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Eucalypt Recruitment and Invasion Potential in Protected Areas of the Iberian Peninsula under Current and Future Climate Conditions

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Abstract: *Eucalyptus globulus* Labill. stands have been expanding in protected areas (sites) of the Natura 2000 network in the Iberian Peninsula (Iberia). This expansion is mostly human-driven, but there is increasing evidence of plant recruitment and escape from cultivation areas. Therefore, it is important to assess the recruitment and invasion potential of sites and associated habitats and how future climate may change this potential. Here, we use SDMs to project current and future climatic suitability for *E. globulus* recruitment in Iberia and combine this suitability with local factors to rate the current recruitment potential of eucalypt stands. This potential is then extrapolated to neighbour areas in Natura 2000 sites to assess the invasion potential. The results show a wide recruitment range along coastal regions of western and northern Iberia (83,275 km^2) and a northward contraction under climate change, similar to the trend projected for plantation suitability. Recruitment potential of any level was identified in 989 km^2, while invasion potential was identified in 878 km^2 across 176 Natura 2000 sites. Heathlands and riparian forests were associated with the largest recruitment and invasion potential areas. This study may help in preventing further negative impacts in protected areas and habitats already affected by *E. globulus* expansion.

Keywords: biodiversity; environmental impacts; climate change; conservation areas; environmental scenarios; *Eucalyptus globulus*; Google Street View; Natura 2000; species distribution models

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1. Introduction

Eucalyptus globulus Labill. is an evergreen tree species native to southeast Australia [1]. In the native range, *E. globulus* occurs across a wide range of climatic and edaphic conditions, being one of the eucalypt species with the largest ranges [2]. This species was introduced in several countries since the mid-18th century and became one of the most popular, widespread eucalypt species in the world [3]. Plantations of *E. globulus* have expanded significantly in some regions of the Iberian Peninsula (Iberia), especially since the mid-20th century, mostly aimed to feed pulp and paper markets [4,5].

Iberia is a large peninsula in southwest Europe, which includes Spain and Portugal and extends over 583,000 km^2 (58 million ha). The Mediterranean biogeographical region [6] that covers most of Iberia is characterised by hot, dry summers and cold, rainy winters. The Atlantic region that covers northern and northwestern Iberia is characterised by milder winters, cooler summers and moderate rainfall throughout the year (Figure 1).

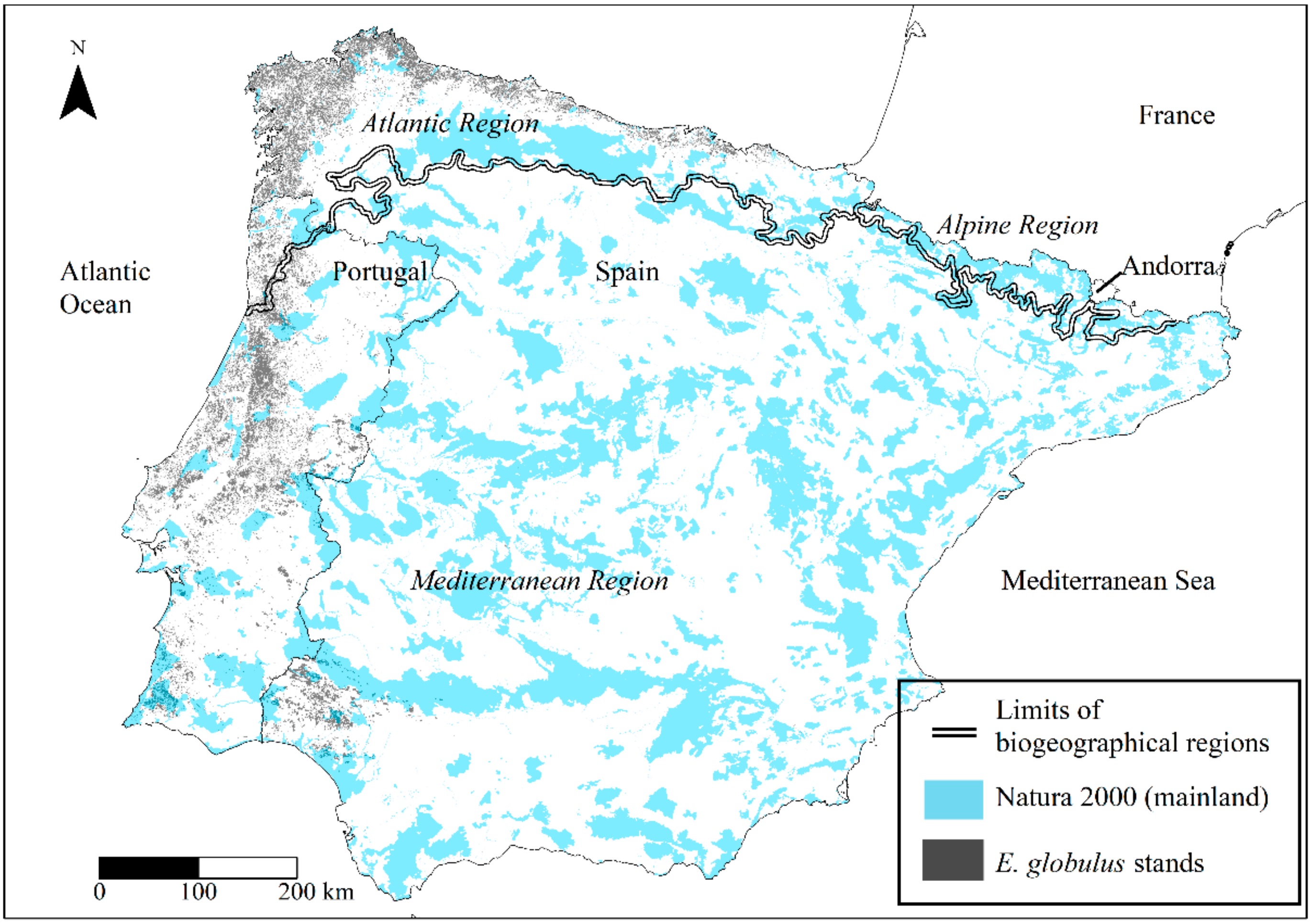

Figure 1. *Eucalypts globulus* Labill. distribution, biogeographical regions (italic text) and terrestrial protected area from the Natura 2000 network in the Iberian Peninsula (Portugal and Spain).

Eucalyptus globulus is considered to be naturalised in many world regions, including North, Central and South America, Indonesia or the Pacific Islands [7], i.e., it can originate thriving offspring, normally nearby parent plants. In some circumstances, *E. globulus* can show invasive behaviour, producing offspring into surrounding habitats [8–11], as reported in Iberia [12–16].

The invasion of neighbour habitats may depend on the type of habitat, since some habitats such as grasslands or native forests are more resistant to invasion than others such as shrublands or pine forests [15–18]. Still, recruitment can occur in a variety of natural or semi-natural ecosystems [14], especially after major disturbances such as wildfires which disrupt the resistance to invasion [12,17,19]. However, seeds from *E. globulus* lack long dispersal adaptations [20]. Dispersal distances up to 80–100 m have been recorded [12–14], and a probable maximum distance of 175 m was reported in a study from Australia in a drainage line [21]. The species is not legally identified as invasive in Portugal and Spain even though different stakeholders recognise its invasive potential [22].

The rapid eucalypt expansion is raising concerns about negative environmental impacts across the introduced range [23,24], particularly in Iberia [4,25–27]. Studies have found negative ecological impacts on several aspects such as bird communities [28], stream ecology [29], water resources [30], understorey vegetation [31] and fire behaviour [32]. Additionally, negative impacts were found on ecosystem services, including carbon sequestration, water quality, soil fertility and biodiversity [33–35]. There are also direct impacts derived from the replacement of valuable habitats [26,36] and the possibility of indirect impacts through habitat fragmentation [4,31].

Iberia is considered a hotspot for biodiversity and hosts nearly 20% of the terrestrial surface of the Natura 2000 network in Europe [37]. Natura 2000 is a network of protected areas (usually called "sites") established across the European Union aimed at preserving and protecting the most endangered species and habitats, including over 1000 species and 233 habitats, of which over one third are forests. Natura 2000 covers almost 20% of the European Union's mainland and 10% of its marine territory [38]. In Iberia, a total of 1483 sites with any terrestrial surface were established, including 1386 sites in Spain and 97 sites in Portugal, covering c. 26% of Iberia's mainland (c. 150,000 km^2).

Conflicts and impacts from *E. globulus* expansion in Natura 2000 sites were shown in previous studies. For instance, in Iberia, it was found that *E. globulus* has been expanding inside many Natura 2000 sites, even after their designation as protected areas [4]. In northern Spain, it was shown that *E. globulus* became widespread inside Natura 2000 sites [39]. In one site in northwest Spain, it was confirmed that valuable habitats such as riparian forests, native forests, pasture and agriculture areas were partly converted into *E. globulus* plantations [26]. In Portugal, it was shown that *E. globulus* covers considerable portions of many Natura 2000 sites, and several invasion foci were found in some sites [40]. Given the conservation value of protected areas in Iberia, it is important to anticipate possible impacts in sites and natural habitats resulting from eucalypt expansion.

In the following decades, overall warming and drying in Iberia are expected to shift regional climates and displace the range of native tree species [41,42] and alien species such as *E. globulus* [4]. Climate change may also affect *E. globulus* recruitment, but in different ways to how it affects plantations, because climatic requirements are different when eucalypts are established with or without competition [43]. In Iberia, the current climatic suitability for *E. globulus* recruitment was modelled, and it was found that the recruitment range is mostly restricted to coastal regions of western and northern Iberia [44]. However, it is not known how climate change may affect the recruitment range and how these dynamics relate to future ranges of plantations.

Anticipating invasions is crucial to preventing impacts on natural values that we want to preserve. Species distribution models (SDMs) are widely used in ecology for this purpose. Over the last few decades, SDMs have been increasingly used to identify key environmental variables driving the distribution of alien invasive species [45–47] and to predict their potential distribution under different environmental scenarios [48].

This study applies SDMs to assess the current and future climatic suitability for *E. globulus* recruitment in Iberia. The present recruitment range is then combined with a set of local scale factors to define levels of recruitment potential for eucalypt stands and levels of invasion potential into neighbour areas inside the Natura 2000 network of protected areas. Future recruitment ranges projected for contrasting climate change scenarios are compared with the suitability range for *E. globulus* plantations projected by [4] using the same scenarios. The sites and habitats under greater threat from eucalypt expansion and invasion are identified, and measures to mitigate possible impacts are discussed.

2. Materials and Methods

2.1. Species Distribution Models

Climatic suitability for *E. globulus* recruitment across Iberia was assessed using species distribution models (SDMs) calibrated and projected using the R [49] package biomod2 [50]. From a set of 19 bioclimatic variables (www.worldclim.org; accessed on 27 July 2019 [51]), after testing for highly correlated variables using Spearman correlations, 5 were included as predictors in the models (correlation < 0.7): temperature seasonality; minimum temperature of the coldest month; annual precipitation; precipitation seasonality–coefficient of variation; isothermality.

Presence–absence data of *E. globulus* recruitment were included as a dependent variable. Recruitment data were remotely collected using Google Street View imagery along roadside transects, up to 100 m long, established adjacent to *E. globulus* plantations throughout the introduced range. Plantations of *E. globulus* were identified in vectorial land cover maps from Portugal and Spain according to [4]. The survey transects were established in 1 km × 1 km (1 km^2) cells containing *E. globulus* plantations; transects with presence were then upscaled into 10 km × 10 km (100 km^2) grid cells. This database was retrieved from a previous work where further details about survey protocols can be found [44], where further details about survey protocols can be found.

Model calibration and evaluation were performed using the ten available modelling algorithms of the biomod2 package and the selected set of five bioclimatic variables. Each individual model was calibrated using 80% of available data and evaluated with the remaining 20% using the area under the curve (AUC). The final ensemble model was obtained by the predictions of all models with an AUC above 0.7, using the Mean (all) consensus method [52]. Model projection was then reclassified into a probability ramp from the threshold to the maximum predicted value using the "filtROC" function available in biomod2. The probability ramp was, therefore, assumed as an index of potential *E. globulus* recruitment.

The SDMs were projected for future conditions according to two contrasting RCPs (Representative Concentration Pathways) 2.6 and 8.5, for the years 2050 and 2070 in order to be comparable with a previous work [4]. The suitability for *E. globulus* recruitment was reclassified and presented into five probability classes: 0% (no recruitment suitability); >0 ≤25% (very low); >25 ≤50% (low); >50 ≤75% (high); >75–100% (very high).

2.2. Classifying Recruitment Potential

The current climatic suitability for *E. globulus* recruitment (Section 2.1) was combined with a set of additional local scale variables known to influence *E. globulus* recruitment (Table 1), in order to define levels of recruitment potential for eucalypt stands established inside and around Natura 2000 sites (Table 2). Eucalypt stands outside the sites, distancing up to 100 m (maximum dispersal distance recorded in [12,13]), were also classified to estimate the potential of invasion coming from outside stands (Section 2.3). Recruitment potential was defined as the likelihood of eucalypt stands to originate recruitment, meaning that stands with higher recruitment potential had more chances of originating recruitment.

Local variables included: eucalypt presence, the occurrence of wildfires, residence time of eucalypt stands and slope (Table 1). These variables represent important drivers of recruitment related to propagule pressure (eucalypt presence; residence time), disturbance (wildfires), stand characteristics (residence time) and topography (slope). Eucalypts lack long-distance seed dispersal adaptations [20], meaning that the presence of mother plants is required for recruitment in a particular area. Wildfires are associated with recruitment and invasion events [12,13,53,54] by triggering a massive, synchronised seed shed from canopies in the weeks following fire [55] and by disrupting the resistance of plant communities to eucalypt establishment [12,17,19]. Higher residence time (a proxy for tree age and stand rotations in coppicing systems) may translate into greater propagule pressure and enhance recruitment [12,13,56]. A minimum residence time of 15 years allows younger stands to be distinguished from older, mature stands submitted to at least one rotation, which is normally 10–12 years [57]. Higher slopes can facilitate recruitment by reducing plant competition and waterlogging [12,56] and enhancing seed dispersal distances [14], including the possibility of hydrochory for dispersal [14,21]. In the study by [58], a threshold value of 30° was found to enhance recruitment.

All variables were mapped in GIS using a 100 × 100 m resolution (pixel size). The five maps (climatic suitability; eucalypt presence; wildfire occurrence; residence time; slope) were combined into an ensemble raster map to provide all possible combinations between variables. Variables assumed different importance in the classification of recruitment potential based on empirical knowledge and the objectives of this study. Additionally, there was an assumption of a cumulative effect of factors enhancing recruitment, meaning that as more factors were combined, the greater the potential for recruitment. Climatic suitability assumed a main role in the classification of recruitment potential due to its critical importance for recruitment and its regional scope. Wildfires also played a key role in the classification of recruitment potential because they are associated with massive recruitment events. The effects of residence time and slope are more local, and for that reason they had less importance in the classification, being considered isolated or together as facilitating factors for recruitment. Eucalypt stands inside and around Natura 2000 sites were therefore assigned to one of five recruitment potential levels based on an empirical combination of variables: very low; low; moderate; high; very high (Table 2).

Table 1. List of variables used to estimate recruitment potential and invasion potential.

Variables	Classes	Details	Map Sources
Climatic suitability for recruitment	0%; 1%–25%; 26%–50%; >50%	Retrieved from SDMs (Section 2.1). Highest classes (51%–75%; 76%–100%) were merged because they are scarcer and to reduce factorial combinations between variables, simplifying the classification of recruitment potential (Table 2).	SDMs
Eucalypt presence	Absence; presence	Retrieved from the most recent and detailed land cover maps from both countries. Minimum mapping area (forests) = 1 ha. Eucalypt stands include different stand types in terms of structure, composition, or management, including monospecific industrial plantations, mixed stands (normally unmanaged) and open stands.	Spain: [59]; Portugal [60]
Wildfires	Burnt; unburnt	Produced using MODIS satellite imagery at 250 m resolution. Period: January 2008–18 March 2022; minimum burnt area = 40 ha.	[61]
Residence time	Low; high	Calculated using land cover maps from different time periods. If eucalypts persisted between maps, a minimum residence time was assured. Minimum residence time of: 15 years in Spain (maps from 1986 to 1996 and 2011 to 2012); 28 years in Portugal (maps from 1990 and 2018).	Spain: [59,62]; Portugal: [60,63]
Slope	<30°; ≥30°	Retrieved from Digital Elevation Models. Spatial resolution = 25 m. Vertical resolution = 5 m.	[64]

Table 2. Combination of factors used for the classification of recruitment potential and invasion potential of eucalypt stands and adjacent areas inside the Natura 2000 network.

Eucalypt Presence	Climatic Suitability	Wildfire Occurrence [1]	1 or 2 FF [2]	Recruitment/Invasion Potential
yes	>50%	Yes	Yes	Very High
			No	High
		No	Yes	High
			No	Moderate
	26%–50%	Yes	Yes	High
			No	Moderate
		No	Yes	Low
			No	Low
	1%–25%	Yes	Yes	Low
			No	Very low
		No	Yes	Very low
			No	Very low

[1] Fires occurred between 2008 and 18 March 2022; [2] yes—presence of one or two facilitating factors (FF), including residence time (minimum of 15–28 years) and/or slope (≥30°); no—absence of facilitating factors.

In order to map the recruitment potential inside and around Natura 2000 sites, a vector map of the Natura 2000 network was downloaded from the European Environmental Agency website [37]. Portuguese and Spanish sites were retrieved (n = 2024), and the maritime sites or the maritime areas of some sites were discarded from the analyses. A total of 1483 sites were retained for analyses, covering c. 152,000 km^2 in Iberia (excludes overlapping areas from different sites).

2.3. Classifying Invasion Potential

It was assumed that eucalypt stands assigned with recruitment potential of any level, inside or around Natura 2000 sites, had the capacity to invade nearby areas, i.e., had some invasion potential. Areas under invasion potential assumed the same level of recruitment potential from the closest stand: very low; low; moderate; high; very high (Table 2). Invasion potential was defined as the likelihood of finding offspring in areas adjacent to eucalypt stands, meaning that areas with higher levels of invasion potential were more likely to have abundant recruitment. When the same area was under the invasion radius of two or more eucalypt stands with different recruitment potential levels, the highest level was adopted.

Invasion potential was restricted to land covers inside Natura 2000 sites where eucalypt invasion is feasible (e.g., forests, shrublands and grasslands). Unsuitable land covers such as wet areas, urban areas, sand environments and agriculture areas were discarded. Even though some studies suggest that different land covers have different degrees of invasibility [15,18], it was assumed that *E. globulus* can potentially invade all "suitable" land covers [14], especially after wildfires [12,17]. Land cover data were retrieved from the European CORINE land cover map from 2018 (CLC'18; available in [65]), which provides homogeneous land cover classification across both countries.

2.4. Testing Recruitment Potential Classification

The efficacy of recruitment potential classification was tested through random surveys in Natura 2000 sites at locations hosting eucalypt stands with different levels of recruitment potential. The survey was performed remotely using Google Street View imagery, which has proven to be effective at detecting *E. globulus* wildlings [66]. A sample of 50 sites was randomly selected for each level of recruitment potential, totalling 250 observations (Figure S1). The samples were chosen through semi-automatic processes in GIS, using the recruitment potential map (pixel centroids in a 100 $\times$ 100 m grid) and a vector road map for Iberia. The centroids (points) of each pixel assigned with some level of recruitment potential were automatically displaced into the nearest road section from the road map. The minimum distance between survey points for the same level of recruitment potential was 200 m to avoid surveying very close locations. Survey points displaced into a nearby road were randomly sorted for the survey according to recruitment potential levels and converted into a KML file to be displayed in Google Earth in order to allow the survey to be performed in Google Street View, similarly to [66]. The number of samples in areas of "high" and "very high" levels was scarce using this semi-automatic process. Therefore, samples were chosen manually in Google Earth by searching for areas with available imagery, keeping the minimum distance criteria.

Each survey was a 360° observation at a static location in order to record the presence or absence of *E. globulus* recruitment. The observer adopted a conservative approach of recording "presence" only when the sighting of eucalypt offspring was unequivocal. Evidence of *E. globulus* recruitment included: the presence of young eucalypts on the roadside; the presence of young, single-stemmed eucalypts inside or near an older stand; the presence of eucalypt stands with individuals displaying irregular distribution and heterogeneous sizes. Observations were not performed when there were poor visibility conditions (e.g., high slope; dense vegetation; visual obstacles) or signs of recent disturbances (e.g., wildfires; recent clear felling of stands). The same observer performed all observations. A chi-square test was performed to test the independence between recruitment presence and recruitment potential.

2.5. Testing Invasion Potential Classification

Testing invasion potential classification was unfeasible using Google Street View due to the lack of adequate imagery to assess invasion in most cases and because invasion may have not yet occurred, i.e., invasion may occur in the future. As an alternative, invasion potential data were compared between sites classified as invaded or non-invaded by [40]. In that study, *E. globulus* was mapped in several Portuguese sites using satellite imagery. Sites hosting naturally-established populations outside regular plantations were classified as invaded (n = 9). Sites classified as non-invaded (n = 6) showed no signs of invasion despite hosting large areas with eucalypt stands. The areas under each invasion potential level were compared between the two groups of sites (invaded vs. non-invaded) using non-parametric Mann–Whitney tests.

2.6. Assessing the Recruitment/Invasion Potential of Sites and Habitats

Mapping recruitment potential and invasion potential allowed the assessment of which sites and which natural habitats were associated with each level of recruitment potential and invasion potential. It was assumed that sites and natural habitats associated with actual or potential eucalypt expansion were more likely to experience negative ecological impacts, either direct impacts (e.g., habitat changes or replacement) or indirect impacts (e.g., habitat fragmentation). Sites are identified by their name and code. The first two characters of the code indicate the country: PT = Portugal; ES = Spain. Data on habitat distribution were retrieved from the latest reports delivered by Portugal and Spain under the frame of Article 17 of the Habitats Directive, for the period 2013–2018, aimed at evaluating the conservation status of habitats and species [37]. These reports include vector maps with the distribution of natural habitats (and species) displayed in a 10 × 10 km grid covering Iberia. These maps were produced using three methods: expert opinion with very limited data (58.5% of observations); extrapolation from a limited amount of data (36.0%); complete survey or a statistically robust estimate (5.5%) [67]. Maps delivered by both countries were combined in GIS, and only areas inside the Natura 2000 network were retained, allowing the total surface of recruitment and invasion potential affecting each habitat to be calculated.

3. Results

3.1. Current Recruitment Range

The model explaining the climatic suitability for *E. globulus* recruitment selected five bioclimatic variables as important predictors, namely (ordered by importance): temperature seasonality (BIO4; importance = 43.0%); minimum temperature of the coldest month (BIO6; 19.5%); annual precipitation (BIO12; 13.0%); precipitation seasonality–coefficient of variation (BIO15; 9.0%); isothermality (0.9). The model had an excellent accuracy with an AUC = 0.975.

Under current climatic conditions, around 83,275 km^2 (c. 8,327,500 ha) of Iberia's territory (15%) featured climatic requirements for *E. globulus* recruitment (≥1% climatic suitability; Table 3). The recruitment range extended along western and northern regions across the Mediterranean (40%) and the Atlantic (60%) biogeographical regions [6] but was confined to a thin coastal strip in the north. The best conditions for recruitment (≥51%), covering c. 40,000 km^2, were mostly found in western regions from central Portugal up to northwest Spain, where *E. globulus* stands are widespread (Figure 1) and tended to decrease towards south and inland (Figure 2). Most eucalypt stands in Iberia (85%; 16,144 km^2) were established inside the current recruitment range. Most of the current recruitment range (c. 90%; 74,922 km^2) and all of the range (100%; 39,798 km^2) featuring the best climate for recruitment (≥51% suitability) overlapped with the current range for plantations projected by [4] (Figure 3).

Table 3. Areas (km^2) in the Iberian Peninsula and inside Natura 2000 according to levels of climatic suitability for *Eucalyptus globulus* recruitment for the present and the years 2050 and 2070 under climate change scenarios RCP2.6 and RCP8.5.

Area	Climatic Suitability	Current	RCP2.6-2050	RCP2.6-2070	RCP8.5-2050	RCP8.5-2070
Iberia	0%	498,993	524,182	521,449	527,287	539,590
	1%–25%	21,771	15,243	15,943	14,601	10,856
	26%–50%	21,707	14,770	15,566	13,539	10,700
	51%–75%	19,895	14,233	14,699	13,341	10,104
	76%–100%	19,902	13,840	14,611	13,500	11,018
	Total ≥ 1%	83,275	58,086	60,819	54,981	42,678
Natura 2000	0%	140,929	146,930	146,507	146,816	148,407
	1%–25%	5149	1311	1569	1636	873
	26%–50%	3083	1748	1644	1475	1189
	51%–75%	1717	1090	1361	1179	1040
	76%–100%	1354	1151	1149	1125	720
	Total ≥ 1% (n sites)	11,303 (206)	5300 (175)	5723 (180)	5415 (177)	3822 (156)

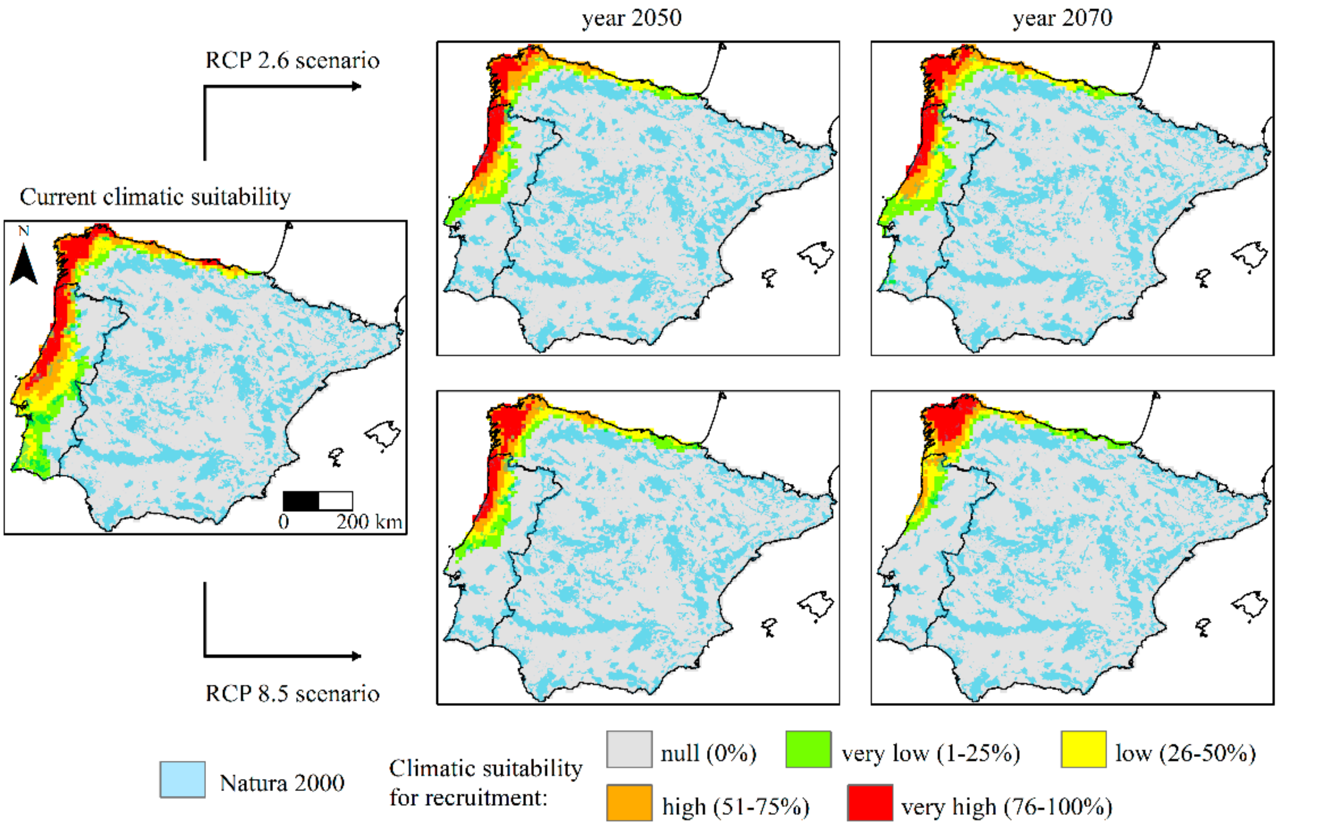

Figure 2. Current and future climatic suitability (%) for *Eucalyptus globulus* recruitment in Iberia in the years 2050 and 2070 under climate change scenarios RCP2.6 and RCP8.5. Climatic suitability corresponds to the probability (%) of finding recruitment.

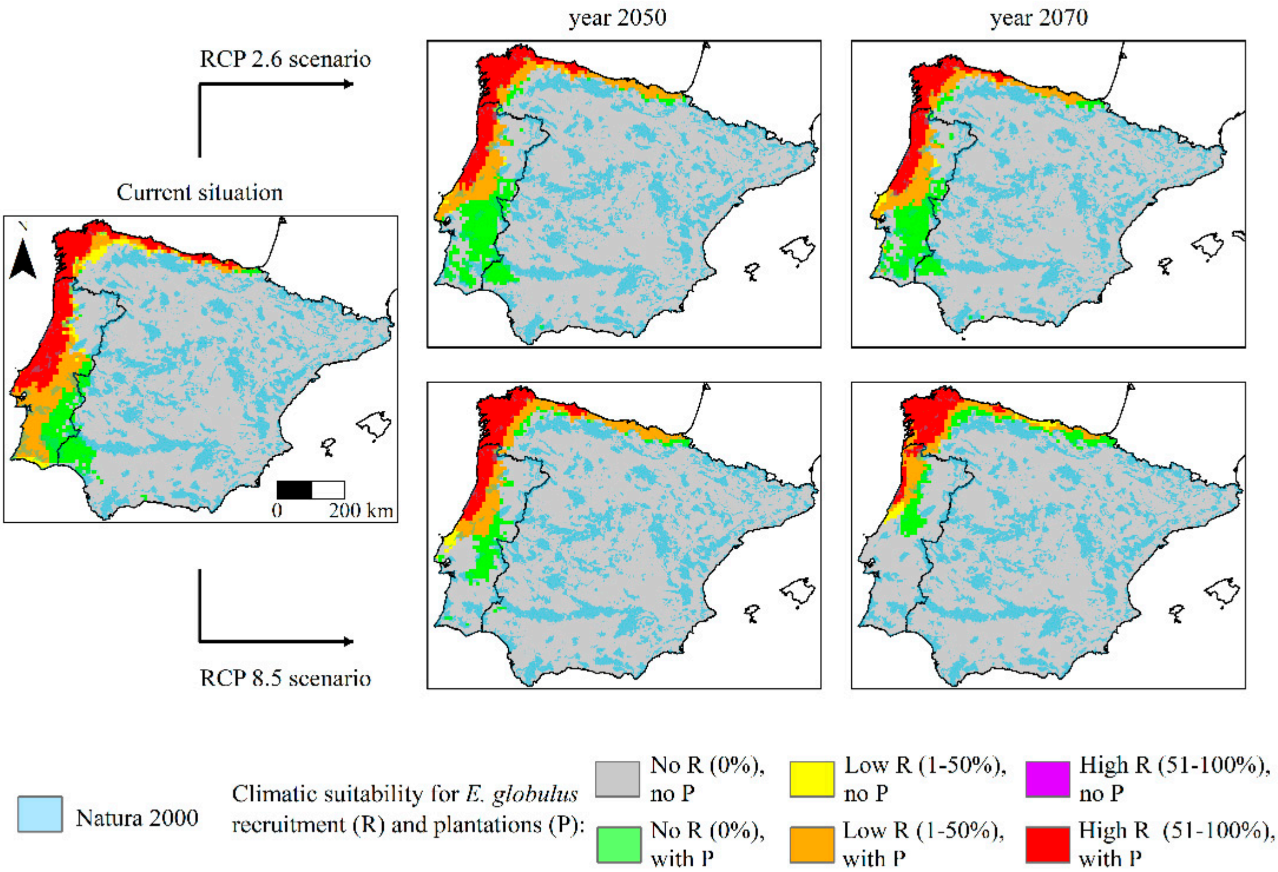

Figure 3. Current and future climatic suitability (%) for *Eucalyptus globulus* plantations and *E. globulus* recruitment in the years 2050 and 2070 under climate change scenarios RCP2.6 and RCP8.5. Climatic suitability corresponds to the probability (%) of finding recruitment.

The recruitment range within the Natura 2000 network covered 11,303 km^2 across 206 sites, including 174 sites already hosting eucalypt stands. High and very high climatic suitability (>50%) was found in 3070 km^2 across 126 sites distributed across western and northwestern coastal regions (Table 3). There were 59 sites with *E. globulus* stands outside the recruitment range. Inside Natura 2000, the recruitment range overlaps to a great extent with the suitable range for plantations (86%; 9745 km^2).

3.2. Recruitment and Invasion Potential by Site

According to recent land cover maps [59,60], eucalypt stands covered 1629 km^2 (c. 162,900 ha) inside 265 Natura 2000 sites and covered 2110 km^2 around (1 km buffer) 335 sites. Eucalypt stands with some recruitment potential covered 988.7 km^2 across 157 sites, most of which were found in Portugal (834.7 km^2; 84%), even though most sites were in Spain (101 sites; 66%). Nine sites, all located in Portugal, hosted c. 60% (624 km^2) of the whole area of eucalypt stands with some recruitment potential. Eucalypt stands with "high" and "very high" recruitment potential covered 133.8 km^2 (96 sites) and 20.7 km^2 (18 sites), respectively. Stands with high recruitment potential were widespread across the recruitment range, but stands with very high potential were restricted to coastal regions featuring "very high" climatic conditions for recruitment (Figure 2).

Several sites with recruitment potential had considerable portions of their surface covered with eucalypt stands (Figure 4). There were 27 sites with more than 20% cover, including sites Valongo (PTCON0024; 70% = 17.8 km^2), Cueva del Rejo (ES1300019; 58% = 1.0 km^2) and Monte Aloia (ES1140005; 52% = 4.1 km^2). Sites with recruitment potential with the largest extensions of eucalypt stands included Monchique (PTCON0037; 256.5 km^2), Costa Sudoeste (PTCON0012; 107.1 km^2) and S. Mamede (PTCON0007; 65.9 km^2).

On the other hand, 25 sites with recruitment potential had a residual portion covered by eucalypt stands (<1%).

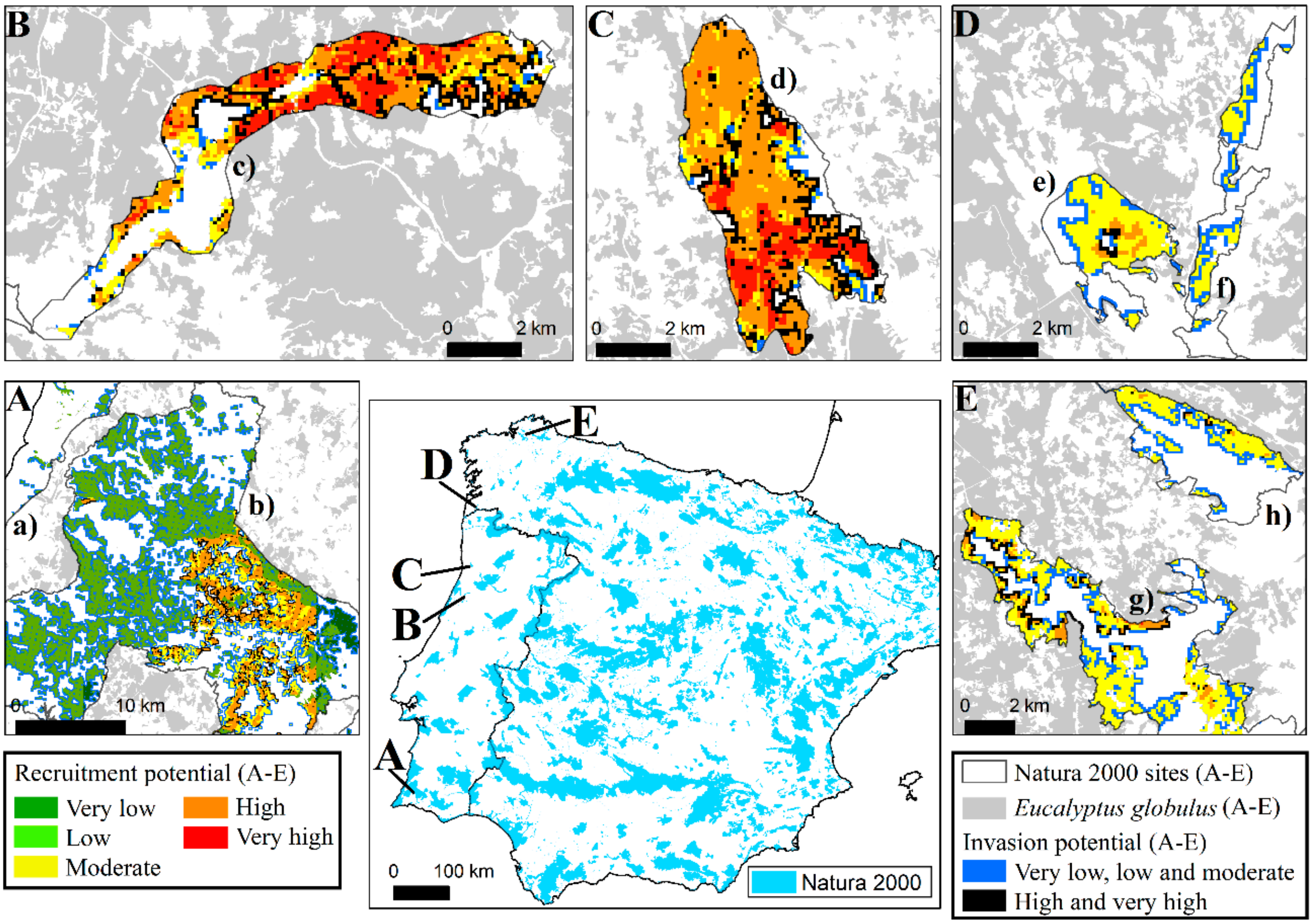

Figure 4. Terrestrial Natura 2000 in the Iberian Peninsula (central frame) and recruitment potential and invasion potential of *Eucalyptus globulus* inside some Natura 2000 sites (frames (**A**–**E**)). Sites include: (**a**) Costa Sudoeste (PTCON0012 and PTZPE0015); (**b**) Monchique (PTCON0037); (**c**) Rio Vouga (PTCON0026); (**d**) Valongo (PTCON0024); (**e**) Monte Aloia (ES1140005); (**f**) Gándaras de Budiño (ES1140011); (**g**) Fragas do Eume (ES1110003); (**h**) Xubia-Castro (ES1110013).

Areas under invasion potential of any class covered 877.7 km^2 across 176 sites (Table 4), mostly in Portugal (721.5 km^2; 82%), even though most sites were in Spain (115 sites; 65%). Areas under "high" or "very high" invasion potential covered 123.9 km^2 in 113 sites, including 21 sites hosting 15.2 km^2 under "very high" invasion potential, distributed across the coastal regions showing the most favourable climatic conditions for recruitment (Figure 2).

Some sites had considerable portions of their surface with invasion potential, such as Turbera de las Dueñas (ES1200045; 72.6% = 14.6 km^2), Cambarinho (PTCON0016; 43.3% = 10.4 km^2) and Sierra Plana de la Borbolla (ES1200042; 34.9% = 356.5 km^2). Sites hosting larger areas with recruitment potential were also those with larger areas under some invasion potential, such as Monchique (167.8 km^2), Costa Sudoeste (86.5 km^2) and S. Mamede (70.1 km^2). Sites hosting larger areas under higher levels (high; very high) of invasion potential were mostly located in Portugal (13 out of the top 15 sites) and included the sites Monchique (22.4 km^2), Serras da Freita e Arada (PTCON0047; 14.2 km^2) and Rio Paiva (PTCON0059; 12.7 km^2).

Table 4. Areas (km^2) and number of sites from the Natura 2000 network according to levels of recruitment potential and invasion potential.

	Recruitment Potential		Invasion Potential		Invasion Potential (Outside Only)		
Class	**Area (km^2)**	**Sites (n)**	**Area (km^2)**	**Sites (n)**	**Area (km^2)**	**Sites (n)**	**Sites (n, no Eg [1])**
Very Low	241	40	226	52	6	46	5
Low	321	55	247	66	12	63	3
Moderate	273	127	281	135	53	128	5
High [a]	134	96	109	113	12	102	1
Very high [b]	21	18	15	21	1	17	0
All classes	990	157	878	175	83	168	11
Total ([a] + [b])	154	96	124	112	12	102	1

[1] no Eg: sites without *E. globulus* stands inside but with invasion potential from the outside. Total ([a] + [b]): sum of classes "high" ([a]) and "very high" ([b]).

Data on invasion potential included cases of *E. globulus* stands located outside the perimeter of Natura 2000 sites (up to 100 m distance) that could originate recruitment inside the sites. Stands in such conditions extended c. 2446 km along the perimeter of 168 sites and originated 61.7 km^2 of areas with some invasion potential, including 9.1 km^2 of "high" invasion potential and 0.9 km^2 of "very high" invasion potential (Table 4). Among these sites (n = 168), 19 sites had no prior record of *E. globulus* stands with recruitment potential inside their limits, and 6 more sites only had residual occupation (<0.01 km^2). These sites were mostly located at the outer edges of the recruitment range of *E. globulus* in Iberia, where stands were less abundant. Examples included the sites Nacimiento del Río Gevora (ES0000407; 0.16 km^2), Río Las Cabras-Bedón (ES1200033; 0.16 km^2) or Río Sella (ES1200032; 0.16 km^2).

Many sites had considerable areas where recruitment and invasion potential overlapped (Figure 4). These surfaces covered more than 20% of the area of 75 sites, and more than 50% in 19 sites. The most affected sites included Río Porcía (ES1200024; 93% = 0.6 km^2), Río Lérez (ES1140002; 94% = 1.38%), Valongo (92% = 23.3 km^2) and Cueva del Rejo (87% = 1.57 km^2). In some cases, recruitment and invasion potential may have been overestimated due to mapping inaccuracy when, for instance, rivers were classified as other land covers and were then assigned to some recruitment or invasion potential. Data regarding recruitment and invasion potential in each site are available as Supplementary Materials in Table S1.

The survey in Natura 2000 sites using Google Street View imagery, which aimed to determine the efficacy of the recruitment potential classification (Section 2.4), showed a positive relation between recruitment potential levels and the frequency of *E. globulus* recruitment. A chi-square homogeneity test confirmed the existence of significant differences between the observed and expected frequencies (df = 4, n = 250, $X^2 = 52.56$, $p < 0.001$). The presence of *E. globulus* recruitment was more frequent in the areas assigned to higher levels of recruitment potential, reaching 98% in locations with "very high" recruitment potential in contrast to 52% at the "very low" level. The results were inverted in areas assigned to "low" and "moderate" recruitment potential, with the first showing more frequent recruitment (82% vs. 68%). Overall, the survey recorded the "presence" of *E. globulus* recruitment in 78% of the sampled locations (195 out of 250 sampled locations) (Table 5).

Invasion potential data were compared between groups of "invaded" (n = 9) and "non-invaded" (n = 5) Natura 2000 sites identified by [40] in Portugal. One of the sites (Mourão/Moura/Barrancos; code: PTZPE0045) belonging to the group of non-invaded sites was discarded because it was outside the recruitment range for *E. globulus*, i.e., outside suitable climatic conditions for recruitment, and thus was not assigned to any invasion potential.

Table 5. Results from a survey using Google Street View to record the presence and absence of *Eucalyptus globulus* recruitment in 250 random locations inside Natura 2000 sites stratified according to classes of recruitment potential (50 observations in each class).

Recruitment Potential	Number of Observations	
	Recruitment Absence (%)	Recruitment Presence (%)
Very low	48%	52%
Low	18%	82%
Moderate	32%	68%
High	10%	90%
Very high	2%	98%
Total	22%	78%

On average, "non-invaded" sites had larger areas with some invasion potential than invaded sites (39.50 vs. 29.02 km^2). However, "invaded" sites had larger areas with the highest levels of invasion potential (moderate; high; very high). Mann–Whitney tests showed significant differences between groups only for areas with "high" and "moderate" invasion potential. Since areas with "very high" invasion potential were residual due to the restrictive conditions of this rank, "high" and "very high" levels were merged and showed significant differences between groups (Table 6).

Table 6. Average percentage of different levels of invasion potential inside 14 Natura 2000 sites, classified as invaded or non-invaded by [40], and comparison between the two groups using Mann–Whitney tests.

Invasion Potential Levels	Invaded (n = 9) (% ± SD)	Non-Invaded (n = 5) (% ± SD)	W Value	p Value
Very low	0.62 (±1.18)	1.60 (±2.13)	13	ns
Low	1.92 (±4.24)	1.60 (±2.67)	21	ns
Moderate	8.69 (±8.50)	1.66 (±3.12)	40	*
High	5.96 (±3.51)	0.37 (±0.54)	45	**
Very high	2.01 (±2.61)	0.04 (±0.06)	31	ns
High + very high	7.97 (±5.91)	0.41 (±0.59)	45	**
Total	19.22 (±5.85)	5.28 (±3.63)	45	***

Significance of p value: ns = non-significant (>0.05); * = $\leq$ 0.05; ** = $\leq$ 0.01; *** = $\leq$ 0.001.

3.3. Recruitment and Invasion Potential by Habitat

Habitats with any level of recruitment and invasion potential were identified in the analysis. Only 5 out of 134 natural habitats had no spatial data in Spain, even though these habitats were less relevant to eucalypt expansion and impacts, such as "Lakes of gypsum karst" (code 3190) or "Dunes with *Euphorbia terracina*" (2220). The largest surfaces were associated with habitats (asterisk means priority habitat): 4030—"European dry heaths" (1664 km^2; 6.9% of the habitat area in Iberia); 91E0*—"Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*" (1464 km^2; 9.4%); and 6430—"Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels" (1432 km^2; 13.7%). The most common habitats inside Natura 2000 sites associated with recruitment/invasion potential were also habitats 4030 (161 sites) and 91E0* (159 sites). The third habitat in this rank was habitat 4020*—"Temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*" (125 sites; 1073 km^2).

The natural habitats with larger percentages of the whole surface with recruitment and invasion potential of any level included three priority habitats: 6110*—"Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*" (47% covered = 175 km^2), 4040*—"Dry Atlantic coastal heaths with *Erica vagans*" (24% = 58 km^2) and 3140*—"*Cistus palhinhae* formations on maritime wet heaths" (23% = 168 km^2). Other priority habitats included: 5230*—Arborescent matorral with *Laurus nobilis* (17% = 666 km^2) and 4020*-Temperate

Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix* (13%; 1072 km^2). If we exclude strictly marine habitats and terrestrial caves, there are 87 habitats within Natura 2000 sites with recruitment or invasion potential of any level. Data on recruitment/invasion potential by habitat are available in Supplementary Materials Table S2.

3.4. Future Climatic Scenarios

Under both climate change scenarios (RCP2.6; RCP8.5), projections show a northward contraction of the recruitment range, more pronounced under the worst scenario (RCP8.5), decreasing to nearly half of the current range in 2070 (83,275 km^2 to 42,700 km^2) (Table 3). In both scenarios, the recruitment potential becomes zero in south Portugal. Areas showing the best recruitment conditions (≥51%) become progressively confined into the northwest (Figure 2), even though new suitable areas emerge in northwest Iberia towards inland, especially under RCP8.5. Maps showing gain–loss range dynamics are available in Supplementary Material (Figure S2).

The recruitment range and the plantation range show similar range dynamics following climate change scenarios, with a general northward range contraction, more pronounced under RCP8.5. Additionally, both ranges expand into inner areas in northwest Spain. However, the apparent "migration" of the plantation ranges seems delayed in all scenarios. As a result, despite overlapping to a great extent, the range for plantations is consistently larger than the recruitment ranges (Figure 3).

As a consequence of the northward range contraction, both the recruitment range and the number of Natura 2000 sites within it decrease accordingly. Under RCP2.6, the recruitment range inside Natura 2000 will reduce from 11,303 km^2 to 5300 km^2 within 175 sites in the year 2050 and recovers part of the lost range up to 5723 km^2 within 180 sites in 2070 (overall, −49% of the original range and −10% of sites). Under RCP8.5, the range decreases progressively from 11,303 km^2 to 5415 km^2 within 177 sites in 2050 and down further to 3822 km^2 within 156 sites in 2070 (overall, −66% of the original range and −24% of sites) (Table 3).

Under both climate change scenarios, areas suitable for both recruitment and plantations decrease to nearly half the extent in 2050, from 9745 km^2 to 5009 km^2 in 175 sites under RCP2.6 or to 5160 km^2 in 173 sites under RCP8.5. In 2070, areas combining both ranges practically stabilise under RCP2.6, while under RCP8.5, they decrease further to 3618 km^2 in 144 sites (Table 7).

Table 7. Areas (km^2) in the Iberian Peninsula and inside the Natura 2000 network according to the combination of climatic suitability for *Eucalyptus globulus* recruitment (R) and plantations (P) in current and future times in the years 2050 and 2070 under climate change scenarios RCP2.6 and RCP8.5 [1].

Area	Climatic Suitability for R and P	Current	RCP2.6-2050	RCP2.6-2070	RCP8.5-2050	RCP8.5-2070
Iberia	No R; with P	25,027	35,234	34,674	16,589	16,342
	Low R; with P [a]	35,124	28,634	28,779	26,355	18,341
	High R; with P [b]	39,798	28,074	29,277	26,841	21,123
	No R; no P	473,967	488,948	486,776	510,698	523,249
	Low R; no P	8355	1381	2730	1787	3216
	High R; no P	0	0	35	46	0
	Total ([a] + [b])	74,922	56,708	58,056	53,196	39,464

Table 7. *Cont.*

Area	Climatic Suitability for R and P	Current	RCP2.6-2050	RCP2.6-2070	RCP8.5-2050	RCP8.5-2070
Natura 2000	No R; with P	6268	7040	7388	2599	2160
	Low R; with P [a]	6677	2771	2588	2859	1858
	High R; with P [b]	3068	2239	2474	2301	1760
	No R; no P	134,642	139,871	139,100	144,198	146,229
	Low R; no P	1555	288	624	251	202
	High R; no P	0	0	33	0	0
	Total ([a] + [b]) (n sites)	9745 (186)	5009 (175)	5063 (169)	5160 (173)	3618 (144)

[1] there are residual differences in some values of climatic suitability for recruitment relative to Table 3 (e.g., +2 km^2 in the total recruitment range) due to the resolution of the combined maps. Total ([a] + [b]): sum of classes "low R; with P" ([a]) and "High R; with P" ([b]).

4. Discussion

4.1. Recruitment Potential inside Natura 2000

Eucalyptus globulus has a relatively wide recruitment range in Iberia, extending across 83,277 km^2 in western and northern regions and across two biogeographical regions—the Atlantic and the Mediterranean. The recruitment range is mostly associated with areas with some oceanic influence, but the climatic suitability for recruitment decreases progressively towards the south and inland until it becomes null in regions with stronger continental influence, where eucalypt wildlings are more vulnerable to extreme temperatures and drought [1,58]. The negative effect of continentality is reflected by the variables selected by the model of climatic suitability for recruitment, such as temperature seasonality (43% importance). The same set of variables was uncovered and thoroughly discussed in the work by [44].

The recruitment range overlaps to a great extent with the range for plantations, meaning that recruitment is enhanced in regions where plantations are favoured. In fact, eucalypt stands already cover extensive areas in most of these regions. This may help to explain the widespread recruitment observed by some studies across the introduced range in Iberia [16,44,68].

The overall recruitment frequency recorded in this study (78%) inside the Natura 2000 network, using random surveys on eucalypt stands with different levels of recruitment potential, was higher than the frequency recorded by [44] across Iberia using Google Street View (33%), or by [58] in Portugal through car surveys (60%). This difference becomes more expressive considering that the surveys in this study were performed at one single location, while in the cited studies, they were performed along road transects up to 100 m long, thus covering potentially larger areas and occasionally more than one stand. These results suggest that the criteria adopted in this study allowed us to identify eucalypt stands that in fact originate recruitment.

When testing the efficacy of the levels of recruitment potential, there was an unexpected inversion in intermediate levels of recruitment potential, where "low" recruitment potential areas showed higher recruitment frequency than "moderate" areas. This could be explained by the fact that, in this study, only wildfires since 2008 were included due to homogenisation purposes and because of limited data in Spain. Further analyses showed that some sampled locations classified as unburnt did in fact burn previously according to detailed Portuguese maps [69], and most of these observations showed recruitment. Coincidentally, these cases were more common in "low" recruitment potential areas (28 vs. 6). Despite this discrepancy in intermediate levels, the tests on recruitment potential levels successfully distinguished areas of lower and higher recruitment potential.

From the initial distribution of *E. globulus* stands inside Natura 2000 sites (1629 km^2), this study allowed 60% of the area (990 km^2) to be retained in 60% of the sites (157 sites) where eucalypt stands have recruitment potential of any level, and for many cases, invasion potential of any level, as well. A few sites in Portugal concentrate most (c. 60%) of the eucalypt cover with recruitment potential. However, eucalypt stands with recruitment potential are scattered across many sites, and in several cases, they occupy a considerable proportion of the site. As a result, many sites are under threat of eucalypt invasion. It is worth noting that eucalypt distribution in Natura 2000 sites is underestimated because land cover maps fail to identify small stands or isolated trees that can play an important role in invasion [12,13]. Some examples of unmapped eucalypt stands are provided in Supplementary Materials Table S3.

4.2. Invasion Potential inside Natura 2000

Eucalypt stands inside Natura 2000 sites assigned to some level of recruitment potential allowed areas under an equivalent level of invasion potential to be defined, totalling 878 km^2. This area is likely overestimated because of the usual limitations of the spatial data used, including its resolution. On the other hand, many areas with invasion potential were not identified because data on eucalypt distribution are limited, as explained above.

The concept of invasion was used in a loose fashion. The reality of eucalypt recruitment covers the whole introduction–invasion continuum along space and time [70]. Invasion, i.e., offspring establishment outside the stand limits, can occur through the establishment of a few scattered plants with few impacts in the surrounding habitats, up to a massive occupation, completely transforming those habitats (sensu "transformers" in [70]). Normally, most recruitment occurs in the first 15–20 m [12,14,18], and wildling densities decrease exponentially with distance. However, massive recruitment events are frequently recorded, especially after wildfires, and higher densities can be found at larger distances. For instance, [13] estimated an average wildling density of 5000 $\pm$ 1000 plants ha^{-1} at 55 m from mother-trees, the equivalent to 0.5 plants in each square meter.

Several Natura 2000 sites show considerable areas with invasion potential, especially the ones with extensive cover by eucalypt stands. The abundance of areas with invasion potential inside sites, especially under higher levels of invasion potential, seemed a good indicator of invasion, as shown in the tests on "invaded" and "non-invaded" Natura 2000 sites classified by Forstmaier, Shekhar and Chen [40] (Section 3.3). These tests failed to show significant differences between the two groups of sites for the "very high" class, despite a larger representation of this class in "invaded sites". This is explained by the absence of areas under "very high" invasion potential in many sites, especially "non-invaded" sites, causing several "ties" of zeros in test ranking, therefore preventing the delivery of an exact p-value. The restrictive criteria for this class, combining all factors enhancing invasion, explain its scarcity in many sites. Nevertheless, the cumulative effect of these factors suggests that invasion is very likely in these areas. As a result, the invasion potential classification proposed here may help identify the most hazardous situations, even though sites under lower invasion potential levels should not be neglected.

There are more sites with invasion potential than sites with recruitment potential (157 vs. 176), because in some cases (19 sites), eucalypts only exist along the perimeter of the sites. This may suggest that the nature protection status of these sites was effective in preventing the establishment of eucalypt plantations, even though these sites were either located at the fringes of the ranges for both plantations [4] and recruitment, or they were mostly unsuitable for eucalypt establishment. The total area of invasion potential under these circumstances is residual (12.66 km^2) but it can affect a considerable portion of some sites, especially riverine sites that figure among the most affected under these circumstances.

Many areas with invasion potential will hardly register significant invasion in the absence of fire because seedling establishment requires the combination of two critical factors: abundant seed rain and a seedbed free from competition. Wildfires can thus play a central role in invasion by triggering a massive seed shed [71,72] and clearing competing vegetation, among other factors such as satiating seed predators and increasing light exposure [73,74]. Most regions in Iberia where eucalypt plantations proliferated are prone to wildfires, and the fire regime has been worsening within the last few decades in terms of fire frequency and intensity [75]. Moreover, the fire regime is forecasted to worsen in the decades to come [76]. Wildfire maps show that the Natura 2000 network is also prone to wildfires. Half of the sites with invasion potential (n = 88) were affected by at least one wildfire since 2008, totalling c. 2850 km^2 of burnt area [77], including c. 194 km^2 of eucalypt stands with some recruitment potential, most of which (97%) were in Portugal.

4.3. Future Range Dynamics

Future projections forecast a loss of suitable recruitment range in the south due to an apparent northward "migration" under both climate change scenarios. However, since the recruitment range already covers the northernmost regions and any further northward expansion is obstructed by the maritime barrier, projections show a northward range contraction instead of an actual range "migration". Similar trends of range dynamics were found for native tree species in Iberia, showing a loss of suitable range [41,78] and/or a northward (and sometimes upward) "migration" of the range [79,80], more pronounced under worst scenarios [42,79], even though the dynamics may vary according to the tree species [41,42]. Similarly, one study forecasted that the bioclimatic zones associated with *E. globulus* will lose range in Portugal (−13%) [41]. Despite both climate change scenarios showing a northward contraction in the following decades, the range dynamics diverge in the mid-21st century. In the RCP2.6 scenario, the recruitment range practically stabilises, while under the RCP8.6 scenario, the northward contraction persists.

The climate change scenarios to assess the climatic suitability for recruitment in this study were set to match the scenarios used by [4] and to allow the comparison with the dynamics for *E. globulus* plantations. Future range dynamics found in this study were very similar with those projected for plantations. There was, however, a meaningful difference. The apparent northward "migration" of the plantation range seemed to be delayed relatively to the recruitment range in all scenarios. As a result, the range for plantations was consistently wider. This displacement between ranges can be understood under the light of the concepts of fundamental niche and realised niche [43,81]. The fundamental niche corresponds to the whole amplitude of environmental conditions that a species can tolerate without competition. The proliferation of plantations in different Iberian regions, due to the appeal of a growing pulp and paper industry, allowed their expansion across a wide amplitude of environmental conditions under minimised competition, enabling their spread towards the full potential of the fundamental niche in Iberia. In contrast, offspring originating from these plantations must withstand competition since the moment of seed shed. Surviving offspring define the recruitment range, which can find some parallel with the realised niche in Iberia. For those reasons, the plantation range was always wider than the recruitment range, explaining the effect of "delayed migration" observed within the next few decades.

We must also consider the many uncertainties not addressed by SDMs that may influence future *E. globulus* recruitment and its recruitment range. Such uncertainties include climate-induced changes in key physiological and phenological processes influencing reproduction [43,82], changes in pests and diseases [83] or advances in genetics and breeding [84]. These uncertainties are also valid for other species interacting with eucalypts that may influence eucalypt distribution.

4.4. Potential Impacts and Recommendations

Eucalypt stands keep expanding both inside and around Natura 2000 sites. Since a previous report from 2006 to 2007 [4], eucalypts expanded by 11% (+166 km^2), and 30 new sites now host *E. globulus*. Likewise, around Natura 2000 sites (1 km buffer), eucalypt stands expanded by 45% (+653 km^2), and 39 new sites have eucalypt stands nearby. Illegal plantations [85] and the establishment of wild eucalypt populations by means of invasion [40] are plausible explanations for eucalypt expansion. Examples of apparent invasion events by *E. globulus* inside Natura 2000 sites are provided in Supplementary Materials Table S3.

Further research is needed to understand how and why eucalypts have been expanding inside Natura 2000. Land cover maps do not discriminate invaded areas, and in some cases it is hard to distinguish abandoned plantations from wild populations in the field. New plantations inside Natura 2000 sites should be halted, and the conversion into natural habitats should be encouraged through economic incentives. The Portuguese Sectorial Plan for the Natura 2000 Network identifies eucalypt plantations as a threat to many habitats and species, and management guidelines include halting and reverting eucalypt expansion, but to our knowledge, little progress has been made in this regard. Land plots in Iberia, particularly inside Natura 2000, are mostly privately owned, and profit-oriented private interests frequently collide with conservation values.

It is not clear to what extent invasion plays a role in eucalypt expansion, but it is clear that it plays some role. Despite the acknowledgement of its invasive behaviour by different stakeholders [22] and the allocation of considerable amount of resources for control [27], the invasive capacity of *E. globulus* is frequently undervalued or dismissed by comparing eucalypts with other woody invaders that are generally more aggressive. Either way, for both scenarios of expansion (new plantations and invasion) landowners are necessarily key stakeholders to achieve land use conversion and to prevent or control eucalypt invasion. In this regard, abandoned plantations deserve particular attention in terms of aggravating fire hazard [86,87] and enhancing eucalypt recruitment [44].

This study allowed the most hazardous situations regarding eucalypt invasion to be retained. However, the existence and abundance of areas under higher levels of invasion potential may not correspond to a higher risk of ecological impacts. One of the main obstacles for an accurate risk assessment is the deficient mapping of natural values to be preserved, as pointed out by other researchers [88,89]. In fact, only a small fraction (5.5%) of the records of habitat distribution used in this study was considered accurate, retrieved from surveys or statistically robust estimates. Improved mapping and local assessment are vital to accurately identify the most vulnerable and urgent situations to allow areas to be prioritised and management resources to be rationalised. Likewise, the monitoring of areas with invasion potential is advisable, especially after wildfires, and the control of invasion foci is urgent, preferably in the early stages of invasion when it is more cost-efficient [53].

The most affected habitats identified in this study include a wide range of land covers associated with varying levels of invasibility regarding *E. globulus* invasion, including different types of native forests, grasslands and shrublands. For instance, they include "European dry heaths", shrublands that in Iberia may correspond to the Mediterranean garrigue, comprised by species from the genera *Ulex*, *Erica*, *Cistus* and other Cistaceae, which are not very resistant to invasion [15,18,90]. On the other hand, other affected habitats include native forests and grasslands such as "Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*" or "Hydrophilous tall herb fringe communities", which are traditionally more resistant to invasion due to shadowing and plant competition [15,18,19,90]. These are also some of the most common natural habitats inside Natura 2000 in Iberia. On the other hand, there were some priority habitats that are rare and endangered that exist in areas where eucalypts proliferate and a considerable proportion of their range conflict with eucalypt expansion, such as "Dry Atlantic coastal heaths with *Erica vagans*" or "*Cistus palhinhae* formations on maritime wet heaths", among others. Some of these habitats are vulnerable to invasion (see a full list in Supplementary Materials Table S2).

Riverine sites were among the most affected sites regarding the total area assigned to recruitment and invasion potential, even though in some cases these areas were inflated due to mapping resolution. In fact, many rivers and even riparian communities were not mapped because of their short size and width (as reported by [26]). As a result, some areas were wrongly classified as eucalypts or as areas with invasion potential. Such cases included sites Río Lérez (ES1140002), Río Tea (ES1140006) and Río Porcía (ES1200024). Nevertheless, these cases reflect the pressure and the threats of eucalypt expansion over watercourses and riparian habitats, which may lead to the replacement of riparian communities [26].

Climate-driven range dynamics for native species may foster an aggravation of conflicts between eucalypts and conservation goals, especially in western and northern coastal regions. The "migration" of many species along the 21st century may be heading towards regions heavily occupied by *E. globulus* stands, while pressure to establish new plantations may increase [4]. Additionally, both climate pathways forecast a new, suitable range for both *E. globulus* plantations [4,39] and *E. globulus* recruitment being gained in inner regions of northwest Spain. Therefore, *E. globulus* may retain a relatively wide recruitment range, except in the worst climate scenario, where the recruitment range, and especially the best conditions for recruitment, may be confined to a small region in northwest Iberia. The recruitment capacity of *E. globulus* associated with greater residence time and an aggravation of climate-driven fire danger [91] may enhance its invasive potential. Despite the loss of recruitment range in the south, suitable conditions for plantations may persist due to "delayed migration", suggesting that both plantations and wild eucalypt populations may prosper in the lost recruitment range. Therefore, *E. globulus* expansion must be reverted and further invasion prevented for protected areas to act as a safe haven where native species can find refuge, because conservation goals can be seriously threatened by a growing, unregulated occupation by eucalypt stands.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f13081199/s1. Figure S1—Surveyed locations to test the recruitment potential classification; Figure S2—Range dynamics of *E. globulus* recruitment in Iberia for the years 2050 and 2070 under climate change scenarios RCP2.6 and RCP8.5; Table S1—Data on the recruitment and invasion potential of 176 Natura 2000 sites from Portugal (PT) and Spain (ES); Table S2—Data on the recruitment and invasion potential of 87 Natura 2000 habitats from Portugal and Spain; Table S3—Examples of probable cases of invasion and unmapped eucalypt stands inside Natura 2000.

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References

1. Kirkpatrick, J.B. Natural distribution of *Eucalyptus globulus* Labill. *Aust. Geogr.* **1975**, *13*, 22–35. [CrossRef]
2. Hui, C.; Richardson, D.M.; Visser, V.; Wilson, J.R.U. Macroecology meets invasion ecology: Performance of Australian acacias and eucalypts around the world revealed by features of their native ranges. *Biol. Invasions* **2014**, *16*, 565–576. [CrossRef]
3. Jacobs, M.R. *Eucalypts for Planting*; Food and Agriculture Organization of the United Nations: Rome, Italy, 1979.
4. Deus, E.; Silva, J.S.; Castro-Díez, P.; Lomba, A.; Ortiz, M.L.; Vicente, J. Current and future conflicts between eucalypt plantations and high biodiversity areas in the Iberian Peninsula. *J. Nat. Conserv.* **2018**, *45*, 107–117. [CrossRef]

5. Silva-Pando, F.J. *Eucalyptus* in South Europe: Searching for the promised land-introduction and dissemination of *Eucalyptus* in Southwestern Europe. In *Invasive Alien Species: Observations and Issues from Around the World*; Pullaiah, T., Ielmini, M.R., Eds.; Volume 3-Issues and Invasions in Europe; John Wiley & Sons Ltd.: Hoboken, NJ, USA, 2021; pp. 278–316.
6. EEA. Biogeographical Regions. Available online: https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3 (accessed on 2 May 2022).
7. Rejmánek, M.; Richardson, D.M. Trees and shrubs as invasive alien species–2013 update of the global database. *Divers. Distrib.* **2013**, *19*, 1093–1094. [CrossRef]
8. Becerra, P.I. Invasión de árboles alóctonos en una cuenca pre-andina de Chile central. *Gayana Botánica* **2006**, *63*, 161–174. [CrossRef]
9. Fork, S.; Woolfolk, A.; Akhavan, A.; Van Dyke, E.; Murphy, S.; Candiloro, B.; Newberry, T.; Schreibman, S.; Salisbury, J.; Wasson, K. Biodiversity effects and rates of spread of nonnative eucalypt woodlands in central California. *Ecol. Appl.* **2015**, *25*, 2306–2319. [CrossRef]
10. Henderson, L. Invasive alien woody plants of the southern and southwestern Cape region, South Africa. *Bothalia* **1998**, *28*, 91–112. [CrossRef]
11. Kirkpatrick, J.B. Eucalypt invasion in Southern California. *Aust. Geogr.* **1977**, *13*, 387–393. [CrossRef]
12. Anjos, A.; Fernandes, P.; Marques, C.; Borralho, N.; Valente, C.; Correia, O.; Máguas, C.; Chozas, S. Management and fire, a critical combination for *Eucalyptus globulus* dispersal. *For. Ecol. Manag.* **2021**, *490*, 119086. [CrossRef]
13. Costa, J.; Silva, J.S.; Deus, E.; Pinho, S.; Pinto, J.F.; Borralho, N. The genetics and ecology of post-fire *Eucalyptus globulus* Recruitment in an isolated stand in Central Portugal. *Forests* **2022**, *13*, 680. [CrossRef]
14. Deus, E.; Silva, J.S.; Larcombe, M.J.; Catry Filipe, X.; Queirós, L.; dos Santos, P.; Matias, H.; Águas, A.; Rego, F. Investigating the invasiveness of *Eucalyptus globulus* in Portugal: Site-scale drivers, reproductive capacity and dispersal potential. *Biol. Invasions* **2019**, *21*, 2027–2044. [CrossRef]
15. Fernandes, P.; Antunes, C.; Pinho, P.; Máguas, C.; Correia, O. Natural regeneration of *Pinus pinaster* and *Eucalyptus globulus* from plantation into adjacent natural habitats. *For. Ecol. Manag.* **2016**, *378*, 91–102. [CrossRef]
16. Fernandes, P.; Máguas, C.; Correia, O.; González-Moreno, P. What drives *Eucalyptus globulus* natural establishment outside plantations? The relative importance of climate, plantation and site characteristics. *Biol. Invasions* **2018**, *20*, 1129–1146. [CrossRef]
17. Calviño-Cancela, M.; Lorenzo, P.; González, L. Fire increases *Eucalyptus globulus* seedling recruitment in forested habitats: Effects of litter, shade and burnt soil on seedling emergence and survival. *For. Ecol. Manag.* **2018**, *409*, 826–834. [CrossRef]
18. Calviño-Cancela, M.; Rubido-Bará, M. Invasive potential of *Eucalyptus globulus*: Seed dispersal, seedling recruitment and survival in habitats surrounding plantations. *For. Ecol. Manag.* **2013**, *305*, 129–137. [CrossRef]
19. Nereu, M.; Silva, J.S.; Deus, E.; Nunes, M.; Potts, B. The effect of management operations on the demography of *Eucalyptus globulus* seedlings. *For. Ecol. Manag.* **2019**, *453*, 117630. [CrossRef]
20. Cremer, K.W. Distance of seed dispersal in eucalypts estimated from seed weights. *Aust. For. Res.* **1977**, *7*, 225–228.
21. Larcombe, M.J.; Silva, J.S.; Vaillancourt, R.E.; Potts, B.M. Assessing the invasive potential of *Eucalyptus globulus* in Australia: Quantification of wildling establishment from plantations. *Biol. Invasions* **2013**, *15*, 2763–2781. [CrossRef]
22. Touza, J.; Pérez-Alonso, A.; Chas-Amil, M.L.; Dehnen-Schmutz, K. Explaining the rank order of invasive plants by stakeholder groups. *Ecol. Econ.* **2014**, *105*, 330–341. [CrossRef]
23. Mallen-Cooper, M.; Atkinson, J.; Xirocostas, Z.A.; Wijas, B.; Chiarenza, G.M.; Dadzie, F.A.; Eldridge, D.J. Global synthesis reveals strong multifaceted effects of eucalypts on soils. *Glob. Ecol. Biogeogr.* **2022**, *31*, 1667–1678. [CrossRef]
24. Shi, Z.; Xu, D.; Yang, X.; Jia, Z.; Guo, H.; Zhang, N. Ecohydrological impacts of eucalypt plantations: A review. *J. Food Agric. Environ.* **2012**, *10*, 1419–1426.
25. Tomé, M.; Almeida, M.H.; Barreiro, S.; Branco, M.R.; Deus, E.; Pinto, G.; Silva, J.S.; Soares, P.; Rodríguez-Soalleiro, R. Opportunities and challenges of *Eucalyptus* plantations in Europe: The Iberian Peninsula experience. *Eur. J. For. Res.* **2021**, *140*, 489–510. [CrossRef]
26. Teixido, A.L.; Quintanilla, L.G.; Carreño, F.; Gutiérrez, D. Impacts of changes in land use and fragmentation patterns on Atlantic coastal forests in northern Spain. *J. Environ. Manag.* **2010**, *91*, 879–886. [CrossRef] [PubMed]
27. Andreu, J.; Vilà, M.; Hulme, P.E. An assessment of stakeholder perceptions and management of noxious alien plants in Spain. *Environ. Manag.* **2009**, *43*, 1244–1255. [CrossRef] [PubMed]
28. Goded, S.; Ekroos, J.; Domínguez, J.; Azcárate, J.G.; Guitián, J.A.; Smith, H.G. Effects of eucalyptus plantations on avian and herb species richness and composition in North-West Spain. *Glob. Ecol. Conserv.* **2019**, *19*, e00690. [CrossRef]
29. Larrañaga, A.; Basaguren, A.; Elosegi, A.; Pozo, J. Impacts of *Eucalyptus globulus* plantations on Atlantic streams: Changes in invertebrate density and shredder traits. *Fundam. Appl. Limnol. Arch. Für Hydrobiol.* **2009**, *175*, 151–160. [CrossRef]
30. Lara, A.; Jones, J.; Little, C.; Vergara, N. Streamflow response to native forest restoration in former *Eucalyptus* plantations in south central Chile. *Authorea* **2021**, *35*, e14270. [CrossRef]
31. Calviño-Cancela, M.; Rubido-Bará, M.; van Etten, E.J.B. Do eucalypt plantations provide habitat for native forest biodiversity? *For. Ecol. Manag.* **2012**, *270*, 153–162. [CrossRef]
32. Fernandes, P.M.; Loureiro, C.; Palheiro, P.; Vale-Gonçalves, H.; Fernandes, M.M.; Cruz, M.G. Fuels and fire hazard in blue gum (*Eucalyptus globulus*) stands in Portugal. *Boletín Del CIDEU* **2011**, *10*, 53–61.
33. Vihervaara, P.; Marjokorpi, A.; Kumpula, T.; Walls, M.; Kamppinen, M. Ecosystem services of fast-growing tree plantations: A case study on integrating social valuations with land-use changes in Uruguay. *For. Policy Econ.* **2012**, *14*, 58–68. [CrossRef]

34. Cunha, J.; Campos, F.S.; David, J.; Padmanaban, R.; Cabral, P. Carbon sequestration scenarios in Portugal: Which way to go forward? *Environ. Monit. Assess.* **2021**, *193*, 547. [CrossRef] [PubMed]
35. Castro-Díez, P.; Alonso, Á.; Saldaña-López, A.; Granda, E. Effects of widespread non-native trees on regulating ecosystem services. *Sci. Total Environ.* **2021**, *778*, 146141. [CrossRef] [PubMed]
36. Acácio, V.; Dias Filipe, S.; Catry Filipe, X.; Rocha, M.; Moreira, F. Landscape dynamics in Mediterranean oak forests under global change: Understanding the role of anthropogenic and environmental drivers across forest types. *Glob. Change Biol.* **2016**, *23*, 1199–1217. [CrossRef]
37. EEA. Natura 2000 Data-the European Network of Protected Sites. Available online: https://www.eea.europa.eu/data-and-maps/data/natura-13 (accessed on 2 May 2022).
38. EEA. *State of Nature in the EU: Results from Reporting under the Nature Directives 2013–2018*; European Environment Agency: Luxembourg, 2020.
39. López-Sánchez, C.A.; Castedo-Dorado, F.; Cámara-Obregón, A.; Barrio-Anta, M. Distribution of *Eucalyptus globulus* Labill. in northern Spain: Contemporary cover, suitable habitat and potential expansion under climate change. *For. Ecol. Manag.* **2021**, *481*, 118723. [CrossRef]
40. Forstmaier, A.; Shekhar, A.; Chen, J. Mapping of *Eucalyptus* in Natura 2000 areas using Sentinel 2 imagery and artificial neural networks. *Remote Sens.* **2020**, *12*, 2176. [CrossRef]
41. Costa, R.; Fraga, H.; Fernandes, P.M.; Santos, J.A. Implications of future bioclimatic shifts on Portuguese forests. *Reg. Environ. Change* **2017**, *17*, 117–127. [CrossRef]
42. Garzón, M.B.; de Dios, R.S.; Ollero, H.S. Effects of climate change on the distribution of Iberian tree species. *Appl. Veg. Sci.* **2008**, *11*, 169–178. [CrossRef]
43. Booth, T.H.; Broadhurst, L.M.; Pinkard, E.; Prober, S.M.; Dillon, S.K.; Bush, D.; Pinyopusarerk, K.; Doran, J.C.; Ivkovich, M.; Young, A.G. Native forests and climate change: Lessons from eucalypts. *For. Ecol. Manag.* **2015**, *347*, 18–29. [CrossRef]
44. Queirós, L.; Deus, E.; Silva, J.S.; Vicente, J.; Ortiz, L.; Fernandes, P.M.; Castro-Díez, P. Assessing the drivers and the recruitment potential of *Eucalyptus globulus* in the Iberian Peninsula. *For. Ecol. Manag.* **2020**, *466*, 118147. [CrossRef]
45. Vicente, J.; Alves, P.; Randin, C.; Guisan, A.; Honrado, J. What drives invasibility? A multi-model inference test and spatial modelling of alien plant species richness patterns in northern Portugal. *Ecography* **2010**, *33*, 1081–1092. [CrossRef]
46. Vicente, J.; Randin, C.F.; Gonçalves, J.; Metzger, M.J.; Lomba, Â.; Honrado, J.; Guisan, A. Where will conflicts between alien and rare species occur after climate and land-use change? A test with a novel combined modelling approach. *Biol. Invasions* **2011**, *13*, 1209–1227. [CrossRef]
47. Guisan, A.; Thuiller, W. Predicting species distribution: Offering more than simple habitat models. *Ecol. Lett.* **2005**, *8*, 993–1009. [CrossRef] [PubMed]
48. Bradley, B.A.; Mustard, J.F. Characterizing the landscape dynamics of an invasive plant and risk of invasion using remote sensing. *Ecol. Appl.* **2006**, *16*, 1132–1147. [CrossRef]
49. R Core Team. R: A language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available online: http://www.R-project.org (accessed on 30 June 2022).
50. Thuiller, W.; Georges, D.; Engler, R.; Breiner, F. R Package Biomod2: Ensemble Platform for Species Distribution Modeling, v. 3.3-7. Available online: http://cran.r-project.org/web/packages/biomod2/biomod2.pdf (accessed on 2 January 2017).
51. Hijmans, R.J.; Cameron, S.E.; Parra, J.L.; Jones, P.G.; Jarvis, A. Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.* **2005**, *25*, 1965–1978. [CrossRef]
52. Marmion, M.; Parviainen, M.; Luoto, M.; Heikkinen, R.K.; Thuiller, W. Evaluation of consensus methods in predictive species distribution modelling. *Divers. Distrib.* **2009**, *15*, 59–69. [CrossRef]
53. Silva, J.S.; Nereu, M.; Pinho, S.; Queirós, L.; Jesús, C.; Deus, E. Post-fire demography, growth, and control of *Eucalyptus globulus* wildlings. *Forests* **2021**, *12*, 156. [CrossRef]
54. Águas, A.; Ferreira, A.; Maia, P.; Fernandes, P.M.; Roxo, L.; Keizer, J.; Silva, J.S.; Rego, F.C.; Moreira, F. Natural establishment of *Eucalyptus globulus* Labill. in burnt stands in Portugal. *For. Ecol. Manag.* **2014**, *323*, 47–56. [CrossRef]
55. Silva, J.S.; dos Santos, P.; Sério, A.; Gomes, F. Effects of heat on dehiscence and germination in *Eucalyptus globulus* Labill. *Int. J. Wildland Fire* **2016**, *25*, 478–483. [CrossRef]
56. Águas, A.; Larcombe, M.J.; Matias, H.; Deus, E.; Potts, B.M.; Rego, F.C.; Silva, J.S. Understanding the naturalization of *Eucalyptus globulus* in Portugal: A comparison with Australian plantations. *Eur. J. For. Res.* **2017**, *136*, 433–446. [CrossRef]
57. Silva, J.S.; Tomé, M. Tasmanian blue gum in Portugal-opportunities and risks of a widely cultivated species. In *Introduced Tree Species in European Forests: Opportunities and Challenges*; Krumm, F., Vítková, L., Eds.; European Forest Institute: Freiburg, Germany, 2016; pp. 352–361.
58. Catry, F.X.; Moreira, F.; Deus, E.; Silva, J.S.; Águas, A. Assessing the extent and the environmental drivers of *Eucalyptus globulus* wildling establishment in Portugal: Results from a countrywide survey. *Biol. Invasions* **2015**, *17*, 3163–3181. [CrossRef]
59. MITERD. Mapa Forestal de España (MFE25) [Spanish Forest Map]. Available online: https://www.miteco.gob.es/es/cartografia-y-sig/ide/descargas/biodiversidad/mfe.aspx (accessed on 2 May 2022).
60. DGT. Carta de Uso e Ocupação do Solo-2018 [Portuguese Land-Cover and Land-Use Cartography from 2018]. Available online: https://snig.dgterritorio.gov.pt/ (accessed on 2 May 2022).

61. San-Miguel-Ayanz, J.; Schulte, E.; Schmuck, G.; Camia, A.; Strobl, P.; Libertà, G.; Giovando, C.; Boca, R.; Sedano, F.; Kempeneers, P.; et al. Comprehensive monitoring of wildfires in europe: The European Forest Fire Information System (EFFIS). In *Approaches to Managing Disaster-Assessing Hazards, Emergencies and Disaster Impacts*; Tiefenbacher, J., Ed.; InTech: London, UK, 2012; pp. 87–105.
62. MITERD. Segundo Inventario Forestal Nacional (IFN2) [Second National Forest Inventory]. Available online: https://www.miteco.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/informacion-disponible/ifn2_descargas.aspx (accessed on 2 May 2022).
63. IGP. Carta de Ocupação do Solo de 1990 [Portuguese Land-Cover Cartography from 1990]. Available online: http://ftp.igeo.pt/produtos/Inf_cartografica.htm (no longer available) (accessed on 1 June 2017).
64. EEA. Copernicus Land Monitoring Service-EU-DEM. Available online: https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem (accessed on 1 June 2022).
65. EEA. Copernicus Land Monitoring Service 2018 (CORINE Land Cover 2018). Available online: https://land.copernicus.eu/pan-european/corine-land-cover (accessed on 2 May 2022).
66. Deus, E.; Silva, J.S.; Catry, F.X.; Rocha, M.; Moreira, F. Google Street View as an alternative method to car surveys in large-scale vegetation assessments. *Environ. Monit. Assess.* **2016**, *188*, 1–14. [CrossRef] [PubMed]
67. DG Environment. *Reporting under Article 17 of the Habitats Directive: Explanatory Notes and Guidelines for the Period 2013–2018*; Directorate-General for Environment-European Commission: Brussels, Belgium, 2017.
68. Catry, F.X.; Moreira, F.; Tujeira, R.; Silva, J.S. Post-fire survival and regeneration of *Eucalyptus globulus* in forest plantations in Portugal. *For. Ecol. Manag.* **2013**, *310*, 194–203. [CrossRef]
69. ICNF. Maps of Burnt Areas between 1990–2020. Available online: https://www.icnf.pt/florestas/gfr/gfrgestaoinformacao/dfciinformacaocartografica (accessed on 1 June 2022).
70. Richardson, D.M.; Pyšek, P.; Rejmánek, M.; Barbour, M.G.; Panetta, F.D.; West, C.J. Naturalization and invasion of alien plants: Concepts and definitions. *Divers. Distrib.* **2000**, *6*, 93–107. [CrossRef]
71. Santos, P.; Matias, H.; Deus, E.; Águas, A.; Silva, J.S. Fire effects on capsules and encapsulated seeds from *Eucalyptus globulus* in Portugal. *Plant Ecol.* **2015**, *216*, 1611–1621. [CrossRef]
72. Cremer, K.W. How Eucalypt fruits release their seed. *Aust. J. Bot.* **1965**, *13*, 11–16. [CrossRef]
73. Mount, A.B. Eucalypt ecology as related to fire. In Proceedings of the 9th Tall Timbers Fire Ecology Conference, Tallahassee, FL, USA, 10–11 April 1969; pp. 75–108.
74. Gill, A.M. Eucalypts and fires: Interdependent or independent? In *Eucalypt Ecology: Individuals to Ecosystems*; Williams, J.E., Woinarski, J.C.Z., Eds.; Cambridge University Press: Cambridge, UK, 1997.
75. San-Miguel-Ayanz, J.; Durrant, T.; Boca, R.; Maianti, P.; Libertá, G.; Artes Vivancos, T.; Jacome Felix Oom, D.; Branco, A.; De Rigo, D.; Ferrari, D.; et al. *Forest Fires in Europe Middle East and North Africa 2019*; Joint Research Centre: Luxembourg, 2020.
76. Amatulli, G.; Camia, A.; San-Miguel-Ayanz, J. Estimating future burned areas under changing climate in the EU-Mediterranean countries. *Sci. Total Environ.* **2013**, *450–451*, 209–222. [CrossRef] [PubMed]
77. EFFIS. Burnt Areas. Available online: https://effis.jrc.ec.europa.eu/applications/data-and-services (accessed on 18 March 2022).
78. Keenan, T.; Maria Serra, J.; Lloret, F.; Ninyerola, M.; Sabate, S. Predicting the future of forests in the Mediterranean under climate change, with niche- and process-based models: CO2 matters! *Glob. Change Biol.* **2011**, *17*, 565–579. [CrossRef]
79. Vessella, F.; López-Tirado, J.; Simeone, M.C.; Schirone, B.; Hidalgo, P.J. A tree species range in the face of climate change: Cork oak as a study case for the Mediterranean biome. *Eur. J. For. Res.* **2017**, *136*, 555–569. [CrossRef]
80. Almeida, A.M.; Martins, M.J.; Campagnolo, M.L.; Fernandez, P.; Albuquerque, T.; Gerassis, S.; Gonçalves, J.C.; Ribeiro, M.M. Prediction scenarios of past, present, and future environmental suitability for the Mediterranean species *Arbutus unedo* L. *Sci. Rep.* **2022**, *12*, 84. [CrossRef]
81. Booth, T.H.; Nix, H.A.; Hutchinson, M.F.; Jovanic, T. Niche analysis and tree species introduction. *For. Ecol. Manag.* **1988**, *23*, 47–59. [CrossRef]
82. Hughes, L. Biological consequences of global warming: Is the signal already apparent? *Trends Ecol. Evol.* **2000**, *15*, 56–61. [CrossRef]
83. Pinkard, E.; Wardlaw, T.; Kriticos, D.; Ireland, K.; Bruce, J. Climate change and pest risk in temperate eucalypt and radiata pine plantations: A review. *Aust. For.* **2017**, *80*, 228–241. [CrossRef]
84. Gonçalves, J.L.M.; Alvares, C.A.; Rocha, J.H.T.; Brandani, C.B.; Hakamada, R. Eucalypt plantation management in regions with water stress. *South. For. A J. For. Sci.* **2017**, *79*, 169–183. [CrossRef]
85. Sánchez, F.G. Las plantaciones de eucalipto en espacios de valor ambiental en Cantabria. In *La Conflictividad de las Plantaciones de Eucalipto en España (y Portugal)*; Veiras, X., Soto, M.Á., Eds.; Greenpeace: Madrid, Spain, 2011. (In Spanish)
86. Moreira, F.; Vaz, P.; Catry, F.X.; Silva, J.S. Regional variations in wildfire susceptibility of land-cover types in Portugal: Implications for landscape management to minimize fire hazard. *Int. J. Wildland Fire* **2009**, *18*, 563–574. [CrossRef]
87. 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]
88. Alberdi, I.; Nunes, L.; Kovac, M.; Bonheme, I.; Cañellas, I.; Rego, F.C.; Dias, S.; Duarte, I.; Notarangelo, M.; Rizzo, M.; et al. The conservation status assessment of Natura 2000 forest habitats in Europe: Capabilities, potentials and challenges of national forest inventories data. *Ann. For. Sci.* **2019**, *76*, 34. [CrossRef]

89. Lomba, A.; Guerra, C.; Alonso, J.; Honrado, J.P.; Jongman, R.; McCracken, D. Mapping and monitoring High Nature Value farmlands: Challenges in European landscapes. *J. Environ. Manag.* **2014**, *143*, 140–150. [CrossRef] [PubMed]
90. Fernandes, P.; Máguas, C.; Correia, O. Combined effects of climate, habitat, and disturbance on seedling establishment of *Pinus pinaster* and *Eucalyptus globulus*. *Plant Ecol.* **2017**, *218*, 201–515. [CrossRef]
91. De Rigo, D.; Libertà, G.; Houston Durrant, T.; Vivancos, T.A.; San-Miguel-Ayanz, J. *Forest Fire Danger Extremes in Europe under Climate Change: Variability and Uncertainty*; Publications Office of the European Union: Luxembourg, 2017; ISBN 978-92-79-77046-3.