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Review

Historical Development of the Portuguese Forest: The Introduction of Invasive Species

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Abstract: Portugal is a country with a territorial dimension of approximately 90,000 km^2. However, the forest occupies a prominent position, since it represents about 35% of the total area of the country. Portuguese people always had a very close connection with the forest, which has provided the necessary resources for the development of its communities. The geological substratum of continental Portugal is very old and may therefore have witnessed the evolution of its plants, from the early beginning to the present time, as well as all sort of historical and environmental landmarks such as glacial periods or mass extinctions. Also, from the perspective of human occupation, Portuguese territory was crossed by hunter-gatherer populations who, initially, were constantly moving and looking for sustenance, but at a later stage, chose to settle. This relationship between human populations and the forest is, thus, very old and demonstrates the interdependence between the subsistence of the populations and the resources exploitation. Currently, the main national economic groups are based on forest industries, which depend directly on the exploitation of the three dominant species, *Eucalyptus globulus* Labill., *Pinus pinaster* Aiton and *Quercus suber* L., demonstrating the human role in the development of the forest, motivated by the satisfaction of its needs. This work reviews the historical development of the forest in mainland Portugal, from geological times to the present, including the arrival of exotic species that later acquired invasive behaviors and now occupy significant areas of the national territory.

Keywords: Forest management; forest development; invasive species; forest economy4

1. Introduction

The widespread opinion of the Portuguese people is that the national forest is composed of a monoculture of eucalyptus that dominates more land than any other species. Important economic interests support eucalyptus plantations, ensuring the supply of raw materials for one of the most important industrial activities in the Portuguese industrial landscape: pulp and paper production. Thus, despite high-water consumption, soil erosion and depletion, reduced biodiversity, and increased difficulty in controlling rural fires, eucalyptus plantations continue to have defenders. According to the results of the National Forest Inventory [1], eucalyptus plantation area grew continuously in the last two decades, and is today the dominant species in Portuguese forests, covering more than 800,000 hectares [2]. As such, it is important to understand how forests evolved in Portugal to the current situation, with approximately 75% of its area occupied by a limited number of species, dominated by eucalyptus, maritime pine, and cork oak.

Forest is a fulcrum for the national economy, in addition to its immense weight from the environmental perspective, as a guarantor of biodiversity and as a social framework for hundreds of thousands of Portuguese people living in its vicinity. This perspective, probably outside the everyday thinking of the majority of the Portuguese people, can easily change, simply by introducing a simple fact into the discussion, namely: "the forest is fundamental for three of the largest national companies." In fact, it does not take much effort to understand that in reality the cork–paper–wood triad has a very significant weight in the national economy, as will be shown in another section.

Beyond these three giants of national industry, there are many other economic activities dependent on raw materials from forestry sector, some even older than those highlighted in the previous paragraphs. These include the furniture industry, which had a great expansion in the northern part of the country; the artisanal shipbuilding industry, especially in some coastal ports, where traditional fishing activities had a great role in local economy; and the cooperage industry, spread throughout the country, since wine production extends from north to south. Some of the other traditional forest-dependent activities, have unfortunately been lost due to the advance of time and the option of using different modern raw materials.

Forests are not solely a provider of wood. The exploitation of other by-products, and even the space itself, allows the development of a significant set of other economic activities that lead to entire populations taking their livelihood directly from the forest through the practice of various economic activities, while others can enjoy the space in the activity of leisure and in conviviality with nature. Examples include the production of nuts, such as walnuts, chestnuts, hazelnuts, and almonds; apiculture, which in addition to producing honey contributes to the pollination of different crops; the picking of mushrooms and wild fruits; or the husking of oaks for the extraction of tannins for the leather industry.

However, perhaps the forestry sub-sector with the greatest industrial tradition is the extraction of resin and the production of rosin derivatives. There remain some large industrial units still in operation, although resin extraction has practically been abandoned, since there are only a few points in the country at which it occurs. Currently, this industry resists the importation of gum, from which pine rosin derivatives are extracted.

In spite of the importance of the forest in its various aspects, in particular the economic and environmental components, it seems that it is still not given due attention. Its exploitation and management, with honorable exceptions, continues to be undertaken in an uncoordinated manner and, as previously mentioned, with one-off measures not based on long-term policies or a perspective of future sustainability.

The main objective of this review article is to analyze the evolution and development of the forests in Portugal, while providing a historical perspective. The present work provides a historical review of the development of the forest in the territory of mainland Portugal, encompassing the geological and the historical period, from the arrival of the humans, until present time. Then, a historical analysis of the arrival of some exotic species and its invasive behavior, namely, acacias and eucalyptus, is also made.

2. Characterization and Evolution of the Forest in Portugal

2.1. From the Early Beginning to the Arrival of Humans

Mainland Portugal is based on a geological substratum so old that all the steps of the evolution of terrestrial plants can be verified here, since there is terrain in Portugal that dates back to the Paleozoic Era (541.0–251.90 Ma). During the Ordovician period (485.4–443.8 Ma), plants occupied the continents, but the first fossil records of the oldest terrestrial plants were dated to the Silurian period (443.8–419.2 Ma). During the Devonian period (419.2–358.9 Ma), trees arose and, consequently, forests. In the Carboniferous (358.9–298.9 Ma) and Permian (298.9–251.9 Ma) periods, forests developed considerably, producing large volumes of biomass that became the source of extensive deposits of coal [3].

During the Mesozoic Era (251.90–66.0 Ma), forests were mostly composed of ferns and conifers. In the Jurassic period (201.3–145 Ma), plants with flowers appeared. In the angiosperms, the seeds stopped being protected by a fruit [3,4].

In the Tertiary Period (66.0–2.58 Cenozoic Era), the climate on the Iberian Peninsula was diverse enough to allow for the proliferation of different types of flora adapted to different environments. For example, coastal areas were covered by mangroves, but species of *Arbutus*, *Cistus*, *Chamaerops*, *Nerium*, *Olea*, *Pistacia*, *Phillyrea*, *Rhamnus*, and *Milax*, and other species of *Quercus*, *Juniperus*, *Dracaena*, and *Olea* were also present. *Pinus* arose primarily to occupy the space left available after occurrences such as fires, tree death, or landslides. This substitution of species was facilitated by the climatic changes that occurred in the Middle Miocene, corresponding to the Languian (15.97–13.82 Ma) and Serravallian (13.82–11.63 Ma) that caused the extinction of the species characteristic of the tropical and subtropical forest regions [3,5].

During the Miocene epoch (23.02–5.333 Ma), most of the territory of the Iberian Peninsula was subjected to a tropical climate, which promoted the proliferation of extensive forests mainly consisting of laurel species (or laurissilva species), but also of species belonging to families that are currently only found naturally in the tropical, temperate or subtropical regions of the Northern Hemisphere, but are now extinct in the Iberian Peninsula [3,5].

In the Pliocene Age (5.333–2.58 Ma), the Mediterranean climate was the dominant form, where, through adaptive radiation processes, new species emerged, many of which were adapted to fire. The common genera of the current flora diversified and organized the most common plant communities in the Iberian Peninsula, such as forests with evergreen species, thick forests with broad and lustrous hard leaves, and communities of aromatic limestone plants. At this stage, grasses expanded through spaces previously occupied by tropical and subtropical species, creating savanna areas [3,5].

In the Quaternary Period, which began 2.58 million years ago, more precisely in the Pleistocene Epoch (2.58–0.012 Ma), a series of glacial cycles occurred, with periods of approximately 100,000 years interspersed with warmer and wetter interglacial periods of about 10,000 years. In the colder periods, most tree species occupied more coastal regions, forming complex associations of arboreal, shrub, and herbaceous vegetation, whereas in the innermost regions, small wooded steppes occupied most of the territory [3,5].

The elements of tertiary tropical and subtropical origin that were more susceptible to temperature variations survived these profound climate changes in some hot, low-lying places near the coast, in deep valleys, in escarpments exposed to the sun, or in very specific lithologies. Some relics of these species are still present in continental Portugal, such as *Ilex aquifolium* L. (Figure 1), *Buxus sempervirens* L., *Prunus lusitanica* L. (Figure 2), *Laurus nobilis* L., *Myrica faya* Aiton or *Taxus baccata* L., but also shrub species such as *Arbutus unedo* (Figure 3), *Olea europaea* var. *sylvestris* L., *Phyllirea media* L., *Viburnum tinus* L., *Myrtus communis* L., and *Rhododendron ponticum* subsp. *Baeticum* L. [3,5,6].

During the Holocene (0.012 Ma), the increase in temperature and precipitation caused a widening of the area occupied by forests to mountains and interior regions. In this period, the steppes of junipers and pines, so common at the end of the Pleistocene, were replaced by forests of oaks, holm oaks, birch trees, pines, and junipers, creating a predominantly forested landscape interspersed with clearings composed of shrub and herbaceous species. These landscapes were formed by the occurrence of forest fires, trampling of plants by large wild herbivores, landslides, floods, strong winds, and falling trees.

Figure 1. *Ilex aquifolium* from Margaraça (Arganil, central Portugal).

Figure 2. *Prunus lusitanica* from Margaraça (Arganil, central Portugal).

Figure 3. *Arbutus unedo* from Margaraça (Arganil, central Portugal).

2.2. Influence of Humans on Forest Development

Human populations also impacted the spread of shrub and herbaceous vegetation areas, increasing the pasture areas available for large wild herbivores, concentrating them in certain places of easier access, creating protection zones around the camps, facilitating the visibility of those who were on watch, and facilitating the growth of shrub and herbaceous species of interest to collectors. This led to the replacement of natural ecosystems with semi-natural ecosystems, such as meadows, and other agro-ecosystems, such as fields with agricultural crops [3,5,7,8].

In the sixth millennium BCE(Before the Common Era), the Neolithic period began with the arrival of small itinerant agro-pastoral groups from the eastern Mediterranean in the Portuguese territory, contemporized with the last groups of hunter-gatherers who inhabited the territory. When the soils were depleted, these populations sought another place and repeated the process, abandoning the terrain, allowing its natural recovery [3,5]. However, this practice of opening fire clearings initially had good results and led to the flowering of meadows since the ashes served as fertilizer, but quickly led to the appearance of pyrophyte species with little value for animal feeding, simultaneously causing soil erosion and soil nutrient impoverishment [3,5,6].

During the fourth and third millennia BCE, in the Chalcolithic Age or the Copper Age, the effects of the actions of humans on the landscape significantly increased with the construction of megalithic structures and the settlement of populations, most probably directly associated with the strong connection of communities with agricultural practice and livestock. During this period, the substitution of forest species for other types of vegetation increased and important technological innovations appeared that allowed greater interventions within the environment. Examples of this include the appearance of the plow and the use of animal traction in agricultural work [3,5].

In the Bronze Age, which covered much of the second millennium BCE and the beginning of the first millennium BCE, new technological knowledge emerged, such as soil drainage and irrigation of crops, enabling in northern and central Portugal, at least, human settlement in areas of lower altitude

with soils with qualities better suited to agriculture. This situation, which was intensified by the needs of ever-increasing communities and increased the ability to increase agricultural production, led to forests being far from communities to the detriment of the agricultural land surrounding the settlements. This increasingly extensive perimeter was essentially destined to serve as pasture for domestic animals [3,9,10].

In the Iron Age, the Portuguese territory was influenced by many different ethnic and cultural factors with the development of organized and structured societies (Figure 4). However, all these societies shared one aspect in common: mining and manufacturing of iron tools. This played a major role in forest development, since large-scale deforestation was initiated during this period, as large quantities of timber were needed for the production of charcoal, which later fueled iron smelting furnaces [5,11].

Figure 4. Reconstruction of a house of "Citânia de Briteiros" in Guimarães (Northern Portugal). It is one of the most important settlements of the so-called "Castro culture", with occupation from the Bronze Age to the Roman period. Upon the arrival of the Romans, the inhabitants of this "castro" and all others in the region were forced to leave the top of the hills and move to the much easier to control valleys. They were likely to have been reoccupied during the short period of the Arab invasion of northern Portugal, and then permanently abandoned.

The arrival of the Roman period brought enormous technological developments, the integration of local economies in a large global economic space, and the intensification of territory exploration. The Romans produced many agricultural innovations and introduced new species of plants. This period of economic development led to a period of forest regression [3,10,12,13].

At the beginning of the fifth century CE(Common Era), the presence of the barbarian tribes ended in this area with the Roman occupation that lasted more than five centuries. These peoples, who sought better locations to live, were most likely attacked by other migrating peoples, such as Huns and Slavs in their homelands. Climate change may also have prevented the cultivation of land. These barbarians began to reach the Iberian Peninsula during the period of Roman occupation.

After the fall of the Roman empire, these tribes took control of the peninsula, with the ruling power passing through several hands, depending on the dominant horde, transforming this period into a time of disorganization, leading to ruralization of society and dispersal of urban nuclei, and increasing pressure on natural resources. The economy of these barbarian peoples was based on semi-sedentary agriculture and cattle raising. The climatic cooling between 450 and 950 CE and the instability caused

by barbarian invasions changed the way of life of the populations, allowing for the recovery of forests, with the reappearance of forests of birch and pine [3,13,14].

The Muslim invasion of the Iberian Peninsula occurred between 711 and 716. This invasion, with no major impact on the northern part of the peninsula, led the population to seek refuge in the abandoned "castros", the old uninhabited villages from the Iron age, at the top of mountains, leaving the lower and more fertile areas. This situation produced a pause in the regression of the forests in the north that only resumed with the Christian reconquest. In the center and in the south, this Muslim presence was more effective, significantly altering the way of life of the populations. These invaders brought with them new irrigation techniques and new agricultural crops, but also involved the use and exploitation of the forest, mainly to obtain wood for shipbuilding and housing. In this region, the forest continued its regression [3,13].

The Christian reconquest occurred in a period of favorable climatic conditions, namely, the Medieval Warm Period, which facilitated the development of agriculture in detriment of pastoralism, in response to the growing needs of an increasing population, but again causing regression of the forest area [3].

Military and religious orders played a decisive role both in the conquest of the territory and in its planning and stabilization. In the Middle Ages, rural spaces were enormously important, since they provided subsistence for populations and guaranteed the permanence of settlements in the conquered territories. There was also a need to occupy territories less suitable for agricultural purposes, such as marshy areas, to protect agricultural land from the advancement of dune fields in some areas of the coast, and, in parallel with the expansion of agricultural land, to occupy extensive forest areas, mainly in coastal areas such as Leiria (central Portugal) and Alentejo (south Portugal) [15,16].

The "montado", the cork oak traditional forest from the south of Portugal, resulted from the simplification of the forests of cork oaks and holm oaks, punctuated by other types of oaks, due to the grazing, cutting, and burning of trees and shrubs. The aim of these activities was to reduce the shading capacity and the density of the trees, eliminating the shrub species and promoting the occurrence of heliophilous herbaceous species. The growth and appearance of the "montado" was closely linked to the process of deforestation, creating a forest that was not completely natural [3,6,15,17]. The "montado" is not capable itself of guaranteeing the replacement of dead trees, even with low grazing intensities. When subjected to grazing without interruption, is converted into "pseudo steppes" devoid of trees, so that, since the Middle Ages, recommendations for reforestation were frequent [3,6,15,17].

The need to extend agricultural production to lesser soils and the lengthening of forest fire cycles in the mountains have accentuated erosion processes, filling large rivers with sediment drawn from slopes. The demographic increase and exhaustion of natural resources in the late Middle Ages led to an accumulation of crises and scarcity that greatly affected populations during the 14th century [3,6,18].

In the following centuries, the construction of different types of vessels for fishing, maritime trade, war, and, above all, for the construction of ships and caravels during the Portuguese maritime expansion period increased the demand for trees, with oak trees leading the list of the most sought-after for the construction of most types of vessel [19].

As was seen previously, the rulers demonstrated concern about the management and exploitation of forest areas, and this concern varied with the use of the forest throughout the different periods of the country's history. Due to the wood products crisis during the 16th century, the Law of the Trees was introduced in 1565, in the reign of King Sebastião, promulgated after the "Cortes" of Lisbon of 1562, and later transcribed in 1603 in the Philippine Ordinances [19,20]. In 1605, the "Monteiro-Mor" Regiment created the first inventory of the crown and pine forests and was one of the first diplomas that separated the pine forests by the two most common species: maritime pine and stone pine [20].

During the reign of King João V (1706–1750), deforestation significantly increased due to the increase in agricultural production. This situation was common in other countries in central and southern Europe, such as France and Germany, where the forestry sector was very important [20,21].

Significant progress occurred in Portugal as early as 1824 with the creation of the "Administração Geral das Matas do Reino", or the Kingdon Forests Management Survey [22]. Subsequently, the actions undertaken by the Forestry Services promoted the recovery of natural forests in some areas of the interior, along with the conservation of soil and water [23]. Construction of the railroad, which began in the mid-19th century, was another blow to the continent's depleted forest cover, with over 2000 km of railroad built in the last half of the century [20,24]. During this same period, the work of fixing and afforesting dunes in a large part of the Portuguese coast continued, due to the systematic and documented start of José Bonifácio de Andrada e Silva [21]. The afforestation of the mountains of the interior of the country was also undertaken [20]. Important changes occurred in the agroforestry space that led to the extension of the agricultural production area (production of cereals in the south and vineyards and olive groves all over the country) and an increase in forest area with reforestation of cork oak and pine [20].

Between 1874 and 1910, the forest area had an average annual growth rate of 37,614 hectares. The Agricultural and Forestry Charter of 1910 is the first and only source of information in which the agricultural, forestry, and uncultivated areas of the national territory were effectively documented [20,21,25]. The evolution of the forest landscape since the 19th century was characterized by a progressive occupation of uncultivated lands and expansion of pine forest area, which grew by approximately 1,800,000 hectares, mainly as a result of private initiatives [20].

Law no. 1971 concerning forest settlement was approved on June 15, 1938, becoming known as the Law of the "Baldios", common designation for the wasteland managed by local populations, and referenced the creation of a large natural park. This park, the Peneda-Gerês National Park, was created in 1971 after the publication of Decree-Law no. 9/70 of June 19, 1971 [20,25].

The 1950s were a turning point for forestry in Portugal. From 1956 to 1964, the forests were most heavily forested, with 270,000 hectares planted in 1970. In 1972, planting comprised 297,641 hectares in the mountains and 8,255 hectares in the dunes, representing just over half the area originally planned. The most widely used species was *Pinus pinaster* (Figure 5). Considerable effort was made to create a road network fundamental to the economic exploitation and defense of forest stands [20,21,26].

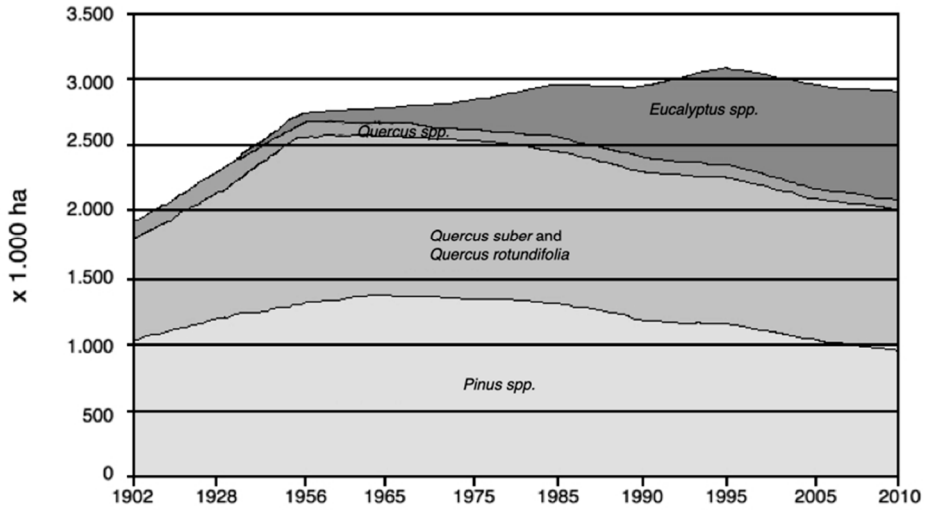

Figure 5. Changes in the area covered by the major tree species in mainland Portugal between 1902 and 2010 (adapted from [27]).

In 1978, the forest area totaled 1,373,891 hectares, representing about 46.5% of the mainland territory. However, some authors thought that the Plan for Forest Settlement had become "an instrument of aggression to the vacant people of the rural areas as being a social disaster" [18]. This situation is still felt today in rural areas, and even in the political environment, where there are frequent references to the way in which the State acts, which has resulted in revolts amongst the population [20,28].

Other authors declared that the launch of the Forest Settlement Plan constituted "forestry management in which productive concern has already overlapped with environmental issues" [18]. This afforestation process may have contributed to accelerating the process of rural exodus and to increasing the vulnerability of forest areas to fires, since half the area was planted with *Pinus pinaster*. The 1960s marked the decline of the complementarity that existed in the use of forests. "Being an integral part of land systems and livelihoods in places and villages" [18], they provided wood for dwellings and agricultural dependencies; resin, pine cones, and wood for heating and cooking; and areas where manure was obtained by the cleaning of shrubs and herbaceous materials [20,29,30].

2.3. Current Forest Development

Currently, according to the data presented in National Forest Inventory 6 (IFN6), about 35% of Portugal's territory is covered with forest. However, according to the same IFN6, this represents a decrease of approximately 150,000 hectares in the period 1995 to 2010, which corresponds to a net loss of 0.3% per year. This decrease is felt especially in the north and central regions, with the conversion of forest use to urban use (around 28,000 hectares) [31].

From the analysis of data provided by the Institute of Nature Conservation and Forests (ICNF), through various documents on its official website, it is possible to verify that the downward trend in forest area in mainland Portugal has continued, with the reduction estimated to have reached 254,000 hectares by 2015 (Figure 6). However, the data are still tentative, as the results of the IFN7 are not yet known, nor is the expected date for their presentation [32].

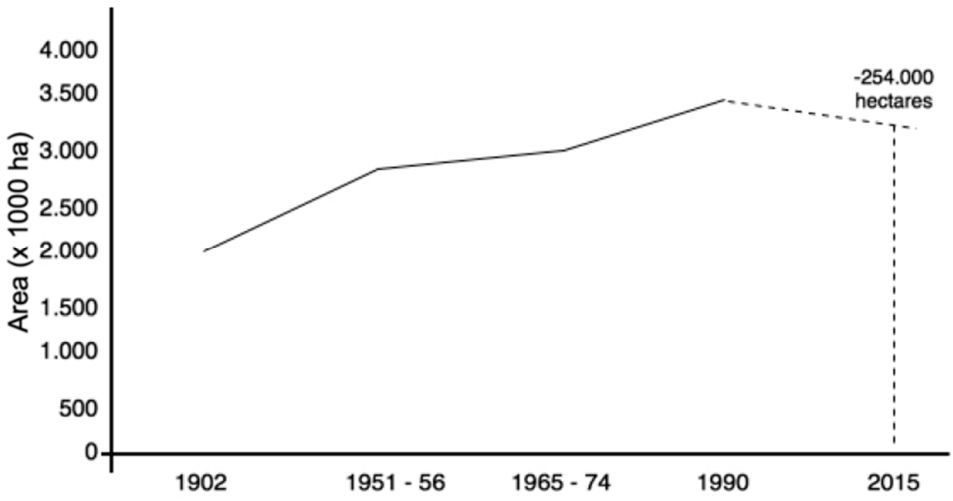

Figure 6. Changes in the forest area of mainland Portugal between 1902 and 2015 (adapted from [27]).

The country's forest structure has changed significantly, but *Pinus pinaster*, *Quercus suber*, and *Eucalyptus globulus* are the three most representative species, representing almost 75% of the forest area. These species are of greatest economic value; they are the species used in the dominant industrial sectors: the pulp industry, agglomerates of wood, biomass pellets, and cork [33].

Eucalyptus globulus became the main species occupying the forest on the continent in terms of area and percentage (812,000 hectares and 26%, respectively), followed by *Quercus suber* (737,000 hectares and 23%, respectively). *Pinus pinaster* (714,000 hectares and 23%, respectively) transitioned from being the main species to the third. The main change in forest area areas between 1995 and 2010 occurred for *Pinus pinaster*, which declined by about 263,000 hectares, and *Eucalyptus globulus*, which increased by about 95,000 hectares [1].

The forest is the basis of a sector of the economy that directly generates about 80,000 jobs [34]. This number has significantly decreased over the last two decades, motivated mainly by the exodus of populations from the interior to the coast, and by the near extinction of activities like resination [35].

These indicators and the increase in production that has occurred suggest an increase in labor productivity in the sector [36].

In the context of forest-based industries, i.e., the industries that obtain their raw materials from the forest and its by-products, the following points are noteworthy:

(1) Sawmills have undergone concentration, with the disappearance of small sawmills. However, it is estimated that the total sales volume will be maintained, comprising about 1.5% of total national exports [37].

(2) The pulp and paper portfolio directly contributes to the creation of around 4,000 jobs, but its main evolution has been an increase in the vertical integration of the sector, with greater production of paper and cardboard, leading to a remarkable increase in the value of the product—a trend that is still increasing. It is the sector with the second highest national value added, corresponding to 5% of national exports [37,38].

(3) The cork industry is an important part of national external trade, accounting for about one-third of total exports of forest products and creating more than 12,000 jobs [39,40].

Cork, perhaps the most beloved of all forest products and which plays a role as a representative icon of the Portuguese forest, has one of the most significant roles in the national industrial environment. The world market is led by a group that, despite its origins in the exploitation of a product of forest origin, has evolved over dozens of years, until it has become an international economic and financial group operating in diverse areas. The AMORIM group goes back to 1870, when António Alves de Amorim founded a manual cork stopper factory at Vila Nova de Gaia. On 11 March 1922, the first company, Amorim & Irmãos, Lda., was officially constituted, with the children of the founder of the first cork stopper as partners. Amorim & Irmãos, Lda. gave rise to the universe of companies that is today CORTICEIRA AMORIM. This second generation gave a new dynamism to the activity of the company and made it a reference for the cork industry nationally and internationally [41].

In 1935, the Amorim family acquired a small warehouse in Abrantes, near the main *Quercus suber* forest area of the country. The acquisition of raw material was made directly to avoid the problem of hoarding by foreign companies. At that time, Portugal, despite being the world's largest producer of cork, only processed about 5% of the raw material, the rest being dominated by foreign entities. The strategy developed by the Amorim family contradicts this trend. It was with this important step towards verticalization of the entire supply chain that the company began to gain importance in forest management, to control as much as possible the production of its raw material, avoiding intermediaries [41].

Even though it does not have its own forestry assets, the scope of its raw material procurement mission is to provide all the needs of the industrial segment. The AMORIM group also promotes long-term projects that ensure the maintenance, preservation, and valorization of cork oak forests and, consequently, the continuous production of quality cork [41].

Currently, the alteration and, especially, the changing of climatic conditions in the regions where the cork oak forests are developed contribute a new set of challenges for the management of these stands. Although the trees are robust and adapted to extreme climates, they require support to continue producing cork, thus justifying the need for the AMORIM group's investment in this area. These projects are developed in partnership with forestry producers, research institutions and local public entities. The AMORIM group's forestry intervention project seeks to create scientific knowledge based on new techniques and processes, and to disseminate and promote new practices to reduce the first cycle of cork extraction, improve the characteristics through genetics and vegetative reproduction of cork oak, and combat pests and disease [41].

THE NAVIGATOR COMPANY, which originated in the 1950s, had its most relevant milestone in 1957 when a team of technicians made the company's Cacia (Aveiro – North Portugal) factory the first in the world to produce pulp from eucalyptus by the kraft process. This was the starting point of a path that would transform a Portuguese company, then called COMPANHIA PORTUGUESA DE

CELULOSE, into one of the world's largest producers of white eucalyptus pulp (BEKP) and uncoated fine paper (UWF) [42].

The growth of the company over more than five decades had several moments. One of those moments occurred in 1975, with the incorporation of PORTUCEL through the integration of several Portuguese factories producing pulp, paper and packaging. At the beginning of the 21st century, an important step towards the consolidation of the company also took place. With the acquisition of PAPÉIS INAPA in 2000 and SOPORCEL in 2001, PORTUCEL consolidated the sector in Portugal. These two steps were decisive and gave rise to THE NAVIGATOR COMPANY [42].

In 2004, SEMAPA acquired a majority stake in THE NAVIGATOR COMPANY. With this new cycle, the company consolidated its leading position in international markets, reinforced in 2006 with the announcement of the construction of a new paper mill in the Setúbal Industrial Complex. In 2009, a second paper mill was inaugurated in the Setúbal Industrial Complex. The construction of this new factory was not only one of the most important milestones in THE NAVIGATOR COMPANY's history, but also a remarkable moment in the country's industrial capacity [42].

With this investment, THE NAVIGATOR COMPANY became the European leader in the production of uncoated printing and writing paper, and one of the largest in the world. The end of the first decade of the 21st century was also a time of great investment in the production of renewable energy and a reduction in the consumption of fossil fuels. One example of this is the significant investments made in 2009 and 2010: two biomass power plants (Cacia and Setúbal), one combined cycle plant (Setúbal) and one steam turbogenerator (Figueira da Foz) [42].

THE NAVIGATOR COMPANY is the largest private forest producer in Portugal, promoting management of 120,000 hectares of forest, with 73% as plantations of Eucalyptus globulus and 27% as diversified plantations. The company has a forest policy and a Code of Forestry Good Practices, which indicate the best practices for the conservation of forest areas, that is, the origin of the business [42].

Another major player in the forestry sector is SONAE INDÚSTRIA, which manufactures products derived from wood, recycled wood, waste from other activities and raw materials from the forest. It was founded in 1959 as an integral part of the SONAE Group and quickly became one of the largest producers of wood-based panels. Located in the north of Portugal, the company underwent a process of expansion through the combination of organic growth and acquisitions, having become one of the leaders in the sector with industrial units in Europe, North America and South Africa, and with a variety of products for the furniture, building and decoration industries that aim to improve people's lives [43].

In May 2016, SONAE INDÚSTRIA entered into a partnership with ARAUCO, a company based in Chile, which is one of the world's largest producers of forest resources. Following this strategic partnership, SONAE INDÚSTRIA holds a 50% stake in SONAE ARAUCO. In addition, SONAE INDÚSTRIA maintains full control of the North American wood-based panel business through TAFISA CANADA, as well as several real estate assets in Europe [43].

3. Historical Evolution of Invasive Species in Portugal

3.1. Exotic and Invasive Species

Throughout the country's history, the forest has experienced advances and retreats, sometimes caused by environmental issues, and sometimes provoked by varying pressure from the population in search of resources to meet their needs. Autochthonous species have not always been capable of providing the necessary answer to the need of the moment, whether sustainable or not.

On several occasions, it was necessary to resort to human intervention to accelerate the process of reforestation, with intensive planting of species considered useful. However, in the very recent past, the paradigm of populations knowing little more than the species they lived in and with which they had always lived in the past, began to change, with the introduction of exotic species from many locations because they were beautiful or could provide a solution to a particular problem.

Thus, begins the legend of the "Pinhal de Leiria" plantation, supposedly ordered to be planted by King Dinis. There is no absolute certainty about who actually ordered the plantation of this pine forest to be created, but there is a strong possibility that it was King Afonso III, the father of King Dinis, or even King Sancho II, his grandfather. Whoever originally planted the pine forest, did it to protect the agricultural fields and the castle from the advancing sands of the coast in the region of Leiria (central Portugal). The pine forest plantation actually increased the forest area since the time of Afonso Henriques, which would have been much smaller and included other species than the pine tree. This may even be the most interesting part of the legend, since it indicates an allochthonous origin for *Pinus pinaster*, because the story says that a group of sailors had returned from the Gulf of Gascony where they had much admired the very tall pine trees that grew in the sand. They saved the seeds and gave them to Queen Isabel, wife of King Dinis, who then went to the sands in Moel, near Leiria, and sowed them to the grown. After a few months, the small trees began to sprout, and the excited Queen showed the King the result of her work. King Dinis, seeing the potential of these trees for his shipbuilding projects, ordered the sailors to bring in more seeds from their next voyages [27,44].

Over the years, many have said, giving even more force to the premonitory tale, that King Dinis foresaw the need to build a large fleet of ships to be used during the period of Portuguese maritime expansion. King Dinis himself established a permanent fleet of boats to counteract the constant harassment of the Portuguese coast by the Saracen pirates, who, from the Moroccan ports and the south of Spain, made consistent incursions on the coast [24].

The spread of *Pinus pinaster* may have begun in force in Portugal and may have existed there in other times but with less range. Since then, *Pinus pinaster* extended its implantation area to the maximum extent reached during the "Estado Novo" period, from 1928 to 1974 at which point one of the largest continuous pine forests in Europe was created, to the point of being almost undeniably considered an autochthonous species. This dispersion encouraged the advance of the fires that seasonally occur throughout the country, especially since the people stopped depending on the pine forest and relied upon other areas, looking for better living conditions and abandoning the traditional activities associated with agro-forestry

In the middle of the 19th century, another species, *Eucalyptus globulus*, was introduced from Australia. The income it generated for forest producers made it an investment that led to a lack of rules guiding where it should and should not be grown, creating continuous forests that, if little managed or not managed at all, create excellent pasture for fires. These are mistakes that time and knowledge are now trying to correct.

Many other species were introduced. One of these is now synonymous of a plague. *Acacia dealbata* Link, which the former National Roads Survey planted profusely, perhaps as an ornamental plant, is a weed that has forced people to invest heavily in their eradication, which is not always successful. Reproducing very easily and quickly, forming densely populated areas that prevent the development of the natural vegetation. This situation is not considered unique, since, in the national territory during the last two centuries, and particularly during recent decades, the number of plant species considered exotic (be they species considered as casual, naturalized or invasive) has grown significantly, reaching approximately 670 species accounting for about 18% of the species found in Portugal [45].

Of all the species of plants classified as exotic that are already found in Portugal, about 15%, several are considered invasive due to their behavior, since they pose a real threat to the natural ecosystems, and even to the land occupied by agricultural crops. The invading behavior depends on certain situations, which are usually the location, soil, and climatic conditions, and response to anomalous situations, such as the occurrence of forest fires. All these exotic species are already well known and well characterized, especially in terms of their provenance, date of introduction, and the reason why the species was introduced [45–47].

Through the promulgation of Decree-Law no. 565/99 on December 21, 1999, and with its updating with the Decree law 92/2019 on July 10, 2019, the national legislation list recognizes the problem caused by these exotic species in the national territory. This law regulates the introduction of exotic species

into natural ecosystems, which are non-native species from other latitudes. In this legal document, all the exotic species introduced to Portugal to date are identified, including those considered invasive, and prohibiting the introduction of new species. However, some exceptions have been made, namely for species that provide the potential for afforestation and are of economic interest, among which 21 species of eucalyptus are listed. This law also prohibits the possession, creation, cultivation, and commercialization of species considered to be invasive and that may present a risk to natural ecosystems [45].

With international trade and tourism, it is increasingly easier for species from other countries and continents to reach our territory, some of which are invasive. These reduce biodiversity, affect the ecological balance and economic activities, and can harm public health through the transmission of diseases or parasites. The process for preventing or delaying the spread of an invader is often costly and impossible. Invasive species must be prevented from being introduced. Therefore, the purchase, sale, cultivation, creation, and use as an ornament or pet animal of a species considered invasive or of ecological risk is prohibited [48].

In Portugal, there are several invaders that have been intentionally or inadvertently introduced (e.g., fish or plants disseminated by aquarium water change, accidental escape from captivity, or introductions by importing goods such as exotic wood).

Among the most known and problematic invasive species in Portugal are several species of the genus *Acacia spp.*, *Ailanthus altissima* (Mill.) Swingle, and *Pittosporum undulatum* Vent. and *Hakea spp*. quickly form dense forests, reduce the availability of water, and increase the risk of fire [48]. Other species that also behave like invaders are *Arundo donax* L., which does not originate from Portugal [46], and *Cortaderia selloana* (Schult. et Schult. f.) Asch. et Graebn., which is widely used as an ornamental plant.

Some exotic species are attractive from an aesthetic point of view, but it is important to consider the risks they may pose, including that of becoming invasive. Therefore, care must be taken to prevent the proliferation of invasive species. The Portuguese Nature and Forests Conservation Survey ICNF has streamlined various activities for the control of invasive alien species, as well as helped citizens to understand some aspects of this problem related to individual behavior [49].

3.2. Eucalyptus

The expansion of eucalyptus in Portugal has produced many lively debates, mainly concerning its negative impacts on the environment, but this has not always been the case. Initially, when it was introduced to the regions of Southern Europe, some of the European colonies in Africa and Asia, and some South American countries in the mid-19th century, it was recognized as having excellent characteristics, quickly gaining interest in these areas [50].

There is no consensus on the date of arrival of eucalyptus in Portugal; the years 1854 and 1859 are suggested [51,52]. Its arrival was related to the chronic shortage of wood that was verified in the country and was common in other regions with a Mediterranean and subtropical climate. A species of rapid growth, its long and slender trunk was a considerable attraction. For the more progressive farmers, eucalyptus provided timber for use on farms and as fuel.

In addition to utilitarian uses, the initial interest, and the values and ideas that prevailed at the time, were conducive to the proliferation of "plant amateurs". Following the "natural explorers" of the previous century, they discovered "the plants of the World" for Europe. Eucalyptus was included in this wave, and although it was discovered on the island of Tasmania in 1792 by Labillardière, it was only 50 years later, after remaining almost ignored in the Botanical Gardens of Europe, that its diffusion occurred [53].

In Portugal, the introduction of eucalyptus and its expansion over many years was not due to any action promoting public forestry, but to individuals, driven by curiosity about the exotic tree in the beautification of parks, gardens, and lands. It was also appreciated for other qualities, including medicinal ones, which were advertised by a qualified group of enthusiasts and publicists, such as

Duarte de Oliveira Júnior, and nursery importers, such as Marques Loureiro, Guilherme Tait, and Rodrigues Batalha, who were merchants from Oporto. Therefore, in this introductory phase of the species, the private owners were the pioneers [53].

In a direct inventory completed by Pimentel in 1884, the presence of eucalyptus in "the most extensive plantations of the country" was well known, showing the predominance of the interest of individuals. Of the 12 properties listed, involving in total some 300,000 trees, the "Pinhal de Leiria" had about 40,000 and "Mata do Valverde" (Alcácer do Sal) had no more than 1,000 trees [53].

In addition to the agricultural and domestic uses of wood, the first clear commercial eucalyptus use was for railway sleepers. Pimentel reported that the first plantations for this purpose were created in 1870 by the Royal Company of the Portuguese Railways from nurseries through the definitive installation in reserved areas of the stations and guard houses, and along the lines [52]. However, there was a long period during which the use of eucalyptus did not increase significantly. Only from the 1940s onward did eucalyptus truly become an obvious and important source of raw material for the production of pulp [50,53].

Questioning of the environmental impacts of eucalyptus, which accompanied the long process of its introduction and expansion (sometimes only as a struggle between enthusiasts and detractors of the species), ran parallel with the lesser role of public options in this evolution. In the last quarter of the 19th century, a Public Forest Administration was created, resulting from the influx of technical and organizational knowledge gathered by a number of notable foresters trained abroad (and some established in Portugal after 1872). This enforced the country's forestation work to combat the centuries-old retreat of forest areas (which produced uneducated, celebrated, and abundant political discussion for a number of decades) [53].

The National Forests Management Survey invested in this objective, culminating in the afforestation plans of the mountains, which began in Manteigas and Gerês (1888–1889). In the work plans of this period, there was no special interest in the use of eucalyptus as a productive species for many years [53].

The dominant action being directed toward the afforestation of the sierras and dunes in the north of the country is largely explained by the lack of interest in the species the last quarter of the century and in the latter part of the 20th century. As a consequence of its better adaptation to ecological conditions, the needs were better satisfied by the pine trees, which due to its characteristics was a pioneer in the occupation of degraded soils [50,53,54].

In the academic world, as well as in the rising research until the 1920s, there was no great interest in the study and dissemination of eucalyptus. A reference index would be the published work on the species. In addition to Pimentel's pioneering and enthusiastic text from 1884, the registration of *Eucalyptus globulus*, still in exclusive botanical description, is only found in the Course of Forestry by António Xavier Pereira Coutinho (1886) with five other species of eucalyptus. In the analysis of the final reports of a forestry course from 1872 to 1920, only a dissertation on "exotic forest essences to be cultivated in Portugal" provides the botanical-cultural description of the species [53,55].

Until the 1940s, the number of publications was scarce. In a widely used forestry manual, the Notions of Forestry by Horacio Eliseu (1926 and 1942), which listed species recommended for the use in the afforestation of the continent with dendrological and cultural information, there is no record of Eucalyptus globulus among the three dozen species described [53,55].

The 1920s and 1930s created situations that led to changes in context to influence the great expansion of eucalyptus. One case is reflected in the first steps taken at this time by the Public Administration in the organization of forest research with the creation of two institutions for experimentation [23,53,55]. Here, work began on the technology of forest products that led to the installation of a Cellulose Laboratory in the early 1940s, in which Portugal's different species were systematically studied from the perspective of their industrialization. In 1925, CAIMA, a company established in Portugal in 1888, used other raw materials, particularly the pine tree, to commercialize the pulp obtained from eucalyptus while developing its own plantations. The State also continued afforestation, with preference for the

planting of hills. The Plan of Forest Settlement of 1938 was executed, but there was no change in its characteristics and their products [53,55].

In the 1940s, however, there was an intensification in the discussion about and the launching of an industrialization policy in the country. This occurred via a permanent polemic between industrialists and ruralists, and the Industrial Development and Reorganization project was approved. Law no. 2005, dated 14 March 1945, provided an important intervention and state support in the creation of industries. In relation to the pulp industry, the order of 12 March issued a license "for the installation of a pulp mill, mechanical pulp, newsprint, and other papers" to COMPANHIA PORTUGUESA OF CELULOSE (Cacia), which started operation in the early 1950s, after the combination of interests between industrialists and Portuguese bankers, with intermediation of the State, and was the first Portuguese project under the support of the famous Marshall Plan [53,54].

The raw material used from the beginning was the pine tree; only later did the use of eucalyptus become important. Eucalyptus was, therefore, a strong option for industrial public policy, which would have a marked effect on forestry, in particular policy of forestry and the agriculture sector, which was always resistant to such developments. In 1959, when the Ministry of Economy was defined as the main line of political action for agricultural industrialization and specifically mentioned the case of eucalyptus pulp production, cooperation became necessary between the three sectors of economic governance: industry, trade, and agriculture [53].

The reluctance to expand eucalyptus production was based on ecological grounds justifying its negative effects, although at that time hardly elucidated. Some misunderstandings were due to the spread of plantations to locations that were not indicated and were much more grounded in the tradition of defense of the "essentially agricultural country" that originated in the 19th century. Therefore, the fear of loss of areas was judged to be more interesting for agriculture at the time. This explains not only the resistance to the expansion of eucalyptus, but more generally to afforestation itself, providing a reason for the lack of success of some public initiatives. Law No. 2069 of 1954 created conditions for afforestation of private property, which was followed by the realization of plans for afforestation of some hydrographic basins of the south of the country. Since the introduction of the law, very little materialized. A proper body was created to achieve this objective, the Forest Development Fund (1965). In the short-term, its action was mainly limited due to financing problems in the sector of public administration responsible for the agriculture sector [53].

As far as eucalyptus is concerned, the roots of innovation in terms of silviculture techniques, such as soil preparation and plant production, were conducted for the application of Law 2069. The activities were mainly conducted by Ernesto Goes and the field teams set up at the time, which allowed the expansion of the geographical areas of eucalyptus but also increasing productivity [53].

From this time on, under the influence of the owners' interest and the pressure of the expanding industry, which was devoid of raw materials, eucalyptus was extended to include the area of exploitation of the industrial companies themselves with support from several origins, ranging from the World Bank to European funds. The plantation areas have expanded from 100,000 hectares by more than six times to date.

The area of eucalyptus cultivation, therefore, expanded slowly until the 1950s (Figure 7). From that time, the area grew continuously until the 1990s, registering a slight decrease in the last National Forest Inventory (2010). The inventory refers to the existence of 295,500 ha of young stands, and a considerable part of this area corresponds to eucalyptus plantations. Excluding the area of these young stands, the eucalyptus area (647,000 ha) represents about 19% of the country's forest area (3,412,300 ha) [53,56].

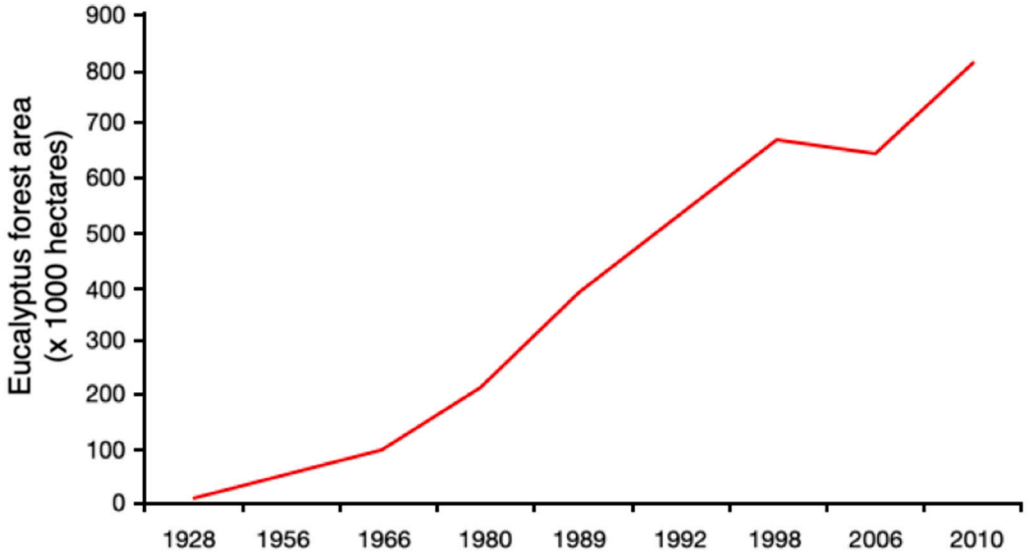

Figure 7. Changes in the area covered by eucalyptus in mainland Portugal (adapted from [57]).

In the second half of the 20th century, the expansion was roughly parallel to the growth of the pulp industry. At present, all the eucalyptus wood used in the national industry is sourced from national forest, and 90% and 77% of pulp and paper sales, respectively, are exported [56].

The intensification of the crop, allowing for production in periods incomparably shorter than the general lifespan of the forest species, was economically attractive, especially in the context of the emerging rural depopulation in the middle of the 20th century. As stated above, environmental concerns, although in embryonic and non-global forms, are no longer a problem today. Earlier, for example, farmers faced decreases in agricultural production in areas adjacent to plantations or windbreaks of eucalyptus. Although it is easy to explain and cannot be generalized, this border effect resulting from the intense consumption of water by the border tree lines has made eucalyptus a subject of controversy [53].

Some legislative interventions were introduced, notably when Law No. 1951 of 9 March, 1937 was published, which prohibited the planting of eucalyptus trees less than 20 m away from cultivated land and less than 40 m from water springs. The environmental debate was stronger in the 1970s and 1980s as a result of the visibility of the expansion of plantations and the opportunity to politicize environmental issues [53].

The controversy was not only confined to Portugal because it covered most of the countries where eucalyptus was used as an intensive crop for the production of wood, paper pulp, or fuel—India, Ethiopia, Brazil, and South Africa—but the arguments were incipient and combined different aspects. For example, the socioeconomic issues that related to the conversion of agricultural and agroforestry lands into eucalyptus plantations were mixed with ecological effects, which were often imaginary. Legislation to limit the expansion of the eucalyptus was introduced in Portugal, highlighted by Decree-Law no. 175/88 of 17 May, 1988, which aimed to prevent the proliferation of large continuous areas of eucalyptus, as well as to convert cork oak and holm oak plantations into eucalyptus plantations [53].

The expansion of eucalyptus cultivation in Portugal occurred at a time when, in the increasingly urbanized Portuguese society, attitudes and philosophies of environmental defense and conservation of biodiversity were growing. Within this context, in which the values of agrarian productivism were confronted by imaginary environmental protection, the modern environmental challenge to the cultivation of this species developed [53,58].

The perception of the forest and the paradigms of its management have shifted, where environmental benefits are increasingly valued in comparison with commodities such as wood. The image has been shifting from the "industrial" forest to the "post-industrial" or "post-productivist"

forest [59]. The environmental benefits, however, tend to revert in favor of the general population, and it is difficult for forest owners to convert them into economic value [53].

3.3. Acacias

The thinker, essayist, and poet Jaime Magalhães Lima, who was born and lived in Aveiro (Portugal), dedicated some of his work to the study of eucalyptus and acacia trees, and in his 1920 work, "Eucalyptos e Acacias - Twenty Years of Experiences", he classified acacias as being "the miraculous baptism by which sterility converts to culture" [60]. At the time, where knowledge about evolution, dispersion, and growth rates was yet to be established, many people, more or less literate, admired the rapid growth of these plants for the economic benefits they provided, the quantity and quality wood that they supplied, the beauty of the flowers, and the gardens that could be produced in a short time. In this work, the author discusses the occurrence of eucalyptus and acacia trees in Portugal at the time, mainly as ornamental species, and that were brought by travelers from other places. The work was published at a time when people were more likely to experience astonishment at the unknown, without much technical and scientific knowledge, than have concern for the environment.

Although the dangers associated with the proliferation of the species in this group are now known, it is necessary to recognize that these species are a prodigy of nature given their resilience and adaptability, posing a risk of rapidly becoming weeds to the detriment of autochthonous species.

The acacias constitute a vast group of species, distributed mainly in the Southern Hemisphere. Observation of the habitats of origin of these species showed that when they are in their original environment, they are associated with many other species, contributing to the profusion of biodiversity, adapting to different environmental conditions, coexisting with other plant species, and providing shelter and food for various animal species. These original habitats are found mainly in Australia, which accounts for 75% of the tree species and forest shrubs, together with the eucalyptus [61].

Among these many species, there is one that, mainly due to its spectacular flowers (Figure 8), quickly aroused attention as an ornamental plant. *Acacia dealbata* has yellow-bright globular inflorescences in bloom with beautiful yellow curls of flowers. Unfortunately, the "miraculous" acacias are no longer restricted to the southern continents from which they originated, becoming a pest that is threatening many ecosystems far away from Australia, including those of Portugal [61].

Figure 8. *Acacia dealbata* flowers.

The acacias form a group of about 1,380 species, 1,000 of which are native to Australia, with the remainder native to the other continents of the Southern Hemisphere, except for some species that originated in North America [62]. Differences exist in the classification of the family to which acacias belong. Some authors place them in the large legume family (Leguminosae), whereas some authors claim that they belong to an independent family, the Mimosaceae [63,64]. Like other leguminous plants, acacia seeds are grown in small pods, which open at the time of seed release [62].

As an essentially Australian species, acacias are well adapted to hot and dry climates, with regular occurrence of forest fires. Many acacias may be called pyrophytes, species for which fire acts as a stimulus of growth and dispersal [61]. Thus, in areas where the climate is hot and dry, as in Southern Europe, acacias are well prepared to compete with native species for resources such as space, water, and nutrients, as well as for regular fires to facilitate dispersal [65].

Humans, since ever, introduced intentionally or unintentionally non-native species to other regions, and species that were previously restricted to a given area can now be easily be transported to the other side of the world. These non-native plants, which are designated exotic, may not cause major problems. In many cases, the new habitat does not have the ideal conditions the species had in its original habitat. Sometimes, however, the exotic species exhibits biological characteristics, such as rapid growth, formation of more seeds, and alteration of the characteristics of the medium, that make it a formidable competitor in a place where it is not native. In these cases, it becomes an invasive species, and this phenomenon is called biological invasion [66]. In Portugal and most of Southern Europe, the most problematic species are *Acacia melanoxylon* R. Br. in W. T. Aiton, *Acacia longifolia* (Andrews) Willd., and *Acacia dealbata*; the latter generally has the greatest impact because it forms the largest clusters and is the most-dispersed species [67]. Like most other acacias, this species is native to Australia, but it does not originate from the warm inland deserts. It can be found in South Australia and Tasmania in areas of more temperate and humid climates, with low precipitation and mild temperatures [68]. Its habitat is open eucalypt forests, but it easily adapts to other conditions. Although it prefers mild climates, it is still a species well adapted to environmental conditions where fires are frequent [69].

At the end of the 18th century and beginning of the 19th century, specimens of this plant began to be brought to Europe, initially by British and French navigators, who first disseminated them through colonies in South Africa or Madagascar, before arriving in Europe [70]. The main reason for their dispersion and acceptance by Europeans was their beautiful flowers, although the wood was appreciated as well as their ability to set slopes [57].

The first records of the occurrence of *Acacia dealbata* in Portugal indicate its use as an ornamental plant in the second half of the 19th century. This was indicated by an article written in 1871 in the Journal of Practical Horticulture on a planting of silver wattle in Oporto, which offered "a coupon that gave subscribers the right to receive a free package of *Acacia dealbata* seeds" [71].

For a long time, mimosa and other acacias continued to be seen as species of exceptional economic or botanical value. Despite observations of its invasive nature, it was only in 1937 that the first legislation was introduced to control the planting of *Acacia dealbata*, although this only controlled minimum distances for sensitive terrain such as pastures, agricultural plantations, or slopes [57,72]. It was only in the 1970s and 1980s that this problem was seriously considered, but at this time the main centers of expansion were related not to plantations but to forest fires that allowed this and other acacias to rapidly colonize land previously occupied by native species [73].

Once colonized by acacias, native species struggle to develop in these areas because, in addition to growing quickly, they create an extensive seed bank in the soil that allows rapid re-colonization in case of disturbances such as fires or removal of vegetation. Their leaves have toxic compounds that inhibit the growth of other plants when they accumulate in the soil (a phenomenon called allelopathy [74]), mainly altering the chemical composition of the soil [75,76].

As already mentioned, acacias belong to the legume family, which are specialists in forming symbiotic relationships with nitrogen-fixing bacteria at their roots [65]. Although the soil is richer in this essential nutrient, the invasive characteristic of the acacia quickly causes any soil full of these

plants to have a chemical composition different from the original, which specifically benefits acacias compared to native plants [77].

Some studies have been conducted in Spain and Portugal where soils with *Acacia dealbata* and *Quercus robur* L. demonstrate the differences they have suffered [78–80]. These studies verified that mimosa-invaded soils have lower biodiversity, more propensity for other exotic species, less ferns and mosses, are richer in nitrogen and have a more acidic pH [81]. These changes in soils are reflected in the remaining biodiversity, the water cycle, and all other processes and functions in an ecosystem [82].

Cutting acacia trees combined with the use of herbicides, or peeling to cause dehydration, may be methods of control (Figures 9 and 10). However, given the seed production capacity of these species, even if all plants were removed at any given time, there would still be enough seeds for them to continue to burst for many years [83].

Figure 9. Application of herbicide, in this case glyphosate, after cutting an *Acacia dealbata* tree.

Figure 10. Peeling of *Acacia dealbata*. The peeling technique should cause all the bark to be peeled from approximately 1.30m to the root.

The best method, apart from the removal of these plants whenever possible, is to prevent their invasion in places still free of the influence of these weeds, conserving the forests and other native habitats. The more natural and stable a habitat, the less chance of invasion occurring, as invasive plants have more difficulty in finding resources not yet used by native species [84].

Another hypothesis that has been studied is the introduction of natural predators of acacias into their habitat, as has already been used on a large scale in South Africa with good results [85]. In Portugal, the species of wasp *Trichilogaster acaciaelongifoliae* (Frogatt) has been tested on *Acacia longifolia* with promising results, but care must be taken in the introduction of this wasp to ensure that this species will not begin to attack autochthonous plants, thereby creating another invasive species [86].

4. Conclusions

Forest is a complex system that is constantly evolving and adapting to new environmental conditions. Forests are also being subjected to increasing pressure from human activities that exploit them. Such exploitation confers several benefits that are rarely, if ever, undertaken from a sustainable use perspective and that prevent evolution and adaptation from occurring over a period of time consistent with the recovery capacities of the natural environment.

Concerns have been consistently expressed throughout history about the ability of forests to recover, not because of widespread environmental awareness, but rather because humankind has always been aware of the need for forest resources for subsistence, implementing permanent reforestation plans. It is these plans that, given new environmental and climatic constraints, must consider all the variables involved in the evolutionary and adventive processes. These processes should not ignore, for example, the presence of invasive forest species and creation of control mechanisms for their dispersion. It will be difficult to irradiate these invasive species, except in very restricted and concrete areas, given the available resources.

Portugal has experienced periods where its forests have evolved, regressed, progressed, and transformed, with its soil being used for other purposes. These changes were sometimes driven by natural changes, while at other times they occurred by human hand. The forest, like any living system, continues on this evolutionary and adaptive course, always affirming, at any time in history, to be fundamental to life, and to be a source of wealth, providing some of the most beautiful scenery in the country.

It is from this perspective that the Portuguese forest reaches the present day, with a set of important challenges that mark its development and evolution in the coming times. At this time, contrary to what has happened in the past, when alterations occur alternately with a more significant weight of the natural changes of the environment, or through anthropic intervention, the forest has to simultaneously evolve and adapt due to natural and human influences. Even natural influences may also be enhanced by human action.

The phenomenon of climate change, the introduction of species into new habitats, the intensive deforestation for industrial and commercial purposes, or the change in land use for other purposes, namely agricultural production, have only occurred at their historical rates due to the influence and intervention of humankind.

Today's rapid changes, many of which are similar to those from the past, make knowledge of these historical events important because they allow solutions to be found by comparing facts. Thus, it is understood that it is in the course of historical events that solutions can be found, often by antagonism, but essentially by avoiding the mistakes of the past.

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