dos estados florestais e préflorestais da vegetação no macrobioclima mediterrânico. A primeira parte (Introdução) expõe a problemática dos incêndios em ambiente mediterrâneo, caracterizado por uma elevada biodiversidade florística. A segunda parte (Materiais e Métodos) contextualiza a área de estudo e apresenta as obras de referência para a identificação taxonómica e de conceitos. A terceira parte (Dinâmica da vegetação) apresenta-se a dinâmica mais comum de um bosque mediterrânico (M. Raposo, 2016). A quarta parte (Resultados e discussão) subdivide-se em duas partes. O primeiro tópico aborda aspetos da vegetação em ambiente pós fogo e relaciona-os com a morfologia das espécies heliófilas vs. espécies preflorestais. O segundo tópico baseia-se nas Classes Fitossociológicas para distinguir géneros de plantas a conservar e a controlar (Costa et al., 2012; Rivas-Martínez, 2011). A quinta e última parte apresentam-se as principais conclusões do estudo.

O segundo artigo incide sobre uma das principais ameaças à conservação das comunidades de *P. lusitanica*, as plantas invasoras (M. Raposo et al., 2021). Outros estudos baseiam-se em dados de inventários florestais regionais para calcular a área de expansão (Hernández et al., 2014). De modo a contribuir para identificar as plantas que apresentam maior ameaça para a conservação e a definir as prioridades no controlo, apresentam-se duas fórmulas para estimar o poder invasivo de plantas com um crescimento do tipo radial, como é o caso da *Acacia dealbata*. A aplicação destas formulas permite inclusivamente, com base em dados históricos, estimar a área potencial de invasão para o futuro. A primeira parte (Introdução) divide-se em dois tópicos. O primeiro tópico aborda o impacte das espécies invasoras na conservação da natureza. O segundo tópico foca as principais características de *A. dealbata* que promovem um comportamento invasor nas áreas de estudo. A segunda parte (Materiais e métodos) divide-se em dois tópicos. O primeiro tópico apresenta uma caracterização das condições biofísicas da área de estudo. O segundo tópico trata a obtenção dos dados espaciotemporais para a realização do presente estudo e apresenta as fórmulas utilizadas. A terceira parte (Resultados e discussão) apresenta os dados de crescimento sobre os quinze núcleos de acácia estudados. Com base no histórico de catorze anos faz uma projeção para vinte anos da área de ocupação espectável dos núcleos de acácia. A quarta parte (Conclusões) aborda a importância da utilização e da replicação destas fórmulas noutros territórios como forma de complementar as decisões de gestão da paisagem, bem como os métodos de controlo mais adequados para esta espécie.

Referências

Costa, J. C., Neto, C., Aguiar, C., Capelo, J., Espírito Santo, M. D., Honrado, J. J., Gomes, C. P., Monteiro-Henriques, T., Sequeira, M., & Lousã, M. (2012). Vascular plant communities in Portugal (continental, the Azores and Madeira). *Global Geobotany*, *2*, 1–180.

Hernández, L., Martínez- Fernández, J., Cañellas, I., & de la Cueva, A. V. (2014). Assessing spatio-temporal rates, patterns and determinants of biological invasions in forest ecosystems. The case of Acacia species in NW Spain. *Forest Ecology and Management*, *329*, 206–213. https://doi.org/10.1016/j.foreco.2014.05.058

Raposo, M. (2016). Séries de vegetação prioritárias para a conservação no centro e sul de Portugal continental. *Botanique*.

Raposo, M., Nunes, L., Quinto-Canas, R., del Río, S., Pardo, F. M. V., Galveias, A., & Pinto-Gomes, C. J. (2021). Prunus lusitanica L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal. *Diversity*, *13*(8), 359. https://doi.org/10.3390/d13080359

Rivas-Martínez, S. (2011). Mapa de series, geosséries y geopermaseries de vegetación de España. (Memoria del mapa de vegetatión potencial de España). *Itinera Geobotanica*, *18*(1).

V.2. Artigo: Selective Shrub Management to Preserve Mediterranean Forests and Reduce the Risk of Fire: The Case of Mainland Portugal

fire

MDPI

Perspective

Selective Shrub Management to Preserve Mediterranean Forests and Reduce the Risk of Fire: The Case of Mainland Portugal

Mauro A.M. Raposo [1,2], Carlos J. Pinto Gomes [1,2] and Leonel J.R. Nunes [3,*]

1 Departamento da Paisagem, Ambiente e Ordenamento, Universidade de Évora, 7000-671 Évora, Portugal; mraposo@uevora.pt (M.A.M.R.); cpgomes@uevora.pt (C.J.P.G.)
2 MED—Mediterranean Institute for Agriculture, Environment and Development, Pólo da Mitra, Universidade de Évora, 7006-554 Évora, Portugal
3 ProMetheus—Unidade de Investigação em Materiais, Energia e Ambiente para a Sustentabilidade, Escola Superior Agrária, Instituto Politécnico de Viana do Castelo, Rua da Escola Industrial e Comercial de Nun'Alvares, 4900-347 Viana do Castelo, Portugal
* Correspondence: leonelnunes@esa.ipvc.pt; Tel.: +351-258-909-740

Received: 23 September 2020; Accepted: 9 November 2020; Published: 10 November 2020

check for updates

Abstract: The recurrent rural fires that occur annually in Portugal have reached great proportions due to a lack of effective landscape management. Attempts to solve this problem led to the legal imposition to cut back the vegetation in the fuel management areas, which has had a negative effect on biodiversity. National legislation protects three native plant species (*Quercus suber*, *Q. rotundifolia* and *Ilex aquifolium*). European legislation, through the Habitats Directive, also identifies some plant species that require strict protection, although it leaves out several endemic and rare plants. In this work we aim to differentiate the types of shrub plant material and their pyrophilic behavior, since the physical and chemical characteristics of vegetation can enhance or inhibit the progression of fire. Thus, based on phytosociological science, specifically at the class level, the dynamics of potential climatophilous vegetation in Portugal are presented and the classes that should be prioritized for control are identified. Based on ecology, it was possible to identify morphological patterns of vegetation. In short, the genera targeted for control under the National Forest Fire Protection Plan belong to the furthest states from the mature potential of a forest, generally consisting of heliophile shrubs and typically growing in degraded soils. The shrub species to be valued belong to dynamic states closer to the mature potential, consisting mainly of broad-leaved shrubs and those growing in better-preserved soils.

Keywords: phytosociology; forest; rural fires; vegetation management; heliophile shrubs

1. Introduction

Of the five existing macro-climates in the world, the Mediterranean is the one with the greatest diversity of shrub plants [1,2]. This fact, associated with the high number of endemic species, led the WWF (Word Wide Fund for Nature) to consider the Mediterranean Basin one of the great biodiversity hotspots worldwide [3]. However, several threats are destroying this genetic heritage, such as the fires that occurred in recent decades in mainland Portugal [4–7]. In addition to occurring more frequently, there has also been an increase in the burnt area, accumulating to hundreds of thousands of hectares. One of the worst years was 2017, with a total of 442,418 hectares burned and 64 human lives lost in the region of Pedrogão Grande [8,9].

Faced with this situation, political agents have been forced to invest in better planning and adopt fire prevention strategies [10,11]. According to the new European Union strategy for forests and the forest sector, there is a need for the reinforcement of protection measures relating to issues such as habitat fragmentation, the spread of invasive alien species, climate change, water scarcity, fires, storms and pests [12]. However, although Portugal has specific legislation to address these joint concerns, such as Decree-Law no. 17/2009, which establishes structural measures and actions related to the prevention and protection of forests against fires, it is necessary to address this issue in a more objective and uncomplicated way [13]. Other studies have been conducted on the management of vegetation cover; however, it is necessary to deepen our knowledge about the constitution of shrub plant material and the main differences between its components [14,15].

Forests in Portugal occupy about 3.2 million hectares, corresponding to 35.4% of the national territory [16]. However, only 2% of this area is under the tutelage of the Portuguese State, the rest being managed by private or local entities, which hinders the correct management and implementation of new measures [17]. In addition to the difficulty in implementing these measures, it is necessary to determine the type of vegetation that must be controlled [18]. Decree-Law no. 17/2009 establishes the mandatory removal of vegetation within national territory (10 m from the road network and 50 m from buildings). This requirement has resulted in the radical cutting of all vegetation within these bounds, with the exception of holly (Decree-Law 423/89), cork oak and holm oak (Decree-Law No. 169/2001, as amended by Decree-Law 155/2004), since these species are protected by national legislation. The protection of the cork oak and holm oak is related to the lack of natural regeneration that was verified in Portugal, especially to the South of the Tagus river, which prevents the renewal of the stands. Equally protected is holly, due to the Christmas tradition of cutting the branches of this species for decoration.

Although the dispersion of flames within wildfires is influenced by a variety of factors, such as temperature, humidity and orography, among many others, in this study we intend to focus on what really burns, namely, the plant material. From the point of view of landscape management to reduce the risk of fire, it is easier to control vegetation than to control climatic factors. The morphology of the flora—the dimensions, shapes, textures and chemical characteristics—can promote or inhibit the advance of the flames. In general, resinous plants are more prone to catch fire than oaks, due to the high amount of flammable terpenes present in the resin [19], as are plants with high levels of essential oils [20]. Accordingly, the National Forest Authority has published a manual with a dozen species to be avoided in the fuel management ranges [21]. Despite this initial contribution, it is necessary to have a better understanding of the high diversity of existing flora, its framing in terms of the dynamics of vegetation cover and its pyrophilic characteristics.

From a conservation point of view, fuel management bands should not be “dead” areas, so it is necessary to distinguish the different types of vegetation [22]. In this sense, there is an intention to improve existing knowledge about plant communities in Portugal, in order to create strategies that are more appropriate to increase resilience and at the same time to reduce the risk of fire. In addition, the Habitats Directive has outlined a set of species of community interest to conserve, due to the high patrimonial value or because they play important functions in ecosystems that must be safeguarded.

The objective of this work is to contribute, based on field knowledge, to reduce the risk of fire in rural Mediterranean landscapes, through a rational management of vegetation cover. Of all the macro-climates in the world, the Mediterranean is the one with the greatest diversity of shrub species. However, some of them are rare and endemic to this region, so it is essential to develop selective management methods that promote their conservation. Although the element of fire is naturally part of southern Europe’s landscapes, this is a factor that inhibits the development of progressive dynamics, namely the mature state of forests, promoting soil degradation and the emergence of primary scrub in ecological succession. Thus, the knowledge produced in this study will directly contribute to the local agents that operationalize the management in the field, as well as to the sensitization and valorization of the floristic heritage. In fact, the selective management of the vegetation cover must even integrate the regional political intrusions, through the National Plan for the Defense of the Forest Against Fires.

2. Materials and Methods

This study focuses on the vegetation of the Mediterranean basin, giving special emphasis to the Portuguese territory due to the serious fire problems that have occurred there in recent decades. The data collection, based on the areas burned in 2017 in the central area of Portugal (Figure 1), was carried out during the spring of 2018.

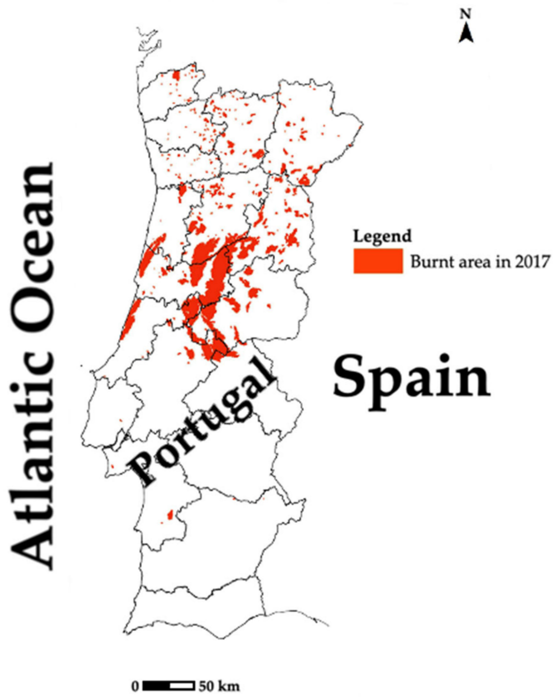


Figure 1. Location of burnt areas in mainland Portugal in 2017 (Source: GNR—Guarda Nacional Republicana, Forestry Technical Offices, Landsat and Copernicus, obtained through the website of ICNF—Institute for Nature Conservation, available at www.icnf.pt).

The following works were used to identify the flora—*Flora Ibérica* [23], *Flora de Portugal* [24], *Nova Flora de Portugal* [25–28], *Flora of Western Andalusia* [29] and *Flora of Italy* [30–33]. For the interpretation of the vegetation cover, we used a phytosociological methodology, according to the standards of the Zurich-Montepellier Sigmatist school, proposed by Braun-Blanquet (1979) [34], Géhu and Rivas-Martínez (1981) [35] and Rivas-Martínez (2005) [36]. The definition and description of the vegetation series followed the taxonomic and syntaxonomic nomenclature presented by Rivas-Martínez et al. (2011) [37] and is complemented by the most recent publication by Costa et al. (2012) [38].

The center of mainland Portugal is influenced by the pluviestational Mediterranean bioclimate, under an ombrotype of subhumid to humid, a thermomediterranean to supramediterranean zone and semihyperoceanic to euoceanic continentality [39]. In terms of vegetation, climatophilous position dominates the *Quercus suber* oak trees of the association *Asparago aphilly-Quercetum suberis* and *Q. pyrenaica* of the association *Arisaro simorrhini-Quercetum pyrenaicae* [22].

The assessment of problems with fuel management areas was based on bibliographic research, consisting of national legislation and documents produced by public entities [40–46]. Based on this information, an analysis was carried out on the indicated measures, with a view to improving the state of conservation through a scientific approach.

3. Vegetation Dynamics

Phytosociology—a science that incorporates the evolutionary and regressive information about a community of vegetation cover until it reaches a mature forest—studies the set of dynamic phases formed by different plants [22]. Usually, after the abandonment of agricultural land and depending on the seed bank available, annual plants appear first (for example, some plants of the genera *Briza*, *Tuberaria*, *Avena*, *Bromus*, *Cynosurus*, *Lagurus* and *Vulpia*). The lack of soil mobilization allows the installation of perennial herbaceous plants (such as many of the plants of the genera *Dactylis*, *Stipa*, *Celtica*, *Brachypodium*, *Avenulla*, *Agrostis* and *Hyparrhenia*). A few years after the abandonment, the first shrubs appear, which are almost always of a heliophilic character (for example, plants of the genera *Thymus*, *Helichrysum*, *Cistus*, *Calluna*, *Erica*, *Lavandula*, *Rosmarinus*, *Pterosparthum*, *Halimium*, *Stauracanthus* and *Ulex*). With the conservation of the soil and in more climatically favorable zones, the most demanding heliophilous shrubs at the substrate level appear (such as plants of the genus *Retama*, *Cytisus*, *Adenocarpus* and *Genista*). With dynamic evolution and after a few years of soil conservation, the first pre-forest shrubs appear, normally producers of small fruits which serve as food for a large number of birds (for example, plants of the genera *Arbutus*, *Myrtus*, *Phillyrea*, *Pistacia*, *Rhamnus*, *Viburnum*, *Crataegus*, *Laurus* and *Ilex*). The most advanced stage of the climatophilic forests of Portugal is normally dominated by trees of the genus *Quercus*, although, due to human action, these formations are very fragmented, consisting of small remnants. Table 1 presents a synthesis of the dynamic evolution of climatophilic vegetation cover in mainland Portugal, and Figure 2 presents the dynamics of climatophilic vegetation in the Mediterranean.

Table 1. Synthesis of the dynamic evolution of climatophilic vegetation cover in mainland Portugal.

Stage	Community	Bioindicator Genera
1	Annual grasslands	*Briza, Tuberaria, Avena, Bromus, Cynosurus, Lagurus, Vulpia*
2	Perennial grasslands	*Dactylis, Stipa, Celtica, Brachypodium, Avenulla, Agrostis, Hyparrhenia*
3	Heathland	*Thymus, Cistus, Calluna, Erica, Lavandula, Rosmarinus, Pterosparthum, Halimium, Stauracanthus, Ulex*
4	Broomland	*Cytisus, Retama, Adenocarpus, Genista*
5	Maquis scrubland	*Arbutus, Myrtus, Phillyrea, Pistacia, Rhamnus, Viburnum, Crataegus, Laurus, Ilex*
6	Forest	*Quercus*

Figure 2. Dynamics of climatophilic vegetation in the Mediterranean: 1—annual grasslands; 2—perennial grasslands; 3—heathland; 4—broomland; 5—maquis scrubland; 6—forest (Author: M. Raposo, 2020).

4. Results and Discussion

4.1. Post-Fire Analysis

During a fire, the vegetation consumed more quickly by the flames corresponds to smaller materials, leaving (according to the intensity of the fire) coarser woody materials (Figure 3). In this study, it was observed that in the burnt areas of autochthonous hardwood forest in central Portugal in October 2017, the leftover woody materials of a smaller dimension were an average of 5 mm thick. All branches with a diameter greater than 5 mm were only scorched and did not burn completely. This result depends on a set of climatic variables and the type of existing vegetation. However, with a view to reducing the spread of fire, human action manages the type of vegetation cover better than climatic conditions.

Figure 3. Vegetation regeneration nine months after a rural fire in Mata da Margaraça (Arganil, Portugal).

This fact helps us to realize that the priority in the control of vegetation can and should be selective, contributing to the reduction of costs/time of management of the vegetation cover. That is, all shrubs of which the well-developed adult form has thin branches, with narrow, long leaves and covered with hair (usually gray-colored bushes and bushes with a fine texture) should be a priority in control actions (Figure 4).

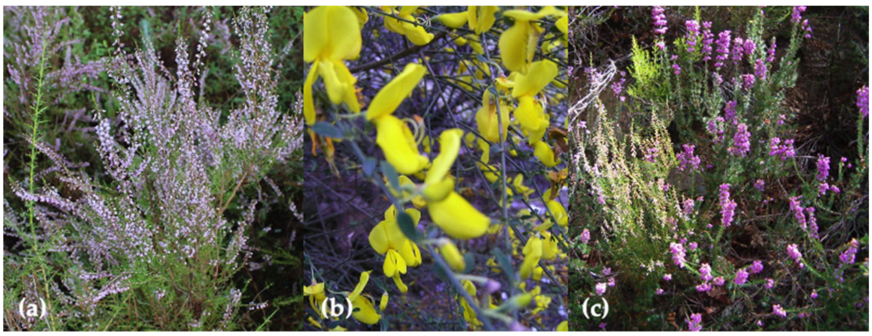


Figure 4. Heliophile shrubs with fine texture and fast combustibility. (**a**) *Calluna vulgaris*; (**b**) *Cytisus scoparius*; and (**c**) *Erica cinerea*.

Smaller shrubs are usually associated with the first stages of evolution of the vegetation cover. These plants often have a set of characteristics in common, specifically related to adaptation to water stress, such as the formation of spines, narrow leaves, having a leathery texture and being covered with hair, and in some cases the production of essential oils. These initial stages of the vegetation cover fall into phytosociological terms in the classes *Cisto-Lavanduletea*, *Rosmarinetea officinalis*, *Calluno-Ulicetea* and *Cytisetea scopario-striati*. On the other hand, larger shrubs have well-developed leaves, are wide and withstand half-shade environments (Figure 5). These characteristics are less prone to the advance of flames.

Figure 5. Pre-forested bushes with broad texture and slower combustibility. (**a**) *Arbutus unedo*; (**b**) *Viburnum tinus*; and (**c**) *Prunus lusitanica*.

4.2. Vegetation Cover Management

The opening of clearings within a forest allows the entry of light and, consequently, the appearance of heliophilous shrubs, thus increasing the risk of fire. Therefore, from an ecological point of view, in order to reduce the prevalence of shrubs with greater flammability, it is necessary to drive the growth of the forest towards a closed canopy. Thus, forest managers should favor pre-forest shrubs (step 5 of Figure 2) and the mature state species (step 6 of Figure 2).

The potential climatophilous vegetation in mainland Portugal is dominated by oak forests. Throughout the main stages of the replacement of these forests, the (pre)forest and heliophile shrubs are differentiated. In short, the climatophilic forest communities to be conserved fall into the *Querco-Fagetea* and *Quercetea ilicis* classes, and on the other hand, the heliophile communities to be controlled mostly belong to the *Cisto-Lavanduletea*, *Rosmarinetea officinalis*, *Calluno-Ulicetea* and *Cytisetea scopario-striati* classes. Thus, Table 2 shows the main shrub species that must be conserved/controlled in the fuel management ranges in mainland Portugal. In addition to this list, all native trees must be conserved, as well as deciduous shrubs.

Table 2. Main native shrub genera to conserve and control in fuel management bands in Portugal.

Genus	Family	Preserve	Control
Adenocarpus	Fabaceae		×
Arbutus	Ericaceae	×	
Asparagus	Asparagaceae	×	
Calluna	Ericaceae		×
Cistus	Cistaceae		×
Clematis	Ranunculaceae	×	
Cytisus	Fabaceae		×
Erica	Ericaceae		×
Genista	Fabaceae		×
Halimium	Cistaceae		×
Helichrysum	Asteraceae		×

Table 2. *Cont.*

Genus	Family	Preserve	Control
Juniperus	Cupressaceae	×	
Ilex	Aquifoliaceae	×	
Laurus	Lauraceae	×	
Lavandula	Lamiaceae		×
Lonicera	Caprifoliaceae	×	
Hedera	Araliaceae	×	
Myrica	Myricaceae	×	
Myrtus	Myrtaceae	×	
Phillyrea	Oleaceae	×	
Pistacia	Anacardiaceae	×	
Prunus	Rosaceae	×	
Pteridium	Dennstaedtiaceae		×
Pterospartum	Fabaceae		×
Retama	Fabaceae		×
Rhamnus	Rhamnaceae	×	
Rhododendron	Ericaceae	×	
Rosmarinus	Lamiaceae		×
Rubus	Rosaceae		×
Ruscus	Asparagaceae	×	
Smilax	Smilacaceae	×	
Stauracanthus	Fabaceae		×
Ulex	Fabaceae		×
Viburnum	Caprifoliaceae	×	

Against this backdrop, the main genera to be controlled belong to Adenocarpus, Calluna, Cistus, Cytisus, Erica, Genista, Halimium, Lavandula, Pteridium, Pterospartum, Retama, Rosmarinus, Rubus, Helichrysum, Stauracanthus and Ulex [47–50]. In addition to controlling the plants referred to in Table 1, it is essential to develop actions to control and eradicate exotic invasive plants. As an example, serious environmental, social and economic problems are caused by Acacia species, such as Acacia dealbata or A. longifolia, Hakea sericea, Ailanthus altissima and Robinia pseudoacacia, among many others [51,52]. Usually, the reduction of the plant material is carried out by human action, through cutting back of bushes. Thus, with this methodology, the operator must have the knowledge to cut only the heliophile bushes and leave all pre-forest and forest bushes. In this way, the technician reduces the necessary work and manages to cover a larger area in less time, although this reduction of time is very dependent on each area of intervention and on the state of evolution of the dynamics of the vegetation cover.

5. Conclusions

Although the control of vegetation in the fuel management areas is mandatory in Portugal according to Decree-Law no. 17/2009, from a conservation and cost management point of view, the control of vegetation must be selective. Despite the national legislation protecting the cork oak, holm oak and holly, it is necessary to value all plants that are characteristic of forest and pre-forest environments, since in the long term, a closed canopy reduces the numbers of heliophile species and, therefore, reduces the risk of fire. Considering this, we sought to study, from the point of view of phytosociological science, the dynamics of vegetation in these areas in order to distinguish target plants for control measures from plants that contribute to the balance and sustainability of the landscape.

It should be noted that the territories targeted by fire are more susceptible to the occurrence of new fires, not only due to greater abandonment of rural spaces, with the consequent increase in the number of heliophilous plants and invasive plants, but also because of the lower resilience of plant communities of greater ecological value, such as forests. This fact is related to soil loss and, consequently, to lower water retention in the short term. In this sense, it will be essential in the future for policy makers to take this information into account in order to establish valuable ecosystem services, holding those who destroy these natural values responsible. Thus, applying this methodology, regardless of climatic, orographic and anthropogenic factors, it is possible to significantly reduce the materials available for rapid combustion and thus inhibit the rapid advance of flames.

In short, the plants to be conserved within fuel management areas belong to more evolved dynamic states, belonging to the phytosociological classes *Querco-Fagetea sylvaticae* and *Quercetea ilicis*, normally presenting broad leaves. Some of these plants are protected by the previously referenced Decree-Law, however, it is necessary to include the species in annexes II, IV and V of the Habitats Directive (92/43/CEE).

On the other hand, the bushes to be controlled belong to dynamic states farther from the mature stages, affiliated with the classes *Cisto-Lavanduletea*, *Rosmarinetea officinalis*, *Calluno-Ulicetea* and *Cytisetea scopario-striati*. These shrubs preferentially live in situations with high sun exposure and low levels of organic matter, often consisting of narrow leaves and covered with hair. In addition to these, all exotic plants, especially those of an invasive nature, must also be controlled through the respective recommended techniques. It should also be noted that interventions must be carried out from upstream to downstream, avoiding (re)sowing from upstream surfaces.

Author Contributions: Conceptualization, L.J.R.N., M.A.M.R. and C.J.P.G.; methodology, L.J.R.N., M.A.M.R. and C.J.P.G.; validation, L.J.R.N., M.A.M.R. and C.J.P.G.; investigation, L.J.R.N. and M.A.M.R.; data curation, L.J.R.N., M.A.M.R. and C.J.P.G.; writing—original draft preparation, L.J.R.N. and M.A.M.R.; writing—review and editing, L.J.R.N., M.A.M.R. and C.J.P.G.; supervision, L.J.R.N., M.A.M.R. and C.J.P.G.; project administration, L.J.R.N., M.A.M.R. and C.J.P.G. All authors have read and agreed to the published version of the manuscript.

Funding: L.J.R.N. was supported by the project UIDP/05975/2020, funded by national funds through FCT—Fundação para a Ciência e Tecnologia.

Acknowledgments: This research received a contribution from the European Commission's LIFE program, through the Life-Relict Project (NAT/PT/000754).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Rivas-Martínez, S.; Rivas-Sáenz, S.; Penas, A. Worldwide bioclimatic classification system. *Glob. Geobot.* **2011**, *1*, 1–634.
2. Raposo, M.; Castanho, R.A.; Machado, M.; Castro, C.; Santos, P.; Pinto-Gomes, C. The Relevance of Vegetation Series on the Maintenance and Sustainability of Public Spaces in the Southwest Iberian Peninsula. In *Landscape Architecture: The Sense of Places, Models and Applications*; IntechOpen: London, UK, 2018; pp. 255–273.
3. Mittermeier, R.A.; Turner, W.R.; Larsen, F.W.; Brooks, T.M.; Gascon, C. Global Biodiversity Conservation: The Critical Role of Hotspots. In *Biodiversity Hotspots*; Springer: Berlin/Heidelberg, Germany, 2011; pp. 3–22.
4. Máximo, P.; Ferreira, L.M.; Branco, P.S.; Lourenço, A. Invasive Plants: Turning Enemies into Value. *Molecules* **2020**, *25*, 3529. [CrossRef] [PubMed]
5. Nunes, L.J.; Raposo, M.A.; Meireles, C.I.; Pinto Gomes, C.J.; Ribeiro, N.; Almeida, M. Fire as a Selection Agent for the Dissemination of Invasive Species: Case Study on the Evolution of Forest Coverage. *Environments* **2020**, *7*, 57. [CrossRef]
6. Turco, M.; Jerez, S.; Augusto, S.; Tarín-Carrasco, P.; Ratola, N.; Jiménez-Guerrero, P.; Trigo, R.M. Climate drivers of the 2017 devastating fires in Portugal. *Sci. Rep.* **2019**, *9*, 1–8. [CrossRef]
7. Meira Castro, A.C.; Nunes, A.; Sousa, A.; Lourenço, L. Mapping the Causes of Forest Fires in Portugal by Clustering Analysis. *Geosciences* **2020**, *10*, 53. [CrossRef]
8. Fernandes, S.; Lourenço, L. Grandes incêndios florestais de março, junho e outubro (fora do período crítico) em Portugal continental. *Territorium* **2019**, *26*, 15–34.
9. Félix, F.; Lourenço, L. As vagas de incêndios florestais de 2017 em Portugal continental, premissas de uma quarta 'geração'? *Territorium* **2019**, *26*, 35–48.
10. Bartolomé, J.; Miró, J.; Panadès, X.; Broncano, M.J.; Plaixats, J.; Rigau, T.; Milán, M.J.; Baraza, E. Preference by donkeys and goats among five Mediterranean forest species: Implications for reducing fire hazard. *Animals* **2020**, *10*, 1302. [CrossRef]

11. Sakellariou, S.; Cabral, P.; Caetano, M.; Pla, F.; Painho, M.; Christopoulou, O.; Sfougaris, A.; Dalezios, N.; Vasilakos, C. Remotely sensed data fusion for spatiotemporal geostatistical analysis of forest fire hazard. *Sensors* **2020**, *20*, 5014. [CrossRef]
12. Pereira, J.S. *O Futuro da Floresta em Portugal*; Fundação Francisco Manuel dos Santos: Lisboa, Portugal, 2016.
13. Lourenço, L. Plano nacional de defesa da floresta contra incêndios. *Agência Para Prevenção Incêndios Florestais Miranda Corvo Ii* **2005**, *236*, 387.
14. Nogueira, C.; Fonseca, F.; Figueiredo, T.D. Propriedades Químicas do Solo em Áreas de Montanha Cobertas por Matos: Efeito do Fogo Controlado. In *Proceedings of Livro de Atas do VI Congresso Ibérico da Ciência do Solo*; Andavira Editora SL: A Coruña, Spain, 2014; pp. 449–452.
15. Rego, F. A importância do fogo controlado na redução dos combustíveis e do risco de incêndio florestal. *Agroforum Rev. Esc. Super. Agrária Castelo Branco* **1997**, *6*, 31–33.
16. Nunes, L.J.; Meireles, C.I.; Pinto Gomes, C.J.; Almeida Ribeiro, N. Historical development of the portuguese forest: The introduction of invasive species. *Forests* **2019**, *10*, 974. [CrossRef]
17. Lopes, D. (Re) ordenamento florestal: Alguns instrumentos de conformação da ocupação florestal em Portugal. *E-Pública Rev. Eletrónica Direito Público* **2017**, *4*, 41–60.
18. Ferreira-Leite, F.; Bento-Gonçalves, A.; Vieira, A.; Nunes, A.; Lourenço, L. Incidence and recurrence of large forest fires in mainland Portugal. *Nat. Hazards* **2016**, *84*, 1035–1053. [CrossRef]
19. Falcon-Lang, H.J.; Mages, V.; Collinson, M. The oldest Pinus and its preservation by fire. *Geology* **2016**, *44*, 303–306. [CrossRef]
20. Butnariu, M.; Sarac, I. Essential oils from plants. *J. Biotechnol. Biomed. Sci.* **2018**, *1*, 35. [CrossRef]
21. Beighley, M.; Hyde, A. *Gestão dos Incêndios Florestais em Portugal numa Nova Era Avaliação dos Riscos de Incêndio, Recursos e Reformas*; Centro de Estudos Florestais–Instituto Superior de Agronomia da Universidade de Lisboa: Lisboa, Portugal, 2018; p. 59.
22. Raposo, M.; Mendes, P.; Cano-Ortiz, A.; Pinto-Gomes, C. Séries de vegetação prioritárias para a conservação no centro e sul de Portugal continental. *Botanique* **2016**, *1*, 113–148.
23. Castroviejo, S.; Aedo, C.; Cirujano, S.; Laínz, M.; Montserrat, P.; Morales, R. Flora Iberica, Real Jardín Botánico. *Csic Madr. Es. Vols* **2005**, *2*, 8.
24. Coutinho, A. *Flora de Portugal (Plantas Vasculares)*, 2nd ed.; Phytochemical Bulletin; Bertrand (Irmãos) Ltd.: Lisboa, Portugal, 1939; Volume 19, pp. 11–15.
25. Franco, J. *Nova Flora de Portugal (Continente e Açores)—Lycopodeaceae-Umbelliferae*; Cimelio Books: Cascais, Portugal, 1971; Volume I.
26. Franco, J.D.A.; Rocha-Afonso, M. *Nova Flora de Portugal (Continente e Açores)*; Cimelio Books: Cascais, Portugal, 1984; Volume II.
27. Franco, J.D.A. *Nova Flora de Portugal: Continente e Açores—Alismataceae-Iridaceae*; Sociedade Astória: Lisboa, Portugal, 1994.
28. Franco, J. *Nova Flora de Portugal (Continente e Açores), Vol. II, Clethraceae–Compositae*; Escolar Editora: Lisboa, Portugal, 1984; p. 184.
29. Valdés, B.; Talavera, S.; Fernández-Galiano, E. *Flora Vascular de Andalucía Occidental*; Ketres: Barcelona, Spain, 1987; Volume 2.
30. Viegi, L.; Cela Renzoni, G.; Garbari, F. Flora esotica d'Italia. *Biogeogr. J. Integr. Biogeogr.* **1974**, *4*, 125–220. [CrossRef]
31. Pignatti, S.; Guarino, R.; La Rosa, M. *Flora D'Italia*; Edagricole: Bologna, Italy, 2017; Volume 1.
32. Pignatti, S. Note critiche sulla Flora d'Italia. I. Appunti miscellanei. *Plant Biosyst.* **1973**, *107*, 207–221. [CrossRef]
33. Pignatti, S. Note critiche sulla Flora d'Italia. VI. Ultimi appunti miscellanei. *Plant Biosyst.* **1979**, *113*, 359–368. [CrossRef]
34. Braun-Blanquet, J.; Lalucat Jo, J. *Fitosociología: Bases Para el Estudio de Las Comunidades Vegetales/Pflanzensoziologie*; Autonomous University of Nuevo León, UANL: San Nicolás de los Garza, Mexico, 1979.
35. Rivas-Martınez, S. Notions on dynamic-catenal Phytosociology as a basis of landscape science. *Plant Biosyst.* **2005**, *139*, 135–144. [CrossRef]
36. Rivas-Martínez, S. Avances en Geobotánica. In *Discurso de Apertura del Curso Académico de la Real Academia Nacional de Farmacia del Año*; Real Academia Nacional de Farmacia: Madrid, Spain, 2005; pp. 1–128.

37. Rivas Martínez, S.; Penas, Á.; Díaz González, T.; Ladero Álvarez, M.; Asensi Marfil, A.; Díez Garretas, B.; Molero Mesa, J.; Valle Tendero, F.; Cano, E.; Costa Talens, M. *Mapa de Series, Geoseries y Geopermaseries de Vegetación de España (Memoria del Mapa de Vegetación Potencial de España)*; Parte II; Asociación Española de Fitosociología: Sarriena, BI, Spain, 2011.
38. Costa, J.C.; Neto, C.; Aguiar, C.; Capelo, J.; Espírito Santo, M.D.; Honrado, J.; Pinto-Gomes, C.; Monteiro-Henriques, T.; Sequeira, M.; Lousã, M. Vascular plant communities in Portugal (Continental, the Azores and Madeira). *Glob. Geobot.* **2012**, *2*, 1–180.
39. Rivas-Martínez, S.; Penas, Á.; del Río, S.; González, T.E.D.; Rivas-Sáenz, S. Bioclimatology of the Iberian Peninsula and the Balearic Islands. In *The Vegetation of the Iberian Peninsula*; Springer: Cham, Switzerland, 2017; pp. 29–80.
40. Tedim, F.; Remelgado, R.; Borges, C.; Carvalho, S.; Martins, J. Exploring the occurrence of mega-fires in Portugal. *Ecol. Manag.* **2013**, *294*, 86–96. [CrossRef]
41. Shakesby, R.A.; Coelho, C.; Ferreira, A.D.; Terry, J.P.; Walsh, R.P. Wildfire impacts on soil-erosion and hydrology in wet Mediterranean forest, Portugal. *Int. J. Wildland Fire* **1993**, *3*, 95–110. [CrossRef]
42. Afonso, R.; Neves, A.; Viegas Damásio, C.; Moura Pires, J.; Birra, F.; Santos, M.Y. Assessment of Interventions in Fuel Management Zones Using Remote Sensing. *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 533. [CrossRef]
43. Meira-Castro, A.; Shakesby, R.; Marques, J.E.; Doerr, S.; Meixedo, J.P.; Teixeira, J.; Chaminé, H.I. Effects of prescribed fire on surface soil in a Pinus pinaster plantation, northern Portugal. *Environ. Earth Sci.* **2015**, *73*, 3011–3018. [CrossRef]
44. Thomas, A.D.; Walsh, R.P.; Shakesby, R.A. Post-fire forestry management and nutrient losses in eucalyptus and pine plantations, Northern Portugal. *Land Degrad. Dev.* **2000**, *11*, 257–271. [CrossRef]
45. Connor, S.E.; Araújo, J.; van der Knaap, W.O.; van Leeuwen, J.F. A long-term perspective on biomass burning in the Serra da Estrela, Portugal. *Quat. Sci. Rev.* **2012**, *55*, 114–124. [CrossRef]
46. Fernandes, P.M.; Guiomar, N.; Rossa, C.G. Analysing eucalypt expansion in Portugal as a fire-regime modifier. *Sci. Total Environ.* **2019**, *666*, 79–88. [CrossRef]
47. Costa, J.C.; Aguiar, C.; Capelo, J.; Lousã, M.; Antunes, J.; Honrado, J.J.; Izco, J.; Ladero, M. A classe Cytisetea scopario-striati em Portugal Continental. *Quercetea* **2003**, *4*, 45–70.
48. Morales-Molino, C.; Devaux, L.; Georget, M.; Hanquiez, V.; Goñi, M.F.S. Modern pollen representation of the vegetation of the Tagus Basin (central Iberian Peninsula). *Rev. Palaeobot. Palynol.* **2020**, *276*, 104193. [CrossRef]
49. Neto, C.; Arsénio, P.; Costa, J.C. Flora e Vegetação do sudoeste de Portugal continental. *Quercetea* **2009**, *9*, 43–144.
50. Nieto, L.R.; González, N.R.; Pibernat, R.A.; de la Fuente García, V. Vegetación serial fruticosa y sufruticosa acidófila de la cuenca del Río Tinto (Huelva, España). *Lazaroa* **2009**, *30*, 49.
51. Neser, S.; Nel, J.; Van Wilgen, B.; Le Maitre, D.; Rouget, M.; Henderson, L.; Richardson, D.; Schonegevel, L.; Mdzeke, N.; Mgidi, T. A proposed classification of invasive alien plant species in South Africa: Towards prioritizing species and areas for management action: Working for water. *S. Afr. J. Sci.* **2004**, *100*, 53–64.
52. Lesoli, M.; Gxasheka, M.; Solomon, T.; Moyo, B. Integrated Plant Invasion and Bush Encroachment Management on Southern African Rangelands. In *Herbicides-Current Research and Case Studies in Use*; IntechOpen: London, UK, 2013; pp. 259–313.

V2.3. Artigo: Evaluation of Species Invasiveness: A Case Study with *Acacia dealbata* Link. on the Slopes of Cabeça (Seia-Portugal)

sustainability

MDPI

Case Report

Evaluation of Species Invasiveness: A Case Study with *Acacia dealbata* Link. on the Slopes of Cabeça (Seia-Portugal)

Mauro A. M. Raposo [1,*], Carlos J. Pinto Gomes [1,2] and Leonel J. R. Nunes [3]

[1] Departamento da Paisagem, Ambiente e Ordenamento, Universidade de Évora, 7000-671 Évora, Portugal; cpgomes@uevora.pt
[2] MED—Mediterranean Institute for Agriculture, Environment and Development, Pólo da Mitra, Universidade de Évora, 7006-554 Évora, Portugal
[3] ProMetheus—Unidade de Investigação em Materiais, Energia e Ambiente Para a Sustentabilidade, Escola Superior Agrária, Instituto Politécnico de Viana do Castelo, Rua da Escola Industrial e Comercial de Nun'Alvares, 4900-347 Viana do Castelo, Portugal; leonelnunes@esa.ipvc.pt
* Correspondence: mraposo@uevora.pt

Abstract: One of the main causes of biodiversity loss in the world is the uncontrolled expansion of invasive plants. According to the edaphoclimatic conditions of each region, plants acquire different invasion behaviors. Thus, to better understand the expansion of invasive plants with radial growth, it is proposed to use two equations, the Annual Linear Increment (ALI) and the Annual Invasiveness Rate (AIR). These equations are applied using spatiotemporal data obtained from the analysis of orthophotomaps referring populations of *Acacia dealbata* Link. in areas located in Serra da Estrela, Portugal. As a result, the area occupied by this species in the parish of Cabeça was evaluated and a 20-year projection was carried out. The data produced by these equations contributed to improving the knowledge about the invasion behavior of exotic species in a rigorous and detailed way according to local ecological conditions. This study may serve as the basis for the application of other similar situations concerning invasive species in other territories, to improve the efficiency of future projections for these species. Local technical and scientific knowledge will contribute to improving spatial and management planning, enabling a better adequacy and effectiveness of the control measures to be adopted.

Keywords: *Acacia dealbata* Link.; biological invasions; invasive species; invasiveness rate; natural habitats

check for updates

Citation: Raposo, M.A.M.; Pinto Gomes, C.J.; Nunes, L.J.R. Evaluation of Species Invasiveness: A Case Study with *Acacia dealbata* Link. on the Slopes of Cabeça (Seia-Portugal). *Sustainability* **2021**, *13*, 11233. https://doi.org/10.3390/su132011233

Academic Editor: C. Ronald Carroll

Received: 22 August 2021
Accepted: 9 October 2021
Published: 12 October 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

1.1. Framework

The impact of invasive plants on ecosystems is a major cause of biodiversity loss in the world, especially in some large well identified hotspots [1–4]. Knowing its invasive potential is essential to create control strategies and prevent further invasions, mainly with the advent scenarios promoted by climate change [5]. In Portugal, according to Morais et al. [6], *Acacia dealbata* Link. is the species with the greatest invasive potential, mainly due to its high seed production capacity, which is associated with an effective germination rate above 70%, a rapid growth and allelopathic capacity [6–8]. According to the latest National Forest Inventory, from 1995 to 2015, the areas occupied by *Acacia* genus species increased by approximately 5.7 thousand hectares in the Portuguese territory, reaching 8.4 thousand hectares in 2015 [9–11].

This problem occurs in areas occupied with native forest species, more often within the habitats of the Natura 2000 Network (ecological network for the European Union's community space), such as the European dry heaths (code of habitat: 4030), pre-desert Mediterranean scrublands (code of habitat: 5330) and the Galician-Portuguese oak trees of

Quercus robur and *Quercus pyrenaica* (code of habitat: 9230), among others [12], but also in recreation and leisure areas used by the population, such as urban parks or other public domain areas [13]. However, the most important economic impacts occur when acacia populations emerge alongside agricultural crops [14–16], impairing the germination and growth of important cultivated food species [10].

In this sense, invasion rate prediction, modeling and management of acacia-dominated ecosystems are challenging tasks that need further investigation and intervention [17,18]. Several studies present results on the prediction of the development of invasive species; however, the models available do not use a stain invasiveness rate, nor an annual linear increment [19–21]. Morphological, chorological and ecological characterization data for this species are well known, as are the most efficient control methods [22,23]. However, the annual invasiveness rates for *A. dealbata* are unknown in the largest majority of the Portuguese territory.

On the other hand, the economic valorization of *A. dealbata* wood and its ornamental value, associated with the exuberant yellow flowers that occur during winter, are factors that contributed to its dissemination [10,24]. In fact, *A. dealbata*, in the past, was promoted at a regional festival that took place in the Serra de Monchique, dedicated to silver wattle, which ended due to the persistent awareness of the botanist Malato Beliz [25,26]. However, in view of the high economic, social and environmental impacts of the rapid expansion of *A. dealbata* in Portugal, it is intended with this article to present the equations to calculate the Annual Linear Increment (ALI) and the Annual Invasiveness Rate (AIR) of invasive species with concentric dissemination; to evaluate, through the analysis of a case study, the expansion of *A. dealbata* on the slopes of Cabeça (Seia-Portugal); and to contribute to improving the knowledge on the invasive capacity of *A. dealbata* through more efficient planning of control actions.

1.2. Characteristics of Acacia Dealbata That Favor Invasion

A. dealbata is a tree of the *Leguminosae* family, originating from the south east of Australia and Tasmania, introduced in Europe (France, Spain, Italy, Turkey), South Africa, New Zealand, western USA (California), Asia (India, Sri Lanka), South America (Argentina, Chile) and Madagascar, where it presents an invasive behavior [23]. It was introduced in Portugal at the end of the 19th century and rapidly spread all over the mainland territory [27]. It is estimated that in 1975, *A. dealbata* occupied 2500 ha [11]. This tree can grow up to 15 m and its flowering occurs from January to March, presenting an exuberant yellow color. The pods are up to 8 cm in length and develop about 8 seeds with 4.5×2.5 mm [28].

Its invasiveness is associated with a high growth rate in poor and acidic soils due to its ability to fix atmospheric nitrogen through symbiosis with bacteria of the genus *Rhizobium* [29–31], in addition to factors such as the high production of attractive flowers for pollinators, self-pollinating capacity, vegetative reproduction and the production of a large amount of viable seeds for a long period of time [32–34]. The accumulation of seeds in the soil can reach more than 62,000 seeds per square meter in the territories of Serra da Estrela (Portugal) [35]. These seeds are often disseminated by ants, birds, water or simply by the force of gravity, and can remain in the soil for decades until they are disturbed, e.g., by fire [36]. In this context, the use of controlled fire can help to reduce the seed banks in the soil, promoting its germination [28,37]. As it is a species with a pioneer behavior, similar to Mediterranean heliophilous shrubs, whenever there is a clearing or an area without vegetation, it finds an opportunity to sprout and develop [38]. The factors that seem to be most unfavorable for its expansion are: neutral-basic soils (pH > 5.5), occurrence of frequent frosts (>21 to 40 days per year) and low annual precipitation (<500 mm) [39].

2. Materials and Methods

2.1. Characterization of the Area under Study

The area chosen for the present study covers the entire administrative territory of the parish of Cabeça, with approximately 850 hectares, located at Serra da Estrela (Portugal). This mountain range is the highest in mainland Portugal, with an altitude of 1997 m, presenting a unique flora with varied endemic species. In biogeographic terms, the selected location is part of the Montemuro and Estrela Mountain Sector [40]. This territory is characterized to as mesosubmediterranean humid to hyper-humid bioclimate, with an altitude between 400 and 700 m [41]. The substrates belong to schist-greywacke complex, dating back to the Pre-Cambrian Era, more than 400 million years old [42]. In pedological terms, the soils are characterized by lithosols and cambisols, with the presence of some superficial rocky outcrops [43]. The potential natural vegetation belongs to the domain of the oak (*Quercus robur* subsp. *broteroana* O. Schwartz), having as one of the most emblematic habitats the "*Laurus nobilis* bush scrubs", of the Azereirais subtype (European code of the natura 2000 network: 5230*pt2) [44,45]. These slopes sometimes have steep slopes, where there is an abandonment of agro-silvo-pastoral activities. Thus, there are surfaces covered by heliophilous scrub, especially *Erica arborea* L., *E. australis* L., *Genista falcata* Brot. and *Cytisus striatus* (Hill) Rothm., highly susceptible to the occurrence of fire. The last fire on these slopes occurred during the summer of 2005 [24].

2.2. Data Collection and Analysis

The identification of *A. dealbata* population was carried out on fieldtrips (Figure 1). Spatiotemporal data were used to develop the equations to calculate the Annual Linear Increment (ALI) and the Annual Invasiveness Rate (AIR) of the populations of this species. To obtain spatial data, ortho-rectified aerial photographs of the territory were used, with very high-quality resolution, obtained through the SNIG platform (https://snig.dgterritorio.gov.pt, accessed on 25 May 2021). To obtain the invasiveness of *A. dealbata*, the time window chosen was from 2005 to 2019, avoiding fire events that could alter its natural growth [22,24]. For a better analysis of the acacia expansion, all the populations of *A. dealbata* growing in Cabeça were identified. For the data treatment and analysis, we used the software ArcGIS (version JSAPI 4.1).

For the calculation of ALI and AIR, we developed two arithmetic equations that allow us to obtain invasiveness rates when the growth of the population of the studied species appears to be of radial type. Based on this premise, the Annual Linear Increment (ALI) of a plant species is the result of the arithmetic mean of the growth increments of each sample. The coefficient of each sample is given by the ratio between the difference in the diameters ($D_f - D_i$) and the double of the time difference ($2 \times (T_f - T_i)$), to obtain the average growth of the sample. For the correct application of this equation, it is necessary that the diameter is measured in the direction of the slope orientation, especially in slopes with greater penchant, since the relief conditions can favor a greater expansion in the downstream direction (gravitational force, greater humidity of the soil, among other factors). To minimize the ecological constraints that can modify the dispersion of the trees, such as the presence of rocky outcrops or the existence of a water line, this equation was applied in fifteen different acacia populations to obtain an average value for the species growth in the chosen territory (Equation (1)).

$$\text{ALI} = \frac{1}{a} \sum_{n=1}^{a} \frac{Df - Di}{2\,(Tf - Ti)}. \tag{1}$$

The Annual Invasiveness Rate (AIR) for a species is the result of the arithmetic average of the rates for each sample. The rate of each sample is given by the ratio between the difference in the occupancy areas ($A_f - A_i$) and the product of the initial area by the time difference (A_i ($T_f - T_i$)). The value is obtained as a percentage of invasiveness (Equation (2)).

$$\text{AIR} = \frac{1}{a}\sum\nolimits_{n=1}^{a} \frac{Af - Ai}{Ai\,(Tf - Ti)}. \quad (2)$$

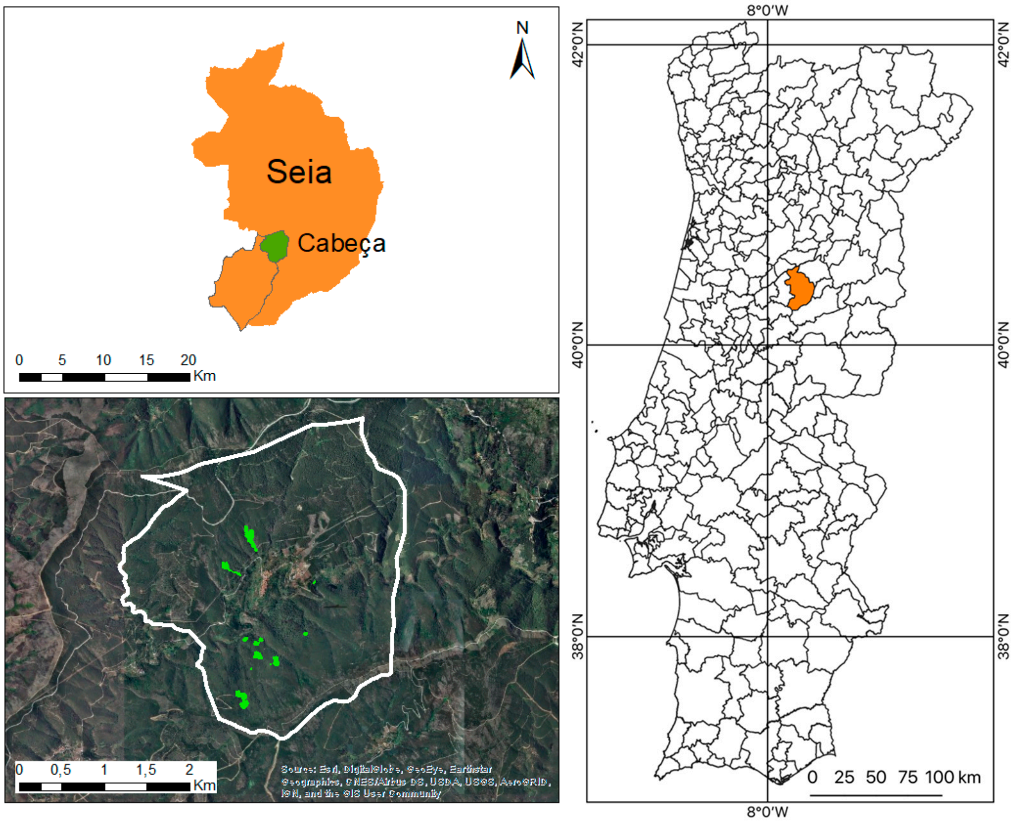


Figure 1. Location of the *A. dealbata* subpopulation studied.

3. Results and Discussion

In the parish of Cabeça, 15 subpopulations of *A. dealbata* were identified, totaling 54,000 m^2, corresponding in 2019 to about 0.6% of the chosen territory. However, in 2005, there were only 13 subpopulations occupying an area of around 24,000 m^2. The population nuclei of *A. dealbata* studied in Serra da Estrela have seen over the past 14 years, an average linear increment of 9.86 m, corresponding to an annual linear increase of 0.82 m (Table 1).

Table 1. Annual Linear Increment of *A. dealbata*. (D_i—initial diameter; D_f—final diameter; Increase—increase over 14 years; LI14—linear increment in 14 years; ALI—Annual Linear Increment).

Sample	D_i (m)	D_f (m)	Increase (m)	LI14 (m)	ALI (m)
1	40.50	65.38	24.88	12.44	1.04
2	51.40	81.32	29.92	14.96	1.25
3	23.60	36.10	12.50	6.25	0.52
4	32.20	43.89	11.69	5.85	0.49
5	18.10	34.60	16.50	8.25	0.69
6	56.27	72.16	15.89	7.95	0.66
7	51.24	96.67	45.43	22.72	1.89
8	59.43	84.67	25.24	12.62	1.05
9	0.00	9.61	9.61	4.81	0.40
10	11.14	17.37	6.23	3.12	0.26

Table 1. *Cont.*

Sample	D_i (m)	D_f (m)	Increase (m)	LI14 (m)	ALI (m)
11	46.13	69.39	23.26	11.63	0.97
12	41.63	58.78	17.15	8.58	0.71
13	38.54	57.69	19.15	9.58	0.80
14	30.11	51.39	21.28	10.64	0.89
15	0.00	17.03	17.03	8.52	0.71
Average				9.86	0.82

The *A. dealbata* invasion rate for the 14-year period was 94%, corresponding to an annual area increase of 8% (Table 2).

Table 2. Annual Invasiveness Rate of *A. dealbata* (A_i—starting area; A_f—final area; Increase—increase over 14 years; IR14—invisibility rate in 14 years; AIR—Annual Invasiveness Rate).

Sample	A_i (m^2)	A_f (m^2)	Increase (m^2)	IR14 (%)	AIR (%)
1	1287.60	5556.45	1691.13	131%	11%
2	2073.94	5782.58	2763.43	133%	11%
3	437.21	1961.50	508.00	116%	10%
4	813.92	2331.77	442.08	54%	5%
5	703.26	1545.50	842.24	120%	10%
6	3006	5087.23	2081.68	69%	6%
7	7206	16,406.74	9200.32	128%	11%
8	648	1189.59	541.44	84%	7%
9	0.00	141.94	141.94	-	-
10	114	280.94	166.56	146%	12%
11	2160	3702.04	1541.86	71%	6%
12	2254	3738.46	1484.60	66%	5%
13	1808	2884.51	1076.41	60%	5%
14	1926	2673.62	747.95	39%	3%
15	0.00	400.78	400.78	-	-
Average				94%	8%

Through the analysis, it was verified that the expansion of *A. dealbata* was very accelerated in relation to its initial occupation area, showing a factor that must be considered in the control actions of this species. In this sense, the economic resources for the control of *A. dealbata* expansion must follow the same dimension, which is why the control of acacia populations should be carried out preferably when plants are young.

The appearance of *A. dealbata* on the slopes of Cabeça seems to be positioned at an early stage, preferably close to the water lines. This position favors a more intense dispersion due to the edaphic compensation. However, the relic communities of *Prunus lusitanica* L., recognized through the Sectorial Plan of the Natura 2000 Network (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora), as a priority habitat for conservation in Europe (arborescent communities of *Laurus nobilis*, of the Azereirais), have in these areas their best ecological position. In this sense, it is expected that this habitat, a priority for conservation at the European level, is one of the most affected by the invasion of *A. dealbata*. Thus, if the progression of the acacia populations remains the same as the past 14 years, it is expected that, according to the projections calculated, the *A. dealbata* populations located in Cabeça can increase in the next 20 years by about 16.43 linear meters surrounding the existing areas. If there are no human-driven actions, especially fires, the expansion of acacias is expected to continue. A significant increase in the acacia area from 2019 to 2039 is projected, from about 54,000 m^2 to 433,000 m^2, which corresponds to an Invasiveness Rate of 807% (Table 3).

Table 3. The 20-year projection of the invasion of the *A. dealbata* areas (D_f—final diameter; IL20—linear increment in 20 years; D20—diameter increase in 20 years; A 2019—existing area in 2019; A 2039—area planned for 2039).

Sample	D_f (m)	IL20 (m)	D20 (m)	A 2019 (m^2)	A 2039 (m^2)
1	65.38	20.73	106.85	5556.45	44,797.83
2	81.32	24.93	131.19	5782.58	46,620.96
3	36.10	10.42	56.93	1961.50	15,814.22
4	43.89	9.74	63.37	2331.77	18,799.46
5	34.60	13.75	62.10	1545.50	12,460.30
6	72.16	13.24	98.64	5087.23	41,014.83
7	96.67	37.86	172.39	16,406.74	132,276.25
8	84.67	21.03	126.74	1189.59	9590.85
9	9.61	8.01	25.63	141.94	1144.36
10	17.37	5.19	27.75	280.94	2265.03
11	69.39	19.38	108.16	3702.04	29,847.00
12	58.78	14.29	87.36	3738.46	30,140.63
13	57.69	15.96	89.61	2884.51	23,255.82
14	51.39	17.73	86.86	2673.62	21,555.56
15	17.03	14.19	45.41	400.78	3231.21
	Average	16.43	Total areas	53,683.65	432,814.31

The use of orthophotomaps for spatiotemporal analysis was found to be adequate for the calculation of ALI and AIR for the population of *A. dealbata* in Serra da Estrela. To calculate the linear increment, the mean of the rays between the highest and the lowest elevation was considered. However, the ease of calculation used in the present study allows its easy replication for the study in other areas invaded by exotic plants.

Several studies on invasive plants calculated the advance of their areas over time [46–49]. However, the majority used data obtained in the National Forest Inventory to calculate the invasiveness rate in relation to the studied territory and not to the species population. Some examples can be found in the studies presented by Hernández et al. [50], which has growth rates of 0.1% within the studied area of northwestern Spain, while others, such as Higgins et al. [51] use empirical data. Therefore, the present study has the advantage of using real data for specific populations. The progression of the species depends on the edaphoclimatic conditions of each location, and in that sense, the invasiveness rates must be calculated at least at the level of the biogeographical district, especially in the Mediterranean area, where these mesological conditions vary within a few kilometers [52,53].

Although other studies propose the calculation of the risk of invasion, answering a set of questions [6,54], the linear advance of invasive plant populations is in fact crucial to calculate the time traveled to cover a specific area or to some physical limit, as is a property or a water line. However, the expansion of acacia populations seems to be favored by the proximity to water lines, as has been identified in other studies [21,55]. This capacity for growth and space occupation is clearly visible in the present (Figure 2). Since 2005, *A. dealbata* has been progressing mainly following the water lines' margins. This rapid occupation of the water lines is most likely related to the fact that theseeds are dragged by rainwater and because these areas are more humid, enhancing their development.

Thus, it is necessary to control the invasions of *A. dealbata* and other invasive species, such as *Eucalyptus globulus* in Serra da Estrela, which, in addition to releasing allelopathic substances inhibiting the growth of autochthonous flora, has high calorific power that increases the risk of spreading fire [56]. Since this is a species with a pioneering and heliophilous behavior, it is necessary to promote forest environments with autochthonous species, thus reducing the ecological conditions necessary for the germination of *A. dealbata*. However, for this, there must be a stimulus, so that rural areas do not continue to be depopulated.

Figure 2. Stands of *Acacia dealbata* (photo captured on 15 March 2021). The yellow color of the flowers makes the identification of the stands evident and it is possible to observe the development of the stand in the water line.

4. Conclusions

The development of the Annual Linear Increment (ALI) formulas and the Annual Invasiveness Rate (AIR) were validated by calculating the growth impact of *A. dealbata* population on the slopes of Serra da Estrela, Portugal. Their implementation benefits from homogeneous conditions from an ecological point of view, as the passage of a water plane or the presence of large rock outcrops can alter the growth behaviour of the species. Thus, we believethat these formulas will be very useful to quickly calculate the expansion of invasive species in other territories. In fact, the prediction of invasion through future scenarios allows the adoption of more effective measures and control strategies, aiding in preventive measures rather than reaction. Thus, actions to control exotic species should preferably be carried out from upstream to downstream, decreasing the possibility of reseeding the intervention areas. It is concluded that the control of *A. dealbata* should be carried out as early as possible, since the control of this species becomes significantly more difficult over time, due to the high volume of seeds generated annually.

Author Contributions: Conceptualization, M.A.M.R., C.J.P.G.; methodology, C.J.P.G., L.J.R.N.; validation, C.J.P.G., L.J.R.N. and M.A.M.R.; formal analysis, C.J.P.G., L.J.R.N. and M.A.M.R.; investigation, L.J.R.N. and M.A.M.R.; resources, C.J.P.G. and L.J.R.N.; data curation, C.J.P.G., L.J.R.N. and M.A.M.R.; writing—original draft preparation, M.A.M.R.; writing—review and editing, C.J.P.G. and L.J.R.N.; supervision, C.J.P.G. and L.J.R.N.; All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by national funds through FCT—Fundação para a Ciência e Tecnologia under the project no. UIDB/05183/2020. L.J.R.N. was supported by proMetheus. Research Unit on Energy. Materials and Environment for Sustainability—UIDP/05975/2020, funded by national funds through FCT—Fundação para a Ciência e Tecnologia.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available because the research is not yet concluded and the data will be updated.

Acknowledgments: This research received a contribution from the European Commission's LIFE program, through the Life-Relict Project (NAT/PT/000754).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Smith, R.J.; Muir, R.D.J.; Walpole, M.J.; Balmford, A.; Leader-Williams, N. Governance and the Loss of Biodiversity. *Nature* **2003**, *426*, 67–70. [CrossRef]
2. Underwood, E.C.; Viers, J.H.; Klausmeyer, K.R.; Cox, R.L.; Shaw, M.R. Threats and Biodiversity in the Mediterranean Biome. *Divers. Distrib.* **2009**, *15*, 188–197. [CrossRef]
3. Khapugin, A.A.; Kuzmin, I.V.; Silaeva, T.B. Anthropogenic Drivers Leading to Regional Extinction of Threatened Plants: Insights from Regional Red Data Books of Russia. *Biodivers. Conserv.* **2020**, *29*, 2765–2777. [CrossRef]
4. Roux, J.J.L.; Hui, C.; Castillo, M.L.; Iriondo, J.M.; Keet, J.-H.; Khapugin, A.A.; Médail, F.; Rejmánek, M.; Theron, G.; Yannelli, F.A.; et al. Recent Anthropogenic Plant Extinctions Differ in Biodiversity Hotspots and Coldspots. *Curr. Biol.* **2019**, *29*, 2912–2918.e2. [CrossRef]
5. Laface, V.L.A.; Musarella, C.M.; Cano Ortiz, A.; Quinto Canas, R.; Cannavò, S.; Spampinato, G. Three New Alien Taxa for Europe and a Chorological Update on the Alien Vascular Flora of Calabria (Southern Italy). *Plants* **2020**, *9*, 1181. [CrossRef] [PubMed]
6. Morais, M.; Marchante, E.; Marchante, H. Big Troubles Are Already Here: Risk Assessment Protocol Shows High Risk of Many Alien Plants Present in Portugal. *J. Nat. Conserv.* **2017**, *35*, 1–12. [CrossRef]
7. Lorenzo, P.; Palomera-Pérez, A.; Reigosa, M.J.; González, L. Allelopathic Interference of Invasive Acacia Dealbata Link on the Physiological Parameters of Native Understory Species. *Plant Ecol.* **2011**, *212*, 403–412. [CrossRef]
8. Rodríguez-Echeverría, S.; Afonso, C.; Correia, M.; Lorenzo, P.; Roiloa, S.R. The Effect of Soil Legacy on Competition and Invasion by Acacia Dealbata Link. *Plant Ecol.* **2013**, *214*, 1139–1146. [CrossRef]
9. Nunes, L.J.R.; Raposo, M.A.M.; Meireles, C.I.R.; Gomes, C.J.P.; Ribeiro, N.M.C.A. Carbon Sequestration Potential of Forest Invasive Species: A Case Study with Acacia Dealbata Link. *Resources* **2021**, *10*, 51. [CrossRef]
10. Nunes, L.J.R.; Raposo, M.A.M.; Meireles, C.I.R.; Pinto Gomes, C.J.; Ribeiro, N.M.C.A. Control of Invasive Forest Species through the Creation of a Value Chain: Acacia Dealbata Biomass Recovery. *Environments* **2020**, *7*, 39. [CrossRef]
11. Nunes, L.J.R.; Raposo, M.A.M.; Meireles, C.I.R.; Gomes, C.J.P.; Ribeiro, N.M.C.A. The Impact of Rural Fires on the Development of Invasive Species: Analysis of a Case Study with Acacia Dealbata Link. in Casal Do Rei (Seia, Portugal). *Environments* **2021**, *8*, 44. [CrossRef]
12. Lazzaro, L.; Bolpagni, R.; Buffa, G.; Gentili, R.; Lonati, M.; Stinca, A.; Acosta, A.T.R.; Adorni, M.; Aleffi, M.; Allegrezza, M.; et al. Impact of Invasive Alien Plants on Native Plant Communities and Natura 2000 Habitats: State of the Art, Gap Analysis and Perspectives in Italy. *J. Environ. Manag.* **2020**, *274*, 111140. [CrossRef] [PubMed]
13. Maitre, D.C.L.; Gaertner, M.; Marchante, E.; Ens, E.-J.; Holmes, P.M.; Pauchard, A.; O'Farrell, P.J.; Rogers, A.M.; Blanchard, R.; Blignaut, J.; et al. Impacts of Invasive Australian Acacias: Implications for Management and Restoration. *Divers. Distrib.* **2011**, *17*, 1015–1029. [CrossRef]
14. Bengtsson, J.; Nilsson, S.G.; Franc, A.; Menozzi, P. Biodiversity, Disturbances, Ecosystem Function and Management of European Forests. *For. Ecol. Manag.* **2000**, *132*, 39–50. [CrossRef]
15. Bardsley, D.; Edwards-Jones, G. Stakeholders' Perceptions of the Impacts of Invasive Exotic Plant Species in the Mediterranean Region. *GeoJournal* **2006**, *65*, 199–210. [CrossRef]
16. Hussain, M.I.; El-Sheikh, M.A.; Reigosa, M.J. Allelopathic Potential of Aqueous Extract from Acacia Melanoxylon R. Br. on *Lactuca sativa*. *Plants* **2020**, *9*, 1228. [CrossRef]
17. Souza-Alonso, P.; Rodríguez, J.; González, L.; Lorenzo, P. Here to Stay. Recent Advances and Perspectives about Acacia Invasion in Mediterranean Areas. *Ann. For. Sci.* **2017**, *74*, 55. [CrossRef]
18. Raposo, M.A.M.; Gomes, C.J.P.; Nunes, L.J.R. Selective Shrub Management to Preserve Mediterranean Forests and Reduce the Risk of Fire: The Case of Mainland Portugal. *Fire* **2020**, *3*, 65. [CrossRef]
19. Mainali, K.P.; Warren, D.L.; Dhileepan, K.; McConnachie, A.; Strathie, L.; Hassan, G.; Karki, D.; Shrestha, B.B.; Parmesan, C. Projecting Future Expansion of Invasive Species: Comparing and Improving Methodologies for Species Distribution Modeling. *Glob. Chang. Biol.* **2015**, *21*, 4464–4480. [CrossRef] [PubMed]
20. Martins, F.; Alegria, C.; Artur, G. Mapping Invasive Alien Acacia Dealbata Link Using ASTER Multispectral Imagery: A Case Study in Central-Eastern of Portugal. *For. Syst.* **2016**, *25*, 13. [CrossRef]
21. Monteiro, A.T.; Gonçalves, J.; Fernandes, R.F.; Alves, S.; Marcos, B.; Lucas, R.; Teodoro, A.C.; Honrado, J.P. Estimating Invasion Success by Non-Native Trees in a National Park Combining World View-2 Very High Resolution Satellite Data and Species Distribution Models. *Diversity* **2017**, *9*, 6. [CrossRef]
22. Lorenzo, P.; González, L.; Reigosa, M.J. The Genus Acacia as Invader: The Characteristic Case of Acacia Dealbata Link in Europe. *Ann. For. Sci.* **2010**, *67*, 101. [CrossRef]

23. Marchante, H.; Morais, M.; Freitas, H.; Marchante, E. *Guia Prático Para a Identificação de Plantas Invasoras Em Portugal*; Imprensa da Universidade de Coimbra: Coimbra, Portugal, 2014; ISBN 978-989-26-0786-3.
24. Nunes, L.J.R.; Raposo, M.A.M.; Meireles, C.I.R.; Pinto Gomes, C.J.; Ribeiro, N.M.C.A. Fire as a Selection Agent for the Dissemination of Invasive Species: Case Study on the Evolution of Forest Coverage. *Environments* **2020**, *7*, 57. [CrossRef]
25. Malato-Beliz, J. *A Serra de Monchique—Flora e Vegetação. Coleção de Parques Naturais Nº 10*; Serviço Nacional de Parques, Reservas e Património Paisagístico: Lisboa, Portugal, 1982.
26. Pinto-Gomes, C.; Meireles, C.; Raposo, M.; Castro, C.; Matos, R.; Santos, P. *Guia da Excursão Geobotânica do XIII Seminário Internacional de Gestão e Conservação da Biodiversidade-Vale do Lobo*; Loulé: Algarve, Portugal, 2019.
27. Breton, C.; Guerin, J.; Ducatillion, C.; Médail, F.; Kull, C.A.; Bervillé, A. Taming the Wild and 'Wilding' the Tame: Tree Breeding and Dispersal in Australia and the Mediterranean. *Plant Sci.* **2008**, *175*, 197–205. [CrossRef]
28. Paiva, J. Acacia Mill. In *Flora Iberica—Plantas Vasculares de la Península Iberica e Islas Baleares*; Talavera, S., Aedo, C., Castroviejo, S., Romero, C., Sáez, L., Salgueiro, F.J., Velayos, M., Eds.; Real Jardín Botánico, CSIC: Madrid, Spain, 1999; Volume VII, pp. 11–25.
29. Liberal, M.; Esteves, M. *Invasão de Acacia Dealbata Link No Parque Nacional Da Peneda-Gerês*; SPCF/ADERE: Gerês, Portugal, 1999.
30. Gallagher, R.V.; Leishman, M.R.; Miller, J.T.; Hui, C.; Richardson, D.M.; Suda, J.; Trávníček, P. Invasiveness in Introduced Australian Acacias: The Role of Species Traits and Genome Size. *Divers. Distrib.* **2011**, *17*, 884–897. [CrossRef]
31. Rodríguez-Echeverría, S.; Fajardo, S.; Ruiz-Díez, B.; Fernández-Pascual, M. Differential Effectiveness of Novel and Old Legume–Rhizobia Mutualisms: Implications for Invasion by Exotic Legumes. *Oecologia* **2012**, *170*, 253–261. [CrossRef] [PubMed]
32. Milton, S.J.; Hall, A.V. Reproductive Biology of Australian Acacias in the South-Western Cape Province, South Africa. *Trans. R. Soc. S. Afr.* **1981**, *44*, 465–487. [CrossRef]
33. Gibson, M.R.; Richardson, D.M.; Marchante, E.; Marchante, H.; Rodger, J.G.; Stone, G.N.; Byrne, M.; Fuentes-Ramírez, A.; George, N.; Harris, C.; et al. Reproductive Biology of Australian Acacias: Important Mediator of Invasiveness? *Divers. Distrib.* **2011**, *17*, 911–933. [CrossRef]
34. Correia, M.; Castro, S.; Ferrero, V.; Crisóstomo, J.A.; Rodríguez-Echeverría, S. Reproductive Biology and Success of Invasive Australian Acacias in Portugal. *Bot. J. Linn. Soc.* **2014**, *174*, 574–588. [CrossRef]
35. Passos, I.; Marchante, H.; Pinho, R.; Marchante, E. What We Don't Seed: The Role of Long-Lived Seed Banks as Hidden Legacies of Invasive Plants. *Plant Ecol.* **2017**, *218*, 1313–1324. [CrossRef]
36. Wilson, J.R.U.; Gairifo, C.; Gibson, M.R.; Arianoutsou, M.; Bakar, B.B.; Baret, S.; Celesti-Grapow, L.; DiTomaso, J.M.; Dufour-Dror, J.-M.; Kueffer, C.; et al. Risk Assessment, Eradication, and Biological Control: Global Efforts to Limit Australian Acacia Invasions. *Divers. Distrib.* **2011**, *17*, 1030–1046. [CrossRef]
37. Silva, J.S.; Vaz, P.; Moreira, F.; Catry, F.; Rego, F.C. Wildfires as a Major Driver of Landscape Dynamics in Three Fire-Prone Areas of Portugal. *Landsc. Urban Plan.* **2011**, *101*, 349–358. [CrossRef]
38. Catford, J.A.; Daehler, C.C.; Murphy, H.T.; Sheppard, A.W.; Hardesty, B.D.; Westcott, D.A.; Rejmánek, M.; Bellingham, P.J.; Pergl, J.; Horvitz, C.C.; et al. The Intermediate Disturbance Hypothesis and Plant Invasions: Implications for Species Richness and Management. *Perspect. Plant Ecol. Evol. Syst.* **2012**, *14*, 231–241. [CrossRef]
39. Vieites-Blanco, C.; González-Prieto, S.J. Invasiveness, Ecological Impacts and Control of Acacias in Southwestern Europe—A Review. *Web Ecol.* **2020**, *20*, 33–51. [CrossRef]
40. Rivas-Martínez, S.; Penas, Á.; Díaz González, T.E.; Cantó, P.; del Río, S.; Costa, J.C.; Herrero, L.; Molero, J. Biogeographic Units of the Iberian Peninsula and Baelaric Islands to District Level. A Concise Synopsis. In *The Vegetation of the Iberian Peninsula: Volume 1*; Plant and Vegetation; Loidi, J., Ed.; Springer International Publishing: Cham, Switzerland, 2017; pp. 131–188. ISBN 978-3-319-54784-8.
41. Rivas-Martínez, S.; Penas, Á.; del Río, S.; Díaz González, T.E.; Rivas-Sáenz, S. Bioclimatology of the Iberian Peninsula and the Balearic Islands. In *The Vegetation of the Iberian Peninsula: Volume 1*; Plant and Vegetation; Loidi, J., Ed.; Springer International Publishing: Cham, switzerland, 2017; pp. 29–80. ISBN 978-3-319-54784-8.
42. Ferreira, N.; Vieira, G. *Guia Geológico e Geomorfológico: Do Parque Natural da Serra da Estrela; Locais de Interesse Geológico e Geomorfológico*; ICNF—Instituto da Conservação da Naturaleza: Lisboa, Portugal, 1999.
43. Marques, J.E.; Duarte, J.M.; Constantino, A.T.; Martins, A.A.; Aguiar, C.; Rocha, F.T.; Inácio, M.; Marques, J.M.; Chaminé, H.I.; Teixeira, J.; et al. Vadose Zone Characterisation of a Hydrogeologic System in a Mountain Region: Serra Da Estrela Case Study (Central Portugal). In *Aquifer Systems Management: Darcy's Legacy In a World Impending Water Shortage*; Chery, L., de Marsilly, G., Eds.; Taylor & Francis: London, UK, 2007; pp. 207–221. ISBN 978-0-415-44355-5.
44. Beltran, R.S. Distribution and Autoecology off *Prunus lusitanica* L. in Iberian Peninsula. *For. Syst.* **2006**, *15*, 187–198. [CrossRef]
45. Costa, J.C.; Neto, C.; Aguiar, C.; Capelo, J.; Espírito Santo, M.D.; Honrado, J.J.; Gomes, C.P.; Monteiro-Henriques, T.; Sequeira, M.; Lousã, M. Vascular plant communities in Portugal (continental, the Azores and Madeira). *Glob. Geobot.* **2012**, *2*, 1–180.
46. Santos, M.; Freitas, R.; Crespí, A.L.; Hughes, S.J.; Cabral, J.A. Predicting Trends of Invasive Plants Richness Using Local Socio-Economic Data: An Application in North Portugal. *Environ. Res.* **2011**, *111*, 960–966. [CrossRef] [PubMed]
47. Marchante, H.; Marchante, E.; Freitas, H. Invasion of the Portuguese Dune Ecosystems by the Exotic Species *Acacia longifolia* (Andrews) Willd.: Effects at the Community Level. In *Plant Invasions: Ecological Threats and Managagement Solutions*; Child, L.E., Brock, J.H., Brundu, G., Prach, K., Pysek, P., Wade, P.M., Williamson, M., Eds.; Backhuys Publishers: Leiden, The Netherlands, 2003; pp. 75–85.

48. Marchante, H.; Freitas, H.; Hoffmann, J.H. Seed Ecology of an Invasive Alien Species, *Acacia longifolia* (Fabaceae), in Portuguese Dune Ecosystems. *Am. J. Bot.* **2010**, *97*, 1780–1790. [CrossRef] [PubMed]
49. Gomes, M.; Carvalho, J.C.; Gomes, P. Invasive Plants Induce the Taxonomic and Functional Replacement of Dune Spiders. *Biol. Invasions* **2018**, *20*, 533–545. [CrossRef]
50. Hernández, L.; Martínez-Fernández, J.; Cañellas, I.; de la Cueva, A.V. Assessing Spatio-Temporal Rates, Patterns and Determinants of Biological Invasions in Forest Ecosystems. The Case of Acacia Species in NW Spain. *For. Ecol. Manag.* **2014**, *329*, 206–213. [CrossRef]
51. Higgins, S.I.; Richardson, D.M.; Cowling, R.M. Validation of a Spatial Simulation Model of a Spreading Alien Plant Population. *J. Appl. Ecol.* **2001**, *38*, 571–584. [CrossRef]
52. Correia, T.P.; Abreu, A.C.; Oliveira, R. Identificação de Unidades de Paisagem: Metodologia aplicada a Portugal Continental. *FIT* **2001**, *36*. [CrossRef]
53. Raposo, M. Séries de Vegetação Prioritárias Para a Conservação No Centro e Sul de Portugal Continental. *Botanique* **2016**, *1*, 113–148.
54. Pheloung, P.C.; Williams, P.A.; Halloy, S.R. A Weed Risk Assessment Model for Use as a Biosecurity Tool Evaluating Plant Introductions. *J. Environ. Manag.* **1999**, *57*, 239–251. [CrossRef]
55. Fernandes, M.R.; Aguiar, F.C.; Martins, M.J.; Rico, N.; Ferreira, M.T.; Correia, A.C. Carbon Stock Estimations in a Mediterranean Riparian Forest: A Case Study Combining Field Data and UAV Imagery. *Forests* **2020**, *11*, 376. [CrossRef]
56. Guerrero, F.; Hernández, C.; Toledo, M.; Espinoza, L.; Carrasco, Y.; Arriagada, A.; Muñoz, A.; Taborga, L.; Bergmann, J.; Carmona, C. Leaf Thermal and Chemical Properties as Natural Drivers of Plant Flammability of Native and Exotic Tree Species of the Valparaíso Region, Chile. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7191. [CrossRef] [PubMed]

CAPÍTULO VI

CONSIDERAÇÕES FINAIS




CAPÍTULO VI. CONSIDERAÇÕES FINAIS

VI.1. Conclusões

Os dados de campo recolhidos e respetivas análises desenvolvidas no âmbito da presente Tese, contribuem para incrementar o conhecimento científico das comunidades de azereiro, tendo em vista a adoção de políticas integrativas de planeamento e ordenamento do território. As informações apresentadas neste trabalho constituem a base fundamental para a criação de planos de gestão favoráveis à conservação do azereiro.

Com base na informação recolhida, foram publicados até ao momento cinco artigos científicos (Raposo, 2020; Raposo, del Río, et al., 2021; Raposo, Nunes, et al., 2021; Raposo, Pinto-Gomes, et al., 2020; Raposo, Quinto-Canas, et al., 2020), os quais permitiram melhorar o conhecimento atual sobre as comunidades de *P. lusitanica* relativamente à sua distribuição, análise fitossociológica, métodos de gestão e uso de ferramentas de apoio à decisão, tendo em vista a conservação deste táxone relíquo. As contribuições desenvolvidas dividem-se em quatro seções: Capítulo II - análise geobotânica das comunidades de *Prunus lusitanica*; Capítulo III - avaliação do estado de conservação de *Prunus lusitanica* no centro de Portugal Continental; Capítulo IV - originalidades edafo-higrófilas identificadas no centro e sul de Portugal; Capítulo V - principais ameaças ao estado de conservação das comunidades de *Prunus lusitanica*.

De forma sintética, os principais resultados deste trabalho foram:

i) A melhoria do conhecimento da distribuição do azereiro em Portugal, com a identificação de novos núcleos populacionais, os quais resultaram em **três novas quadrículas** (10 x 10 quilómetros) no mapa de distribuição na base de dados da Sociedade Portuguesa de Botânica (https://flora-on.pt/#1Prunus+lusitanica).

ii) A análise fitossociológica permitiu identificar **cinco novidades sintaxonómicas** para o Centro e Sul de Portugal Continental e Sudoeste de França, nomeadamente *Smilaco asperae-Prunetum lusitanicae* Raposo, del Río, Pinto-Gomes & Lazare, *Lonicero periclymeni-Prunetum lusitanicae* Raposo, del Río, Pinto-Gomes & Lazare, *Frangulo baeticae-Salicetum atrocinerea* Raposo, Quinto-Canas, Cano-Ortiz, Sampinato & Pinto-Gomes, *Clematido flammulae-Salicetum australis* Raposo, Quinto-Canas, Cano-Ortiz, Sampinato & Pinto-Gomes e *Cheirolopho uliginosii-Molinietum arundinaceae* Raposo, Quinto-Canas, Cano-Ortiz, Spampinato & Pinto-Gomes.

iii) A análise sinfitossociológica desenvolvida permitiu identificar **duas novas séries e uma nova minorisérie** de vegetação:

Séries edafo-higrófilas: *Frangulo baeticae-Salico atrocinerea* sigmetum; *Clematido flammulae-Salico australis* sigmetum.

Minorisérie tempori-higrófila: *Lonicero periclymeni-Pruno lusitanicae minorisigmetum*.

iv) As comunidades de azereiro distribuem-se por nove setores biogeográficos, sendo que a presente Tese permitiu alargar a sua corologia para o **Distrito Beirense Meridional** (Região Mediterrânea, Província Mediterrânea Ibérica Ocidental, Setor Cordilheiro Oretano-Tagano) (Rivas-Martínez et al., 2017).

v) Os azereirais do centro de Portugal apresentaram uma **redução de 40%** da sua população durante os últimos 15 anos, quando comparados com os dados publicados por Calleja (Calleja, 2006).

vi) A melhoria da gestão do coberto vegetal, através do **controlo seletivo do coberto arbustivo**, onde, com base na dinâmica das séries de vegetação, se propõe um conjunto de arbustos a controlar e a conservar, tendo em vista a redução do risco de incêndio.

vii) **Duas fórmulas para calcular a expansão de plantas invasoras** com base em dados espaciotemporais, contribuindo para o apoio à decisão no planeamento e ordenamento da paisagem, nomeadamente a *Annual Linear Increment* (ALI) e a *Annual Invasiveness Rate* (AIR):

$$\text{ALI} = \frac{1}{a}\sum_{n=1}^{a}\frac{Df - Di}{2\,(Tf - Ti)} \qquad \text{AIR} = \frac{1}{a}\sum_{n=1}^{a}\frac{Af - Ai}{Ai\,(Tf - Ti)}$$

Referencias

Calleja, J. A. (2006). Geobotánica, estructura demográfica, consevación y biología predispersiva de *Prunus lusitanica* L. (loro) en la Península Ibérica. [Memoria de Tesis Doctoral.]. Universidad Autónoma de Madrid.

Raposo, M. (2020). Control of Invasive Forest Species through the Creation of a Value Chain: *Acacia dealbata* Biomass Recovery. Environments. https://doi.org/10.3390/environments7050039

Raposo, M., del Río, S., Pinto-Gomes, C., & Lazare, J.-J. (2021). Phytosociological analysis of *Prunus lusitanica* communities in the Iberian Peninsula and south of France. Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology, 0(ja), 1–19. https://doi.org/10.1080/11263504.2021.1998242

Raposo, M., Nunes, L. J. R., Quinto-Canas, R., del Río, S., Pardo, F. M. V., Galveias, A., & Pinto-Gomes, C. J. (2021). *Prunus lusitanica* L.: An Endangered Plant Species Relict in the Central Region of Mainland Portugal. Diversity, 13(8), 359. https://doi.org/10.3390/d13080359

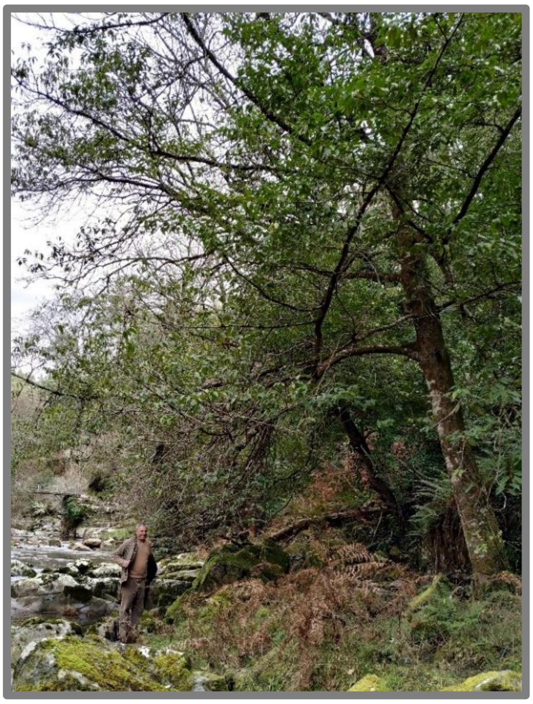
Raposo, M., Pinto-Gomes, C. J., & Nunes, L. J. R. (2020). Selective Shrub Management to Preserve Mediterranean Forests and Reduce the Risk of Fire: The Case of Mainland Portugal. Fire, 3(4), 65. https://doi.org/10.3390/fire3040065

Raposo, M., Quinto-Canas, R., Cano-Ortiz, A., Spampinato, G., & Pinto Gomes, C. (2020). Originalities of Willow of *Salix atrocinerea* Brot. In Mediterranean Europe. Sustainability, 12(19), 8019. https://doi.org/10.3390/su12198019

Rivas-Martínez, S., Penas, Á., Díaz González, T. E., Cantó, P., del Río, S., Costa, J. C., Herrero, L., & Molero, J. (2017). Biogeographic Units of the Iberian Peninsula and Baelaric Islands to District Level. A Concise Synopsis. Em J. Loidi (Ed.), The Vegetation of the Iberian Peninsula: Volume 1 (pp. 131–188). Springer International Publishing. https://doi.org/10.1007/978-3-319-54784-8_5

Anexo I

Comparação morfológica entre *P. lusitanica* e *P. serotina*.

Prunus lusitanica L.	***Prunus serotina*** Ehrh.
	
Ramos geralmente patentes a ereto-patentes.	Ramos maioritariamente ereto-patentes com a parte final pendentes.
	
Ritidoma liso, acinzentado.	Ritidoma fendilhado, castanho-acinzentado.

Domínio de ramos patentes

Domínio de ramos pendulinos

Folhas submenbranaceas. Página inferior com nervuras secundárias pouco evidentes.

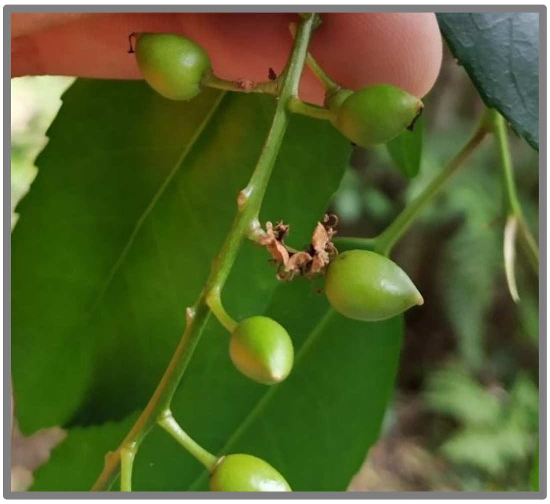
Folhas membranaceas. Página inferior com vários nervos evidentes.

Folhas ovado-lanceoladas ou oblongo-lanceoladas, planas ou ligueiramente onduladas
(7-15 x 2,5-6 cm)

Folhas eliptica, onduladas
(10-19 x 2,5-6 cm)

Folha crenada a serrada

Folha serrulada



Fruto ovoide a subgloboso, atenuado até ao ápice.

Fruto subgloboso, algo deprimido nas extremidades.

Endocarpo com cerca de 6 mm de largura,
ovoide ou subgloboso.

Endocarpo com cerca de 8 mm de largura, ovoide.

Anexo II

Evolução do conhecimento da área de distribuição de *Prunus lusitanica* em Portugal Continental (as quadriculas assinaladas a verde representam novas localizações).