Chapter 8

# Exotic Plant Species in the Mediterranean Biome: A Reflection of Cultural and Historical Relationships

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Additional information is available at the end of the chapter

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**Abstract**

The Mediterranean basin was the world's cradle of agriculture and the first human civilisation. In the Neolithic age, the agrarian culture expanded throughout the Mediterranean basin from the East to the West. Later, an expansion of agrarian culture and trade occurred, associated with the European colonialism, giving rise to a great plant exchange among Mediterranean-type regions. Despite being a biodiversity hotspot, the Mediterranean biome has been subjected to several anthropic impacts, such as alteration of land-use and cross-introductions of exotic species. The millenary anthropic modification of the landscape occurred in the Mediterranean basin gave rise to the formation of seminatural systems in which plants co-evolved with anthropogenic activities over a long time. Thus, species that originated in the Mediterranean basin might have developed a key role in other agro-silvo-pastoral systems along the whole Mediterranean biome. Research is biased towards highlighting the negative impact of exotic species on the ecosystems. To defy the traditional belief, outstanding recent literature focused on the positive effects of exotics on native communities was reviewed. Exotic species seem to have a key role in Mediterranean-type seminatural systems, as evidences of tolerance and facilitation processes were found. Exotic species that have co-evolved with human practices over millennia seem to enhance biodiversity in the Mediterranean biome.

**Keywords:** biodiversity, coexistence, exotic species, facilitation, grasslands, Mediterranean biome, native species, naturalisation

## 1. Introduction

Human history and activity have given rise to a wide range of new planetary-scale forces [1] that exert an increasing impact on the ecosphere creating cascades of repercussions on natural and socioeconomic systems [2]. The magnitude of that anthropic influence has increased so much that a new geological era has been recently recognised, the Anthropocene [3]. The impact and ecosystem alteration exerted by humans on the Earth is known as global change and is of major concern within an ecological framework. Basically, it is a question of an unbalanced growth of human population in relation to the energy consumption by different societies [4] and the fact that human activities occurred at local or regional scale affect the global functioning of the planet [5]. Global change comprehends, among others, changes in carbon cycle [6], climate [7, 8], land-use [9], and areas of species distributions [10]. The areas of species distribution in the context of the Mediterranean biome will be the main focus of the current study. Thus, to fully understand this ecological issue, it is necessary to adopt a holistic approach including the socio-cultural and historical contexts which will allow perceiving the interconnection of all components involved [11].

The Mediterranean basin was, around 10,000 years ago, the world's cradle of agriculture and first human civilisations. During the Neolithic era, the first forms of agriculture and human settlements came up in the territory known as fertile crescent, located in the Eastern Mediterranean, and comprised within the ancient territories of Mesopotamia and Near East. Back to that time, eight founder crops, including four cereals (wheat, einkorn, emmer wheat, and barley) and four pulses (lentil, pea, bitter vetch, and chickpea), were domesticated [12]; moreover, farming activities also started taking place with the associated domestication of several livestock species, including mainly sheep, goats, cattle, and pigs [13]. As a consequence of the human displacements which occurred in Southern Europe from the East to the West, archeophytes (i.e. the exotic species that were introduced before 1500) were established in Western European territories such as the Iberian peninsula. It took about three millennia until the agrarian and farming cultures expanded throughout the whole Mediterranean basin, reaching the Iberian peninsula (**Figure 1**) [14, 15]. Once agriculture and farming were integrated in humans' lives, food supply was under control and populations grew drastically, involving an increase in the dependence on and the intensification of agriculture [16].

Later on, changes in the area of species distribution have occurred in three other key phases. The first key phase took place at end of the Middle Ages (1500 AD), with the European rediscovery and exploration of the Americas [17]. The birth of colonialism at the end of the fifteenth century had consequences in human demography, agriculture expansion, and trade and industrial intensification. The expansion of the European colonial powers (remarkably Spain) radically increased the transport of living material. One major aim associated with colonialism was to exploit new economic crops for the empires. Particularly, the discovery of the New World by Spaniards coming from the Mediterranean basin gave rise to a great surge of plant exchange ([18] and references therein) among different Mediterranean-type regions. This phenomenon was specially marked when first female settlers established in the colonised lands [19]. The second key phase took place during the Industrial Revolution (1800 AD) [20], when traditional forms of rural economy were substituted by urban industrialised and mechanised economy. The third key phase has occurred over the last three decades, related to the rise in ease and efficiency of long-distance transport, income growth [21], and tourism [22], which prompt the globalisation era [20]. As a result, species movement and worldwide interconnectedness have become more intensive, occurring across wider space and in a shorter time than before [23]. Thus, humans' activities have radically modified species' distance dispersal and areas of distribution [18, 24–27].

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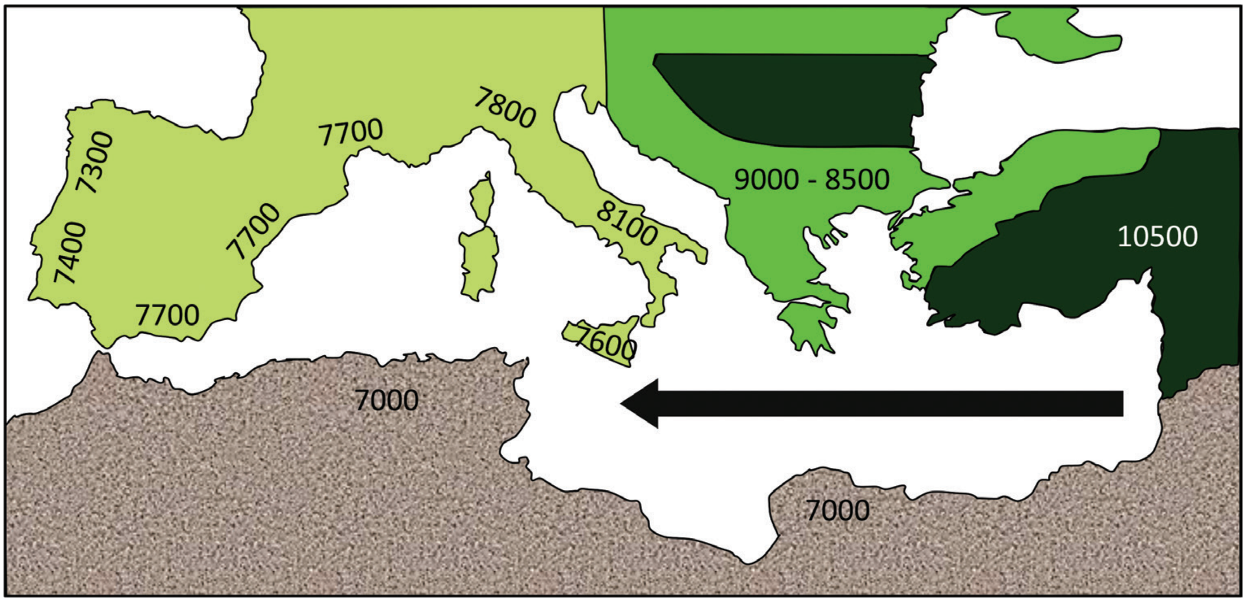


**Figure 1.** An integrated model of the Neolithic expansion in the Mediterranean basin. The location and approximate dates of colonist farming enclaves are shown by numbers (calibrated years before present). The darkest areas represent the place settled by colonist farmers; the lightest area indicates where indigenous foragers adopted elements of the Neolithic package and the areas with intermediate tonality indicate areas of the proposed integration of colonist farmers with indigenous foraging groups (modified from Ref. [13]).

As a result of the human-favoured transit of organisms [28–31] and habitat alteration, a reshuffling of species on the Earth has taken place. This gives rise to economic and ecological damage [10, 32–37] and a loss of cultural diversity. In this way, the subsequent biological invasions and biodiversity loss have important consequences at a variety of levels, affecting ecosystem structure [32], function, services, and human wellbeing [38–43], being therefore considered of major environmental and social concern and hence a focus of ecological research [44–47].

In the case of plants, species that have been transported from one region to another are defined as weeds, non-native, exotic, or alien to that new occupied region [48]. The introduction of plant species in an exotic area took place as a result of the movement of specimens around the world with ornamental, gardening, agricultural, and forestry purposes [18]. Since agricultural practices were introduced in human cultures, whenever people moved, plants also did, either deliberately (domesticated crops) or accidentally (associated spread of weeds and ruderal species) [18]. Due to their fast way of reproduction, their ability to withstand difficult environmental conditions through dormancy period in seed form, and the variety of ways of seed dispersal, exotic plants have been traditionally considered as a threat in the biological invasion context, with a greater number of invasive species than animals [32].

Notwithstanding the factors enabling establishment, one of the consequences associated with the colonisation process that has been highlighted in previous reports is that exotic species naturalisation involves landscape and global floristic (taxonomic and phylogenetic) homogenisation of regional flora at a biogeographical scale [49, 50]. Moreover, naturalisation of exotic plants has commonly been considered as a threat to native biodiversity, and most scientific studies have been centred around their negative impacts instead of considering the socio-ecological opportunities that the introduction of a new species could bring. During the last decades, numerous studies have highlighted the importance of control, monitoring, and managing of exotic species introduced in new areas [51–55]. In fact, many conservation policies have been implemented to conserve the native flora and sometimes, although being controversial, eradicate exotic invaders [56]. As an example, the Strategic Plan for Biodiversity called for urgent action by the parties to the Convention on Biological Diversity (CBD) to reduce the rate of biodiversity loss by 2020 [57]. To that end, they encountered the target of identifying, prioritising, and managing invasion pathways by 2020 to prevent the introduction of invasive exotic species [58]. Despite all this, it has been shown that human influence on the landscape is not always negative regarding the preservation of biodiversity assets. Traditional rural activities also represent important natural values and they maintain a positive relationship with diversity, at least in the Mediterranean biome [59].

## 2. The Mediterranean biome: historical relationships among the Mediterranean regions

The Mediterranean biome is defined because of its distinctive Mediterranean climate. It is mainly characterised by mild wet winters and warm to hot, dry summers and may occur on the west side of continents between about 30 and 40° latitude [60]. The summer drought period characteristic of the Mediterranean climate has become accentuated by the deforestation that has taken place around the Mediterranean regions during the last 2000 years and the subsequent loss of plant evapotranspiration and evaporation from soils [61–63].

Mediterranean regions with the above-described climatic characteristics are located in five different continents of the planet, including the Mediterranean basin, California, central Chile, Southern Australia, and South Africa. The international relationships and trade activities among these five Mediterranean regions started long time ago, during the colonialism. As an example, the Malaespina expedition (1789–1794) carried out by Spaniards involved four of the five Mediterranean regions; it departed from Spain and reached Chile, California, and Australia.

Although sharing climatic patterns, the five Mediterranean regions have had different biogeographical and environmental histories associated with the density of human populations as well as the time and intensity of the changes and land-use shifts that humans have caused in the territory. Despite being the Mediterranean biome known for its diverse flora, including five of the biodiversity hotspots [56] comparable to tropical rainforests or coral reefs, it has been subject to several impacts caused by humans but with different intensities and durations in each of the Mediterranean regions.

The use of fire and grazing and agricultural practises have been ancestral activities in the Mediterranean basin that play an essential role in shaping the current cultural landscape. The landscape, however, is also subjected to natural phenomena. Among anthropic impacts of important concern in the Mediterranean biome are alteration of land use, habitat fragmentation caused

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mainly by land clearing and urbanisation, climate change, alteration of fire regimes, and cross-introductions of alien species [64]. The cultural component generated a landscape maintained and cared for humans by means of reciprocal interactions and interdependencies involving natural processes and human activities. Thus, human culture and technology became integral parts of the ecosystems that underlie the Mediterranean cultural landscapes. In this sense, historical and societal characteristics of the Mediterranean basin, especially those associated with demographic pressure and millenary exploitation of land for agriculture and grazing, determined the patterns of land use change that the territory has presented since ancient times. Those anthropic effects on the environment led to the formation of seminatural systems or cultural landscapes [65, 66]. In fact, agro-silvo-pastoral systems (savanna-like formations characterised by a continuous herbaceous layer with scattered trees and land-use management defined by continuous extensive grazing with a low stocking rate in flatlands and rotation of grazing and cereal cropping in the better-drained hillsides) constitute a characteristic type of exploitation in the Mediterranean biome (e.g. *dehesas* in Spain, *montados* in Portugal). In these socio-ecological systems, plants have co-evolved with people over a long time [67, 68].

Similar cultural landscapes can also be observed in the other four Mediterranean regions worldwide, but the co-evolution of plants with humans has recently occurred, given that effective colonisation times vary depending on the region considered. Due to the fact that Mediterranean regions are enough far away from each other, which impedes the natural flow of exotic species among them, exotic species spreading is expected to follow the cultural landscapes associated with the main navigation routes from the colonialism period onwards (**Figure 2**).

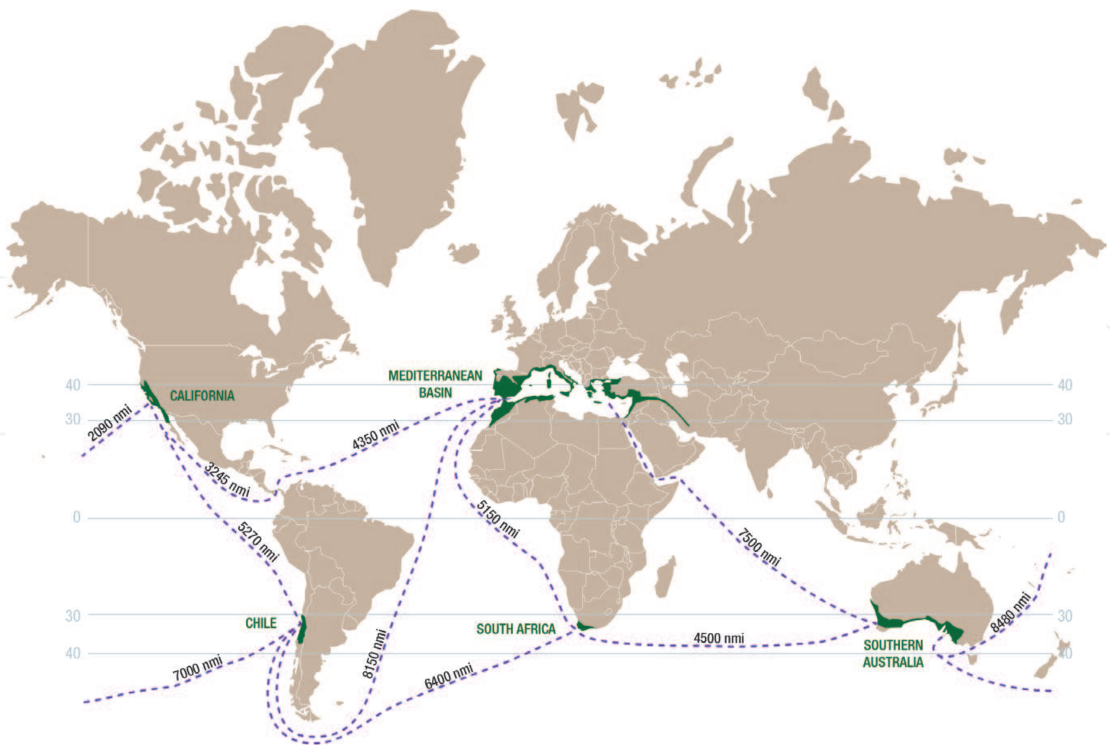


**Figure 2.** A map of the world showing the five Mediterranean regions and the navigation routes among them. Distances between the regions are shown in nautical miles (modified from Ref. [69]).

For example, Spaniard colonialism occurred in Chile during the sixteenth century due to the expedition led by Pedro de Valdivia that took place in 1541. In central Chile, sclerophyllous forests were cleared and displaced by modified woodlands dominated by introduced exotic species [70], and later those woodlands were opened for grazing and cropping, resulting into grasslands (i.e. called *espinales* in Chile) mostly dominated by species coming from the Mediterranean basin. The implementation of European livestock and agricultural culture led to big direct (ploughing, cropping, and grazing) and indirect (fire and deforestation employed as techniques for preparing the land for agriculture and livestock farming) changes, the extent of which are not well known yet [71]. Associated with the Spaniards arrival, the exotic species were introduced by exozoochory, coupled with merino sheep transported for wool trade, with hay for livestock fodder and with wool and cereals [72]. Several studies have associated the naturalisation (i.e. exotic plants that have been able to establish and self-perpetuate in a new area, according to the definition provided by Richardson et al. [48]) of those plants with processes of grazing by livestock [73–76]. Thus, although Chilean and Spanish plant communities have undergone different processes of invasion, previous reports highlighted the large number of species common to both regions (64% of Chile's non-native flora, [77]).

California was first sighted by Spaniards led by Juan Rodriguez Cabrillo in 1542, after several failed attempts to find a land that was famous for its gold and gems [78]. In the eighteenth century, the Spaniards supported the establishment of ranches granted free of charge, which covered large areas but did not have many inhabitants. The main aim was to support the agricultural and livestock development of the area. Again, the agrarian European culture was exported and implemented in this settlement. The *chaparral* and coastal grasslands of California constitute one of the principal plant formations in the region; they are characterised by having grazing activities and fire as the main agents of disturbance.

South Africa was first sighted by Europeans during the Portuguese expedition led by Bartolomé Díaz in 1488. After that, in the seventeenth century, disputes between Portuguese and Dutch settlers took place and South Africa became a Dutch colony. Finally, in the eighteenth century, South Africa became a British colony [79]. The Mediterranean-type ecosystem of Western South Africa is commonly known as *fynbos*. South African *fynbos* comprise mainly shrublands, grassy shrublands, and grasslands. As in other livestock-based economies, in the Mediterranean region of South Africa, a process of clearing for pasture and grazing intensification also took place [60]. Since then, Europe, particularly the Mediterranean basin, has been the source of 60% of the naturalised exotic grasses in southern Africa [80].

Regarding the Mediterranean region of Australia, Dutch expeditions along the Indic Ocean over the seventeenth century reached the Western Australia State. Nevertheless, British settlers were the ones that finally conquered both Mediterranean regions in Australia. Western Australia was colonised in 1829 and the South Australia State in 1836 [81]. Originally, *mallee* and *kwongan* were typical formations of shrublands and woodlands in this ecoregion. In the late 1800s, large-scale clearing of those formations began giving rise to opened woodlands and grasslands for agrarian and farming activities [82]. Although constituting a biodiversity hotspot, the Mediterranean region of Australia is dominated by naturalised annuals originating from the Mediterranean basin.

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For all the above exposed, relationships among all the Mediterranean regions—but of particular importance relationships between the Mediterranean basin and each of the others Mediterranean regions worldwide—have been frequent over the last centuries. As a consequence, natural and ancestral cultural factors based on silvo-pastoral activity converge in the Mediterranean biome, involving the establishment of disturbance regimes that favoured the entry of alien species [73, 83]. Due to the historical-cultural context of the colonialism [19], Europe, and especially the Mediterranean basin, has constituted the main source area donor of exotic flora to the whole Mediterranean biome. Surprisingly, while in some Mediterranean-type ecosystems a displacement of the native flora caused by exotic invaders has occurred, this trend has barely been observed in others. Thus, Mediterranean-type ecosystems worldwide provide a great chance to compare the impact of plant species introduction [84, 85].

## 3. Exotic plant species naturalisation in the Mediterranean biome

As a result of the landscape transformation carried out by humans in all the Mediterranean regions, empty niches were created (notice that the notion of empty niche does not imply species extinction). That has constituted an opportunity window [86, 87] for the entry of exotic species [73, 83, 88] which were already adapted to disturbances and cultural landscapes [89, 90] in their region of origin for millennia (eco-evolutionary experience [91]). The long-term coexistence of Mediterranean agro-silvo-pastoral systems with anthropic management in the Mediterranean basin has determined processes of co-evolution between plants (crops, forages, etc.) and human practices [67, 76, 92, 93]. In fact, most of the species present in the Mediterranean biome originated in the Mediterranean basin. Plants from the Mediterranean basin presenting more advantageous traits in a context of livestock grazing and ploughing became selected [94]. In particular, among the exotic flora in the Mediterranean biome, the families most represented are Poaceae, Asteraceae, and Fabaceae, in accordance with the three most invasive families worldwide [95]. The rapid growth and high reproduction rates of annual plant species and their capacity to resist unfavourable periods in the form of seeds makes them more suitable to develop in disturbed open spaces by fire, ploughing, or grazing [96, 97]. Poaceae and Fabaceae are typical families associated with livestock grazing and crop cultivation practices while Asteraceae take advantage in spreading mechanisms and dispersal ability [98]. On the contrary, native flora in the rest of Mediterranean regions lacked adaptations to continuous grazing and other disturbances such as fire; thus, native species have resulted negatively affected with the introduction of livestock and crops and the alteration of fire regimes, which have favoured the establishment of exotic species [73, 75, 99, 100].

The factor determining which exotic species became naturalised in a new area depended on the scale of analysis. At a broad scale (i.e. continental), it has been reported that climate determined the possibilities of exotic species establishment because of the significant biogeographical association existing between the climates in the source and the recipient regions [101]. Therefore, the similarity of the climate in source and recipients areas played a crucial role in the current distribution of exotic species [102–105]. The species' climatic tolerance was essential to successfully establish in the new region which highlighted the importance of co-adaptive mechanisms.

Additionally, habitat characteristics of the source area (climate, soil nutrient status, propagule pressure, disturbance, and remarkably human activities) determined the communities' potential to act as main donors of exotic species [101]. However, the relative importance of those factors ultimately depended upon the climate of the recipient region and the distribution of the main land uses which highlighted the importance of human pressure as a driver of exotic species distribution [106].

Species that can potentially colonise new areas undergo environmental filtering. Regarding abiotic filters (climate- and edaphic-related) acting at a regional scale, previous reports suggested a filtering process in both the source and the recipient areas but acting with different intensity in each of them [107]. Existing literature stated that the influence of abiotic factors was stronger in the recipient area, where especially the climate determined the successful naturalisation of exotic species [107], agreeing with previous reports about invasibility [108–110]. For example, in the Mediterranean region of central Chile, the increase in species richness with precipitation, and with the shortening of summer drought, was greater for exotic than for native species [107]. Therefore, exotic species naturalisation appeared enhanced by an improvement in the main limiting resource (water) (supported by the 'resource availability hypothesis') [103, 111, 112]. In the recipient area, not only abiotic filters but also biotic ones can be acting as filters, for example, plant-plant interactions occurring along the processes of plant community's secondary succession [113–115]. Possible processes between exotic and native species in the invaded area could be competence, tolerance, or facilitation; as a consequence, the relationship observed between both species groups would be negative, neutral, or positive, respectively. However, sometimes, this relationship appears conspicuous; the 'invasion paradox' stated that the relationship between species richness of native and exotic flora depends on the scale of study (being negative at small spatial scales $< 10\ m^2$ and positive at larger spatial scales $> 10\ m^2$) [116]. At the ecological community level, a consensus on the general impact of exotic species diversity has not been reached yet.

## 4. Positive relationships between native and exotic species in the Mediterranean biome

Although the frequency of exotic species in Mediterranean ecosystems is considerable, it varies among different regions [117] and types of studied system. Habitats with a higher degree of invasion are usually those related to anthropogenic activities [118] in terms of both, human population density and human-mediated disturbances [119]. Disturbances open a window of opportunity that promotes exotic species success by altering the environmental and soil conditions as well as by establishing new interactions within the native plant community [120]. For example, exotic species appeared associated with disturbed biological soil crusts [121], agrarian practices [122], grazing land use (e.g. 87.5% of the species significantly associated with continuously grazed grasslands in Southern Australia were exotic [123]), and fire events—the latter especially in California [120, 124]. Thus, better understanding of the influence of exotic species on native diversity is highly relevant to the management of Mediterranean ecosystems. However, a publication bias towards studies focusing on biological invasions by exotic species with negative impacts [125], especially in ecological terms, has been common within the scientific community. For example, in Mediterranean grasslands, invasion by exotic species has been frequently cited as a key threat responsible for decreased native abundance, richness, growth and regeneration [126–128], and altered species composition [128]. Although the scientific community is aware of reports about serious negative impacts in ecology [129, 130], economy [34, 35], and society [131], studies focusing on the possible benefits that exotic species can provide have been overlooked receiving much less attention [132–134]. Fortunately, over the past years, the bias in the literature towards negative impacts from exotic species has started to revert. Positive associations between exotics and natives have recently been reported, especially in the Mediterranean biome. Here, the findings of some of the most outstanding studies reporting positive relationships are summarised.

In terms of richness, positive correlations between native and exotic species have been reported in all the Mediterranean regions. In central Chile, positive relationships were found in both shrublands [135] and grasslands [107, 122]. Similar relationships were also documented in the Californian shrublands [123] and for post-fire vegetation communities in the Californian *chaparral* [124, 136] and grasslands [137]. In the Mediterranean basin, positive correlations between native and exotic species were also found on different systems such as floodplains [138] and marine benthos communities [139].

Controlling for the environmental conditions and land uses has been proposed as key important steps when assessing relationships between natives and exotics at a broad scale. When including environmental variability, positive relationships were found in South Australian grasslands in terms of species richness, cover, and Shannon diversity index [140]. In the Mediteranean basin, common anthropic factors such as landscape heterogeneity and human pressure partially explained both native and exotic richness, but a significant percentage remained unexplained, revealing that biotic interactions between both species groups might be occurring [141].

Some studies that were not conducted in the Mediterranean biome stated that exotic species established in early successional stages impeded the re-establishment of native ones [142–144]. Contrarily, no apparent competition between both species groups has been reported along secondary succession in grasslands of central Chile and post-fire Californian plant communities [122, 124, 145]. Rather, in Ref. [122] a complementary role between native and exotic species possibly as a consequence of niche segregation at a local scale in earlier stages of succession was documented. Whereas time since the disturbing event had a positive effect on native species richness, exotic species richness and cover increased right after the disturbance and then richness remained stable until the end of the chronosequence while cover decreased [122, 140]. The increase in vegetation cover associated with the early colonisation by exotics seemed to create the appropriate conditions for the successful re-establishment of native species, which increased in number. Thus, exotic species acted as passengers [146] or even as facilitator species, playing a complementary role to the natives' one. In central Chile and Southern Australia, the coexistence under the conditions of extensive livestock grazing was achieved through two different strategies: alien species were mainly grazing-tolerant species, whereas native species were grazing-defensive species [94, 122, 140].

Other positive effects of exotic species in native communities have been shown in other systems or for other type of species. For example, an exotic nitrogen-fixing shrub was able to build up an island of fertility under its canopy by accumulating considerable stocks of C, N, and P in the soil and by improving the soil hydrological properties [147]. Likewise, the presence of another exotic species, *Lantana camara*, also improved soil quality [148].

Regarding effects of exotics on germination rates or seedling growth of native species in grasslands, the presence of the invasive species *Thymus vulgaris* originated in the Mediterranean basin that presents allelopathy showed no negative effect [149]. Moreover, facilitative effects on the reproductive success of co-flowering native plants have been reported in the presence of the invasive weed *Oxalis pescaprae* [150]. Likewise, it has been shown that litter of invasive exotic plants facilitated growth of the dominant native plants by altering soil moisture in Californian shrublands [151]. Additionally, in some cases, the presence of exotic plant species facilitated the visit of pollinators to native species [152]. In central Chile, alien European rabbits filled a role similar to the one played by native mammals, by dispersing native seeds [153].

Recent studies even showed that certain invasive species have become keystones for the survival of local endemisms. Therefore, eradication programmes to re-establish the original vegetation might provoke severe local extinction of endemic species [127, 154], population bottlenecks, and cascading effects across trophic levels [126, 155], as well as on pollinator communities [150]. Some exotic species can contribute to achieve native species conservation policies [133]; sometimes, even the employment of exotic species has been proposed as an effective action for ecological restoration [156, 157].

Many of the results reviewed here pointed out that exotic species coming from the Mediterranean basin were pre-adapted to the environmental conditions and land-use management in the recipient regions. Similarly, it has been shown that once they got naturalised in a non-native environment, they formed mixed native/exotic plant communities due to effective mechanisms of tolerance and facilitation that allow the coexistence between both species groups. This coexistence did not seem to be aggressive in opposition to the traditional beliefs that aliens' naturalisation always decreases native biodiversity [158] or displaces it by exclusion [49]. On the contrary, the coexistence between native and exotic species appears to be smooth as exotics seem to ameliorate the harsh environmental conditions created after a disturbance so that natives can re-establish in that area.

## 5. Towards a new paradigm

As reported here, many positive interactions between exotic and native assets have been described over the past decades. It seems therefore that it is time to rethink the traditional paradigm which, by default, considers exotic species as a threat for Mediterranean-type ecosystems. It would be desirable the employment of neutral terminology such as nonindigenous species to avoid negative predisposition to the effect of exotic species [159]. In fact, it has been reported that the perception of the consequences that exotic species have varies among different stakeholders [160]. Stakeholders with different socio-cultural contexts have very different opinions about exotic species; some of them recognise the benefits of exotic species not only on the native flora at local scale but also on other species they have established relationships with [154], on the ecosystem services [124], on the human wellbeing [161], on the local and global economy [127], and so on. Thus, the crucial importance of adopting a more balanced view of exotic species and understanding their presence in a new area as a holistic process [162] need to be highlighted.

Assessing the functional roles that exotics may have established in their new areas to avoid unexpected results from incorrect management and being critical and open minded to find any possible mutualistic interactions between exotics and natives are crucial. In the foreseeable future, it would be desirable to evaluate in detail other possible facilitation processes between natives and exotics by studying plant-plant interactions. Future outcomes could also include the combination of the current ecological knowledge in invasion processes with forthcoming global change scenarios [37]. Merging the prospection of future climate change [8], landscape heterogeneity, land-use shifts, and the subsequent modelled displacement of exotic plant species distribution with current knowledge on invasive processes would be a fruitful study for determining areas which are more prone to invasion.

Evaluating the factors involved in naturalisation and invasion processes is key to accomplish the objectives of the Millennium Ecosystem Assessment Program [163]. The species reshuffling and its impact on the native plant communities undoubtedly contribute to the emergence of new environmental scenarios. These new scenarios have ecological and socioeconomic repercussions that are difficult to evaluate short term [164] or at a determined spatial scale. As multi-scale patterns are determinant of naturalisation success, evaluations should be conducted from broader to finer geographical scales and in the short, medium, and especially in long term [165]. To that end, we should take a comprehensive and systemic approach, coming to understand that fundamental ecology is context dependent, being tightly bound up to the social-cultural history, the anthropic activity, the economic implications, and the social tradeoffs [124]. Thus, it is necessary to accomplish transdisciplinary decision-making processes [166] which take into account not only ecological consequences but also ecosystem services and human well-being [167].

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