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

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

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)).

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

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)).

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

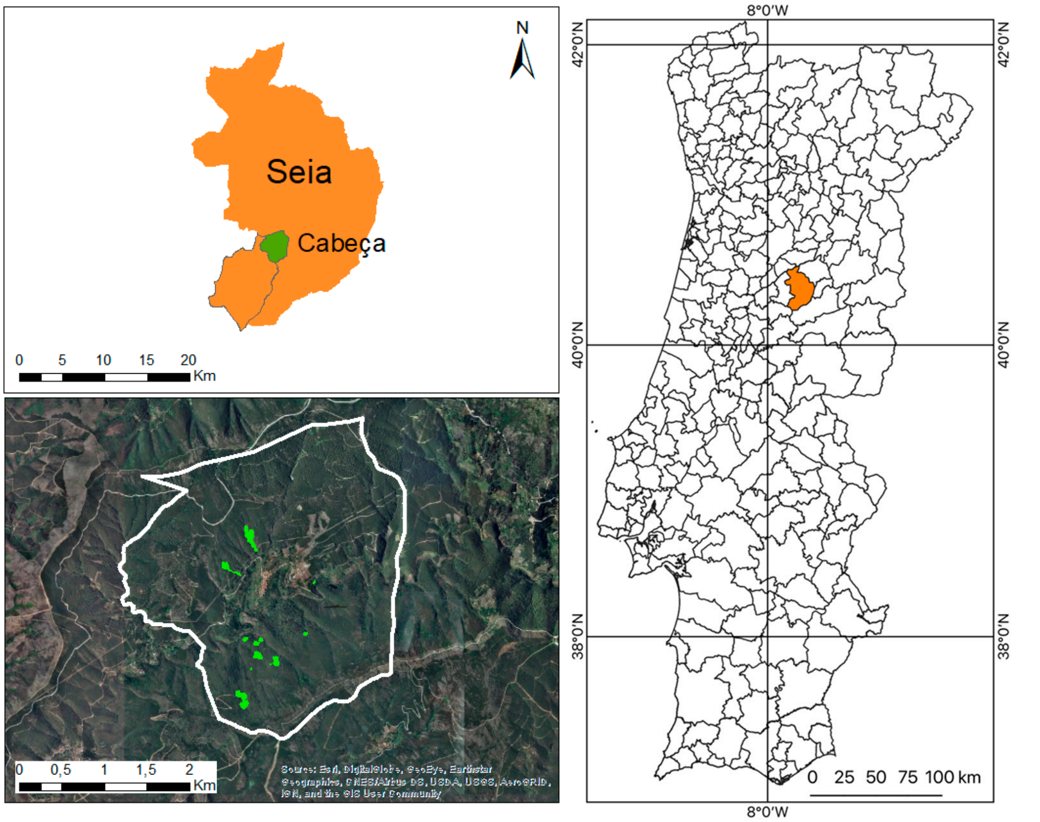

Figure 1. Location of the *A. dealbata* subpopulation studied.

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 believevthat 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]