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REVIEW PAPER

Pathways for resilience in Mediterranean cork oak land use systems

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Abstract
· ***Context*** Loss of woodlands and degradation of vegetation and soil have been described for all Mediterranean-type ecosystems worldwide. In the Western Iberian Peninsula, overexploitation of evergreen cork oak land use systems has led to soil erosion, failures in oak recruitment, and loss of forests. Degraded and dry sites are quickly colonised by pioneer heathland rockrose (*Cistus* spp.) shrubs forming highly persistent patches.
· ***Aims*** Although traditionally shrublands have been considered as a transient successional state, we present evidence that they can represent persistent alternative states to former cork oak forests.
· ***Review trends and conclusions*** We first describe how Mediterranean vegetation evolved in the Iberian Peninsula and the role of fire and long-term human management as main disturbances. We then discuss alternative pathways through state-and-transition models indicating the ecological and land use variables that halt cork oak regeneration and recruitment and drive vegetation transitions towards persistent shrublands. Unless concerted management actions and restoration programmes are undertaken, the cork oak land use systems will not be sustainable.

Keywords Alternative stable state · *Cistus* · *Quercus suber* L. · Mediterranean-type ecosystem · Resilience · Restoration

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Contribution of the co-authors Vanda Acácio first conceived the paper. Vanda Acácio and Milena Holmgren wrote the paper.

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1 Introduction

Mediterranean-type ecosystems evolved through the major geological and climatic changes that took place during the Pliocene and early Pleistocene periods (3.2 to 2.3 million years ago) shaping plant communities that have adapted successfully to natural disturbances and are considered highly resilient. However, loss of original forests and woodlands has been observed in Mediterranean-type ecosystems worldwide, particularly in the Mediterranean Basin, as a result of a combination of human management and climate changes (Blondel et al. 2010).

A distinctive Mediterranean land use system dominates the landscape of southern Portugal where cork oak (*Quercus suber* L.) is the main tree species; this region is the largest cork oak habitat in the world corresponding to approximately 30% of the species area worldwide (about 737,000 ha, National Forest Inventory Data 2005–2006). This cork oak land use system is the result of long-term combined ecological and land use dynamics. Cork oak forests were gradually transformed into open woodlands as a result of grazing, clearing and ploughing for agriculture. In some cases, overexploitation of the land led to soil degradation and a lack of natural regeneration of cork oak trees (Costa and Pereira 2007). Cleared and disturbed understory patches, where cork oak natural regeneration became difficult, were commonly colonised by monospecific stands of pioneer rockrose shrubs (*Cistus* spp. shrubs) that have persisted for decades.

Succession has traditionally been thought to be a relatively linear process, but growing evidence indicates that persistent alternative vegetation or ecosystem states separated by critical thresholds may occur in many different types of ecosystems (Scheffer et al. 2001), including Mediterranean vegetation types around the world (Arianoutsou-Faraggitaki and Margaris 1982; Holmgren 2002; Kefi et al. 2007; Laycock 1991; Van de Wouw et al. 2011; Westoby et al. 1989).

In this paper, we summarise the evidence that *Cistus* shrublands, characterised by lower plant biomass and diversity than cork oak forests, may represent a persistent vegetation state in areas originally covered by cork oak forests in Portugal and describe the ecological and land use mechanisms underlying the resilience of this system. These *Cistus* shrublands are early successional vegetation assemblages dominated by *Cistus* spp., pure or mixed with *Lavandula*, *Ulex*, and *Genista* species. To date, few studies have identified persistent alternative vegetation states to cork oak ecosystems (Acácio et al. 2009) analysing the underlying ecological mechanisms (Acácio et al. 2007) and social drivers (Acácio et al. 2010) that explain their resilience. We start by describing how Mediterranean vegetation evolved in the Iberian Peninsula where cork oak was likely to be one of the main tree species. We then revise the effects of fire and long-term human management as the main disturbances affecting Mediterranean ecosystems and the consequent vegetation changes. Finally, we discuss the factors that limit oak recruitment and forest regeneration and contribute to shrubland persistence using a state-and-transition model to describe the dynamics between vegetation states and ecological feedbacks, as a contrasting view to the traditional succession model.

2 The past: evolution of vegetation and human management

2.1 Evolution of vegetation in the Iberian Peninsula and the cork oak species

Mediterranean climatic regimes are characterised by a dry summer season and a mild wet winter restricted to five regions of the world between latitudes 32° and 40° north and south of the equator, on the western side of the continents, namely in the Mediterranean Basin, California, central Chile, southwestern Australia and the southwestern tip of South Africa. These Mediterranean conditions developed during the Pliocene and early Pleistocene when summer rainfall decreased greatly (Suc 1984). At present, Mediterranean regions occupy only about 1% of the Earth's surface mostly around the Mediterranean Basin. Despite this small area, Mediterranean ecosystems are recognized as biodiversity hotspots with a rich endemic flora (Blondel et al. 2010; Myers et al. 2000).

There is wide consensus that, since the last glacial period (10,000 years ago, Holocene), the forest cover of the Iberian Peninsula has predominantly consisted of *Quercus* species, particularly evergreen oaks such as cork oak (*Q. suber*) and Holm oak (*Quercus ilex* L.) (Blanco et al. 1997; Pons and Reille 1988). It is likely that cork oak and Holm oak formed different combinations of mixed forests, together with other *Quercus* species (e.g. *Quercus coccifera* L., *Quercus faginea* Lam., *Quercus pyrenaica* Willd. and *Quercus canariensis* Willd.), *Pinus* species (*Pinus pinaster* Sol. in Aiton and *Pinus pinea* L.) and a diverse shrubby understory (species of *Erica*, *Pistacia*, *Myrtus*, *Viburnum*, *Sambucus*, *Phillyrea*, *Cistus*, *Buxus*, *Rhamnus*) (Blanco et al. 1997).

Cork oak is today restricted to the western part of the Mediterranean Basin (Bugalho et al. 2011), its largest extent being in Portugal with approximately 737,000 ha, representing about 30% of the species distribution area worldwide (National Forest Inventory Data 2005–2006). In the southern Iberian Peninsula, present forests dominated by cork oak may be accompanied by other oaks (*Q. ilex*, *Q. faginea*, *Quercus robur* L. or *Q. pyrenaica* Willd.) and late-successional shrubs (e.g. *Phillyrea angustifolia* L., *Lonicera implexa* Aiton, *Viburnum tinus* L., *Rhamnus alaternus* L., *Pistacia lentiscus* L., *Arbutus unedo* L.) (Natividade 1950). In disturbed cork oak forests, late-successional understory species are replaced by early successional species such as *Cistus*, *Lavandula,* and *Ulex*.

2.2 Long-term human impact and the role of fire

The existence of scattered cork oak forest patches all over the Iberian Peninsula suggests that the area of cork oak forests distribution in the past used to be larger and more continuous (Blanco et al. 1997). It has been estimated that only about 10% of the former Iberian cork oak forests remain (Blanco et al. 1997).

Although fire is a natural disturbance in the Mediterranean Basin, it has been used as a management tool for about 10,000 years to keep forests open, as well as for hunting, cooking, heating, pasturage, and weed and pest control (Naveh 1990). The regularity of human-made fires stimulated the dominance of plants with fire resistance strategies: species with resprouting capacity and species with propagule-persistence capacity (Keeley 1986; Pausas and Verdú 2005). Today, most plant species that dominate Mediterranean-type ecosystems show adaptive strategies for post-fire recovery. Less resistant species have been drastically reduced or completely eliminated. Cork oak is fire-resistant, being partially protected against fires by bark insulation (the cork) and its capacity to resprout (recover aboveground biomass) after fire. The cork oak is the only European tree able to resprout from stem through epicormic buds located high on the trees (Moreira et al. 2007; Pausas et al. 2009b).

2.3 Historical human use of cork oak forests in Portugal

Before the fifteenth century, cork oak woods were used by kings and nobility to hunt large game, for firewood, and for extensive grazing. Between the fifteenth and the seventeenth centuries, the area covered by cork oak woods in Portugal diminished substantially because wood was increasingly needed for shipbuilding, and the land needed for growing crops and pasture. Cork began to be used for wine bottle stoppers after the seventeenth century and acquired an increasing commercial value. From the eighteenth century onwards, a land use system that included cork extraction, crop cultivation, and livestock grazing at the farm unit level became common and constituted what is called an agro-silvopastoral production system or agroforestry system (Pinto-Correia and Fonseca 2009). Cork oak agro-silvopastoral systems in the Iberian Peninsula have a specific name: "montados" in Portugal and "dehesas" in Spain. It is likely that the management of such agro-silvopastoral systems throughout the centuries also included promoting natural regeneration of oak and artificially seeding or planting, in order to maintain cork production.

From 1929 until the early 1960s, most of the land in southern Portugal was cultivated for wheat, following a government policy known as the Wheat Campaign that strongly subsidised wheat production (Baptista 1993), which resulted in depleted soil fertility, increased erosion, and tree clearing (Costa and Pereira 2007). Only the forest areas on steep slopes were not put under wheat, because here topography made understory management for crops difficult or impossible. Between the 1960s and 1970s, the agricultural workforce in Portugal decreased by about one third (Baptista 1993) as a result of wide-ranging national and international socio-economic changes (industrialization, agricultural mechanization, the exodus to cities, and emigration), and there was massive rural abandonment. Between 1975 and 1995, after rural exodus, understory use ended in the least productive lands and smaller properties, with cork maintained as the single production component. In this period, the area occupied by cork oak in Portugal increased by approximately 10% (from 657,000 ha to 713,000 ha) (National Forest Inventory Data 1995–1998) as new plantations were subsidised by Common Agriculture Policy (Costa and Pereira 2007). On the other hand, during the same period, some agro-silvopastoral systems were maintained in flat areas and on larger properties, sometimes with intensified production especially in the more fertile regions (Pinto-Correia and Mascarenhas 1999). From 1995 to 2006, there was a further rise—of over 3%—in the cork oak cover reaching 737,000 ha in 2006 (National Forest Inventory Data 2005–2006).

3 The present: understanding landscape dynamics

3.1 Cork oak land use systems in Portugal

As a result of land use changes of the last decades, two main types of cork oak land use systems coexist in Portugal: (1) agro-silvopastoral systems (the montados or dehesas); (2) cork oak forests.

Agro-silvopastoral systems currently cover about 70% of the total cork oak area in Portugal (Costa and Pereira 2007) and are found mainly in the province of Alentejo, on flat terrain. They have low tree density (40 to 80 trees/ha), trees are exploited for cork and the understory is cleared of shrubs for pasture, crops (mainly wheat, barley and oats), or both. Tree density is determined by the need for space for pasture or cereal cultivation in the understory. Land use intensity (grazing and crop production) depends on soil fertility and landholding size. On smaller properties and where soils are less fertile, grazing is more extensive.

When the canopy structure of cork oak agro-silvopastoral systems has a low tree density, the vegetation closely resembles natural savannas. Mediterranean climatic and soil conditions favour woody rather than herbaceous species, which is why savannas have always had an anthropogenic origin in the Mediterranean Basin (Tomaselli 1981). Agro-silvopastoral systems must be continually maintained through human management by thinning and understory use through grazing, ploughing and shrub clearing (Huntsinger and Bartolome 1992). In any case, the term cork oak savannas will be used for agro-silvopastoral systems throughout this paper.

Cork oak forests have higher tree density than agro-silvopastoral systems (more than 80–100 trees/ha) and are managed solely for cork production without understory cultivation. When not regularly cleared for fire prevention, the understory contains diverse shrub species (e.g. *A. unedo*, *Erica arborea, P. lentiscus, P. angustifolia*, *L. implexa*, *Ruscus aculeatus*). Cork oak forests today cover a small percentage (about 30%) of the total cork oak area in Portugal and are located mainly in the mountain regions of Algarve, hilly areas of Alentejo and the north of the country, where the soils are shallow and poor. The area currently occupied by forests results from: (1) agro-silvopastoral land use systems that were abandoned after the rural exodus in the 1960s, where forests recovered naturally, or that were gradually transformed into cork oak forests through artificial cork oak planting, (2) forest areas where understory management was rarely practised because of the difficult (steep) terrain, (3) new cork oak plantations with high tree densities (Costa and Pereira 2007).

3.2 *Cistus* shrublands: an alternative stable state?

Despite increasing cork oak cover, tree density of Portuguese cork oak stands has fallen over the last decade. Stands with less than 40 trees per hectare increased from 10% of the cork oak area in 1995 to 30% in 2005 (Vallejo et al. 2009). Cork oak natural regeneration is rare, and recruitment is often not sufficient to compensate for natural or induced mortality (Costa and Pereira 2007). Lack of tree seedling establishment has been identified as a main barrier preventing tree recruitment and explaining the persistence of early successional stages dominated by pioneer heathland shrub species in the Iberian Peninsula (Acácio et al. 2007; Zavala 2003) and France (Curt et al. 2009) in a condition of arrested succession (Acácio et al. 2007).

Traditionally, vegetation succession in Mediterranean Europe has been understood as a predictable and linear process in which shrublands are an intermediate phase before the reestablishment of forests (Mazzoleni et al. 2004). Although natural forest regeneration has indeed occurred in some areas after agricultural land was abandoned during the 1960s (Mazzoleni et al. 2004), cork oak forest recovery is rare in the Iberian Peninsula, and *Cistus* shrublands have been very persistent, particularly on highly disturbed soils. *Cistus* shrubs usually colonise cleared understory patches, particularly on south-facing slopes exposed to long-term intensive land use and with low soil moisture and nutrient conditions, such as abandoned understory of cork oak savannas or very disturbed understory of cork oak forests (Gonçalves 1991; Natividade 1950; Seng and Deil 1999). Recent estimations for southern Portugal indicate that 60% of the shrubland patches remain as such after 45 years (1958–2002) and only about 8% shifts to oak savannas and oak forests (Acácio et al. 2009). A growing number of studies indicate that vegetation changes in response to disturbances are frequently discontinuous, not easily predictable, and with multiple-trajectories that may become arrested in persistent vegetation stages. Shrublands may represent an alternative stable state to cork oak forests under degraded soils and dry conditions.

3.3 A state and transition model to describe landscape dynamics

State and transition models provide an alternative framework for describing the vegetation dynamics of arid and semiarid ecosystems (Westoby et al. 1989). Few authors have used them to describe the dynamics of Iberian cork oak ecosystems (Acácio et al. 2009; Cortina et al. 2006; Huntsinger and Bartolome 1992) but seldom have they identified the underlying ecological and social mechanisms that explain the barriers for vegetation change (Acácio et al. 2007, 2010).

Figure 1 represents cork oak forests, cork oak savannas and *Cistus* shrublands as alternative vegetation states highlighting the ecological and management factors that trigger

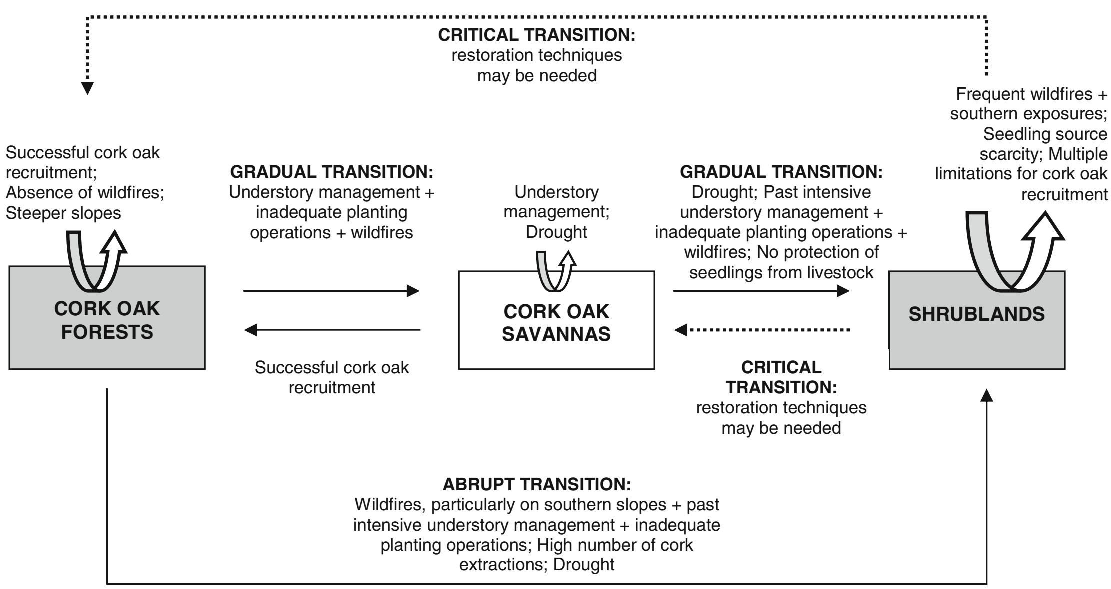

Fig. 1 Ecological and management factors that trigger transitions between cork oak forests, cork oak savannas and shrublands. *Dashed lines* indicate critical transitions; *circular arrows* indicate persistency of vegetation states and the *plus symbol* indicates a combination of factors

transitions between them. Each transition is driven by both ecological and land use mechanisms that act in conjunction to affect cork oak natural regeneration, seedling establishment and tree recruitment, and consequently lead to forest recovery or maintenance, or to the persistence and expansion of shrublands. Disturbances such as wildfires, drought and intensive or inadequate human management have a strong effect on the different phases of the recruitment cycle. The overall effect of multiple disturbances as well as the net effect of plant–plant interactions on oak performance and recruitment vary along resource gradients such as water availability and soil fertility, shaping the trajectories of vegetation change. In the next sections, we develop these ideas in depth.

3.3.1 Transitions with successful cork oak recruitment

In cork oak forests, seed and seedling availabilities are usually high (up to 3,000–7,000 or more of seedlings/ha have been reported; Acácio et al. 2007; Pons and Pausas 2006), and dispersal agents are present—both jays and mice, which promote long and short distance acorn dispersal, respectively (Pausas et al. 2009a). The viable acorns that escape predation from rodents or other wild herbivores are more likely to germinate under the moister and cooler forest conditions than in oak savannas (Acácio et al. 2007) due to higher tree density and the presence of a shrub layer. Shading is favourable for cork oak seedling growth and survival (Acácio et al. 2007; Plieninger et al. 2010), since it may significantly alleviate thermal and water stress during the typical Mediterranean summer drought (Gómez-Aparicio et al. 2004; Quero et al. 2006).

Cork oak agro-silvopastoral systems (savannas), without understory management, can become forests if naturally established seedlings are successfully recruited into the mature population, or if artificial planting is successful.

3.3.2 Transitions with cork oak recruitment failures and decreasing tree density

A complex pattern of disturbances may act in conjunction to disrupt one or more phases of the tree recruitment cycle, either in savanna or forest patches. Livestock overgrazing, continuous ploughing and cereal cultivation severely affect seedling establishment. Indeed, forests located on steep slopes, rarely or never subjected to intensive and prolonged understory use during the Wheat Campaign, were more persistent in time (Acácio et al. 2010).

Also, seed dispersal has been pointed as a key process limiting tree recruitment in oak savannas (Acácio et al. 2007; Pulido and Díaz 2005). Experimental research in southern Portugal showed that, among the mice-buried acorns, none were able to germinate in savannas, whereas 16% of buried acorns germinated in forests (Acácio et al. 2007). Even if successfully dispersing and germinating, seedlings and saplings in savannas are more susceptible to water stress and livestock damage and less likely to survive than in forests (Acácio et al. 2007 and references therein).

The great increase in fire frequency in the last few decades in the Mediterranean Basin (Pausas and Vallejo 1999) has become a major barrier to cork oak survival and recruitment (Acácio et al. 2009, 2010). Although cork oak is able to withstand fire by bark insulation and to resprout afterwards, frequent or intense wildfires may kill mature trees, especially if wildfires occur immediately after cork extraction, which takes place in the summer (the wildfire season in Mediterranean Europe) and hence the remaining cork layer is too thin to protect the trees (Moreira et al. 2007). Cork oak post-fire survival and resprouting after fire depends on the interaction of fire intensity, land management practices, topography and climatic conditions (Catry et al. 2009; Moreira et al. 2007). In cork oak forests, the shrubby understory (fuel load) might contribute to intense wildfires and consequently lower post-fire cork oak survival, especially on dry southern slopes (Acácio et al. 2009; Moreira et al. 2007). In savanna patches, wildfire damage on saplings and trees is likely to be less severe than in forests because lower fuel and larger tree spacing contributes to faster fires but with lower intensity (Acácio et al. 2009). Additionally, the use of inadequate techniques for cork oak planting, in combination with summer drought, has led to high seedling mortality (Almeida et al. 2009) and establishment of persistent *Cistus* shrubs (Acácio et al. 2010; Zavala et al. 2004). This complex pattern of combined ecological and land use disturbances has also been linked to the dramatic increase in cork oak vulnerability to pests and diseases (particularly a fungus, *Phytophthora cinnamomi*) and abnormal cork oak mortality throughout the Western Mediterranean (including Portugal) in the last few decades (Moreira and Martins 2005).

3.3.3 Persistence of shrublands

Cistus shrublands affect oak growth and recruitment in different ways. They can act as reservoirs for oak diseases (such as *P. cinnamomi*) (Moreira and Martins 2005), impede tree seedling recruitment (Acácio et al. 2007), affect the physiological performance of adult trees (Rolo and Moreno 2011) and affect disturbance regimes in such a way that oak recruitment becomes more difficult (Acácio et al. 2009).

Tree seedling recruitment is limited in multiple ways. Not only is the cork oak seed rain very low in shrublands but there are multiple limitations for cork oak seedling establishment and survival. Experimental research in southern Portugal showed that cork oak seedling establishment in shrubland patches is impeded by multiple mechanisms during the early phases of the tree recruitment cycle: high rates of weevil infestation on acorns, low rates of buried acorns (scatter-hoarded by mice), high rates of post-dispersal predation and very high seedling mortality (Acácio et al. 2007). Furthermore, seed dispersal in shrublands is likely to be distance-restricted because the main agent responsible for long-distance dispersal—the European jay (*Garrulus glandarius*)—tends to avoid closed shrublands (Pausas et al. 2009a). Also, in the Spanish systems, cork oak recruitment fails under *Cistus* shrublands (Pausas et al. 2006).

Competition between *Cistus* spp. and tree seedlings tends to prevail, in contrast to the rather neutral or facilitative effect that other shrub species more commonly have in Mediterranean environments (Acácio et al. 2007; Gómez-Aparicio et al. 2004; Pulido and Díaz 2005; Rivest et al. 2011). Facilitation is the net effect of positive and negative effects between neighbouring plants where the unavoidable lower light availability under shade is compensated by amelioration of limiting stresses (e.g. abiotic or biotic). The combined effects of shade and drought on plant performance and the implications for species interactions are highly debated in plant ecology. Recent meta-analysis of the published literature shows that drought effects are ameliorated at intermediate irradiance, becoming more severe at higher or lower light levels and indicating that facilitation is more likely to occur within certain range of environmental conditions (Holmgren et al. 2011). Moreover, there is a growing body of evidence indicating that facilitation may peak at intermediate levels of environmental stress and that competition may prevail under very stressful conditions (Holmgren and Scheffer 2010; Maestre et al. 2009). Indeed, the effects of *Cistus*, which are predominantly negative, become stronger in dry years indicating that competition with oak seedlings for soil resources increases during drought (Rolo and Moreno 2011). *Cistus* shrubs have a superficial and dense root system that is very effective in the competition for soil resources (Rolo and Moreno 2011).

The response of *Cistus* to disturbances also explains its success. *Cistus* are not only well adapted to drought (Werner et al. 1998), but they are also unpalatable to livestock (Natividade 1950) and highly resilient to wildfires. *Cistus* species are typical active pyrophytes, propagated solely by seeds and are able to disseminate numerous seeds that colonise extensive areas after fire (Corral et al. 1989; Ferrandis et al. 1999). The seed bank persists in the soil for a long period because the seeds have hard coats and are impermeable to water, which prevents them from germinating. *Cistus* shrubland patches will persist and expand as long as the interval between successive fires exceeds the time needed for seed bank restoration (3 years for *Cistus ladanifer* in Spain; Ferrandis et al. 1999).

Degraded soils with lack of vegetation cover, high incoming solar radiation and frequent wildfires make conditions for oak seedling survival very difficult, contributing to the dominance of *Cistus* shrublands. After a critical threshold has been reached, feedback mechanisms of increased soil degradation and erosion, increased shrub encroachment and increased constraints to cork oak recruitment will prevent recolonisation by cork oak even after external disturbances have ceased, implying an irreversible tree loss. Active restoration executed during rainy years will likely be most successful in releasing the system from arrested succession and reverting it to a forest dominated condition (Fig. 1). Climatic windows of opportunity have proved effective in the regeneration and restoration of arid and semiarid plant communities in various regions of the world (Holmgren et al. 2006; Holmgren and Scheffer 2001; Sitters et al. 2012). Wet summers are rare events in Mediterranean regions characterised by a summer drought, but experimental results suggest they can strongly boost the abundance and diversity of recruiting woody species (Matías et al. 2011).

4 The future: how resilient is the cork oak land use system?

4.1 Implications for management and restoration

The drivers of transitions and the probable feedback mechanisms and thresholds indicate that ecosystem restoration for forest recovery should include practices that improve soil condition as well as relief of multiple constraints to recruitment in the early life history of oaks. The concrete actions that could be taken in shrubland patches include a combination of *Cistus* removal, seeding of acorns or seedling planting, planting of nurse shrubs to facilitate oak seed germination and seedling survival (Gómez-Aparicio et al. 2004), and perch trees to attract long-distance dispersers like jays (Walker and Del Moral 2009). In savanna and forest patches, protection of acorns and oak seedlings from grazing (from livestock or wild herbivores, if present) is also necessary to ensure seedling establishment in the medium term. In Mediterranean-climate regions, drought is the main threat to the survival of nursery-raised seedlings, so nursery and field techniques in restoration projects based on artificial regeneration must be devised to improve seedling performance in such dry conditions, especially in the face of climate change or as post-fire restoration techniques (Vallejo et al. 2006).

4.2 Resilience and climate change

This paper presents evidence that natural succession has been arrested and the system remains in a pioneer state of *Cistus* shrubland, which can be considered as a persistent alternative vegetation state. The forest ecosystem has lost the capacity to recover from past practices damaging the soil and vegetation and is now additionally threatened by more frequent wildfires and longer and more severe drought periods. Frequent and severe drought as result of global climate changes may further contribute to the expansion of *Cistus* shrubland and loss of cork oak forests, due to difficulties in regeneration and an increase of tree mortality, especially in the south of the country. Climate change may be too rapid to allow the species to migrate, so it may become extinct locally (Pereira et al. 2009). Climatic conditions might also interact with diseases: drought and changes in rainfall regimes may contribute to the development of new forest plagues and diseases and increasing pest attack (Moreira and Martins 2005).

4.3 Achieving sustainability

Cork oak landscapes are a fascinating ecosystem and European Union protected habitats (Habitats Directive 92/43/EEC) (Zavala et al. 2004). Cork oak ecosystems have high biodiversity, allow for the protection of soils in dry environments, and provide other important ecosystem services (Bugalho et al. 2011). Furthermore, cork is responsible for 3% of total Portuguese exports and represents approximately 10% of total employment in the Portuguese forest sector (Mendes 2002). The primary economic incentive for the management of these land use systems is cork production, but cork prices have fallen in recent years (Bugalho et al. 2011). If cork loses its market value, these unique landscapes of southern Europe will become endangered. Seeking and developing alternative activities, which generate additional income, such as “payment for ecosystem services” schemes may provide additional incentives to conserve these systems (Bugalho et al. 2011). Other possibilities include ecotourism, the production of edible mushrooms, fruits and natural oils, beekeeping or hunting.

The renewal of cork oak woodlands is economically unattractive to many private landowners as it represents a long-term investment with an economic return 35–40 years after the initial investment; therefore, management and restoration actions will not be undertaken without subsidies (Ovando et al. 2009) or other economic incentives. However, the lack of public subsidies for the restoration of degraded cork oak forests through assisted natural regeneration represents a policy failure, since recent studies show that compared with the artificial creation of new stands, the restoration of established woodlands might be better in terms of biodiversity conservation and long-term carbon storage (Ovando et al. 2009). The future of cork oak land use systems will depend on people’s willingness and capacity to undertake concerted management actions and restoration programmes and on the development of entrepreneurial skills to develop multipurpose businesses. Unless such actions are undertaken in the short-term, the cork oak land use systems will not be sustainable. Further research is needed to unveil the mechanisms that maintain feedbacks and thresholds in these systems.

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