Review

Mediterranean cork oak savannas require human use to sustain biodiversity and ecosystem services

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Mediterranean cork oak savannas, which are found only in southwestern Europe and northwestern Africa, are ecosystems shaped by human use of high socioeconomic and conservation value. Characterized by sparse tree cover and a diversity of understory vegetation – ranging from shrub formations to grasslands – that support high levels of biodiversity, these ecosystems require active management and use by humans to ensure their continued existence. The most important product of these savannas is cork, a non-timber forest product that is periodically harvested without requiring tree felling. Market devaluation of, and lower demand for, cork are causing a decline in management, or even abandonment, of southwestern Europe's cork oak savannas. Subsequent shrub encroachment into the savanna's grassland components reduces biodiversity and degrades the services provided by these ecosystems. In contrast, poverty-driven overuse is degrading cork oak savannas in northwestern Africa. "Payment for ecosystem services" schemes, such as Forest Stewardship Council (FSC) certification or Reducing Emissions from Deforestation and Degradation(REDD+), could produce novel economic incentives to promote sustainable use and conservation of Mediterranean cork oak savanna ecosystems in both Europe and Africa.

In a nutshell:

- Mediterranean cork oak savannas are human-shaped ecosystems with high conservation value that are maintained through human use
- The primary economic incentive for the management of these savannas is cork production, but cork prices have fallen in recent years
- Cork oak savannas are threatened by disuse and abandonment in southwestern Europe and by overuse in northwestern Africa
- "Payment for ecosystem services" schemes may create economic incentives that promote the ecological and economic viability of cork oak savannas, and of socio–ecological systems elsewhere

Anthropogenic influences, including ancestral uses of the land (Foster *et al*. 2003), affect most ecological communities on Earth, and gradually become a fundamental part of many ecosystems (Seastedt *et al*. 2008). More than 75% of all terrestrial ecosystems show such marked evidence of human alteration that they are best perceived as "human-made systems with natural ecosystems embedded" rather than "natural systems with human embedded influence" (Ellis and Ramankutty 2008).

Human and ecological systems are integrated in many landscapes (Western 2001). Some of these landscapes have high conservation value; that is, they contain high habitat heterogeneity and are rich in endemic species. Examples include the highly diverse forests of (1) the Mahaweli Basin in Sri Lanka that were developed on ancient rice fields (McNeely 1994) (2) Central and South America that resulted from the afforestation of ancient croplands created by indigenous peoples such as the Maya (McNeely 1994) and cultures of the Amazon Basin (Clement 2006). Selective burning and other forms of forest clearance by native peoples throughout the Americas and Australia have promoted a mosaic of ecosystems in different states of ecological succession, thereby maintaining high levels of biodiversity at the landscape scale (eg Anderson 2005).

The conservation value of human-shaped ecosystems is particularly notable in the Mediterranean Basin, where numerous societies have shaped natural ecosystems for more than 10 000 years (Blondel 2006), generating many cultures and land uses that have contributed to the landscape diversity now present in the region (Blondel *et al.* 2010). Indeed, the Mediterranean Basin is one of the world's biodiversity "hotspots" (Myers *et al*. 2000), partially as a result of the long-term human presence and related activities. The biodiversity-rich cork oak (*Quercus suber*) savannas of the western Mediterranean Basin, which resulted from human-mediated disturbances such as forest clearance (including fire use) and livestock grazing, provide a good example of such a human-shaped ecosystem. Today, the spatial distribution of and tree density within cork oak savannas are decreasing in both southwestern Europe and northwestern Africa (Pereira *et al.* 2004; Vallejo *et al*. 2009). These ecosystems are threatened by poor or nonexistent land-management practices in some areas, and by chronic overuse in others.

How can these socio–ecological systems – which are inherently dependent on human use – be conserved? Can novel economic incentives be employed to promote their sustainable use and maintain their conservation value?

Cork oak savannas in the Mediterranean Basin

A human-shaped ecosystem

Currently, cork oak savannas occur in the warmer parts of the humid and subhumid western Mediterranean Basin, covering approximately 1.5 million ha in Europe and 1 million ha in North Africa (Figure 1). They have a sparse tree cover of cork oak (30–60 *Q suber* trees per hectare), at times mixed with Holm oak (*Quercus rotundifolia*) and, more rarely, with other tree species (eg *Pinus pinaster*, *Pinus pinea*). The understory is a heterogeneous mix of shrub formations interspersed with grasslands, fallows, and, less often, cereal crops (Diaz *et al.* 1997). These savannas may have been present in prehistory, promoted in part from the use of fire by early humans, as has often happened in other savannas associated with early human occupations (Gil-Romera *et al*. 2010). Cork oak has competitive advantages over other tree species when facing disturbances such as periodic burning, given its high re-sprouting capability and insulating bark composed of cork (Pausas 1997; Panel 1).

Cork has been harvested and used by humans since remote antiquity; the first known description, by the Greek philosopher Theophrastus, dates to the 4th century BCE. The Roman poet Virgil (70–19 BCE) noted that soldiers of Latium (a region, located in the western-central Italian Peninsula, associated with ancient Roman civilizations) covered their heads with "stripped bark from trees", an apparent reference to cork oak bark. During the Middle Ages, Portugal exported cork to other European countries (Aronson *et al*. 2009). However, cork only gained genuine commercial importance in the 18th century, as the need for cork bottle stoppers increased with the expansion of the trade in bottled wine. From the 19th century onward, there was a sustained effort to expand the existing areal extent of cork oak lands – most notably in the Iberian Peninsula – in direct response to the increasing value of cork in international markets (Bugalho *et al*. 2009).

Traditionally, cork oak savannas are low-input management systems. Cork is manually harvested from living trees once every 9–12 years. A shifting rotation is generally practiced, whereby encroaching shrubs are cleared at intervals of 4–7 years to reduce the risk of severe wildfires and to promote the establishment of pasturelands or annual crops (Pinto-Correia 2000). This rotation creates an ever-changing mosaic of land uses and habitat types of high conservation value (Diaz *et al.* 1997).

Associated biodiversity

Cork oak savannas are protected ecosystems under the Pan-European network of protected areas (Natura 2000) and can be considered a "biodiversity-based product system", as defined by the Convention on Biological Diversity. The variety of habitats that coexist within cork oak savanna ecosystems supports a diversity of animal and plant species (Figure 2). Human management has favored habitat heterogeneity and biodiversity at local and regional levels, creating a multiplicity of ecotones (see Blondel [2006]). For example, more butterfly and passerine bird species have been found in cork oak savannas than in adjacent closed-canopy oak woodlands, grasslands, or croplands (Diaz *et al.* 1997). The long-term habitat continuity offered by the evergreen cork oak trees benefits a wide range of species, whereas the open tree structure and the shrubland–grassland matrix of managed oak savannas provide habitat for several critically endangered species – including the Spanish imperial eagle (*Aquila adalberti*), the Eurasian black vulture (*Aegypius monachus*), and the Iberian lynx (*Lynx pardinus*), among others (Carrete and Donázar 2005).

Mediterranean oak savannas are also crucial for overwintering bird populations. The supply of acorns in oak savannas contribute to attract approximately 70 000 Eurasian cranes (*Grus grus*) and 6 million woodpigeons (*Columba palumbus*) to the Iberian Peninsula alone (Diaz *et al*. 1997). Many other migratory and overwintering birds transiting between northern Europe and Africa also use Iberian and other oak savannas (Blondel *et al*. 2010).

The understory grasslands found in oak savannas are predominantly composed of annuals that survive the hot and dry Mediterranean summers as seeds in the soil, resulting in a relatively high turnover of plant species composition between years. More than 135 species of vascular plants can be found per 0.1 ha of cork oak savannas (Diaz-Villa *et al*. 2003), including a diversity of shrub species.

Contrasting socio–economies

The Mediterranean Basin has been characterized by high human population densities for millennia, but differences in the intensity of human land use between southern Europe and northern Africa in recent years are differentially affecting cork oak savanna systems. The "active rural population" – the number of economically active persons engaged in agriculture, hunting, forestry, or fishing – is decreasing in southern Europe but is steadily increasing in northern Africa (Figure 3).

Disregard of traditional land-use systems and land abandonment is generally widespread throughout most of Mediterranean Europe. In the European Union (EU), agriculture is supported by a set of programs and subsidies (eg direct payments to farmers, subsidizing exports) known as the Common Agricultural Policy (CAP). Agri–environmental schemes (AES) were also established under CAP to protect biodiversity by reducing the negative effects of agriculture (eg reductions in the use of pesticides and/or fertilizers) and promoting environmentally friendly practices, including traditional farming, through compensating payments to farmers. Because they were rarely integrated with other CAP policies, AES had limited success in counteracting land abandonment trends; for example, landowners in areas that were authorized to receive AES support for maintaining traditional farming could receive higher payments if they converted their croplands to forest plantations (Pinto-Correia 2000). Moreover, the environmental targets of AES were frequently ill-defined (Baylis *et al*. 2008).

In Mediterranean Europe, land ownership is predominantly private, and cork harvesting is the primary economic driver for the management of cork oak savannas. Livestock production, mainly cattle, is also a source of income, supported by CAP payments to farmers who own livestock, based on a per-head basis. Although grazing is important to maintain the open savanna structure and to control shrub encroachment, CAP per-head basis payments may encourage overgrazing and lead to tree regeneration failure in some areas. Decreasing revenues, partially due to reduced market prices of cork, are contributing to an increasing trend of land abandonment and subsequent shrub encroachment of cork oak savannas in southwestern Europe. In the absence of human activity, these ecosystems are quickly overgrown by native, flammable shrubs, such as *Cistus* spp, which in turn promotes an increased risk of severe wildfires (Joffre *et al*. 1999), loss of habitat heterogeneity, and, ultimately, a decrease in the area's conservation value.

In contrast, persistent human overuse of land and biological resources is common in many parts of northwestern Africa, where national policies are lacking or unable to counteract this trend. In this region, cork oak lands and cork harvests are generally owned by the state but local populations have access to woodland resources, such as fuelwood, which are intensively exploited for subsistence purposes. Overharvesting for fuelwood, overgrazing, and excessive collection of acorns for human and animal consumption are degrading tree cover, reducing oak regeneration, and jeopardizing the ecological sustainability of the system (Berrahmouni *et al*. 2007; Figure 4). Inappropriate cork stripping, including too frequent harvests and unintentional wounding by unskilled laborers, may damage individual cork oak trees and even result in tree mortality.

In sum, contrasts in the intensity of land use by humans are negatively affecting the ecological and socioeconomic sustainability of cork oak savannas in southwestern Europe and northwestern Africa (Table 1).

Payment for ecosystem services programs and cork oak savannas

Although their effectiveness as tools for conservation and sustainable resource management is debatable (eg Nelson *et al*. 2009), "payment for ecosystem services" (PES) programs are increasingly being applied (Daily and Matson 2008) as a means to mitigate ecosystem mismanagement, the loss of biodiversity, and the reduction in ecosystem services (Bennett and Balvanera 2007). Although various explanations as to what constitutes a PES exist, here it is defined as a reward extended to landholders who provide environmental benefits (eg water quality, biodiversity conservation) through appropriate land management practices (Wunder 2005; Engel *et al*. 2008). The concept has been applied in various ways, including government payments for watershed and aquifer protection in Mexico and Costa Rica, private payments to landowners for biodiversity protection in Bolivia and Australia, and payments made for carbon (C) sequestration in Ecuador (Engel *et al*. 2008) – to name just a few examples. Payment may be direct (ie in cash) or indirect (ie in-kind compensations, such as the provision of tree seedlings or beehives) and/or complemented by technical assistance for the development of management plans. Some PES projects generate positive benefits for the conservation of biodiversity, as well as improve human well-being (Tallis *et al*. 2008). We argue that PES programs can be applied to the conservation and restoration of overused cork oak savanna ecosystems, and extended to savannas where human disuse is endangering the persistence of this socio–ecological system. Conventional conservation instruments (eg protected areas, regulation) and AES have proved insufficient to safeguard cork oak savannas (Pinto-Correia 2000). PES are better adapted to human-shaped ecosystems, because they provide economic incentives for improved management practices and can be used to compensate landholders for clearly defined targets, such as C storage or other ecosystem services.

Carbon-related services of cork oak savannas

Similar to other types of savannas (Lehmann 2010), cork oak savannas play an important role in the global C budget. As with old-growth forests (Luyssaert *et al*. 2008), cork oak savannas accumulate and maintain C stocks for long periods. For instance, a cork oak savanna with an average tree cover of 30% may sequester up to 140 g C m^{-2} yr^{-1} (Pereira *et al*. 2007), a value within the range of savannas in California (Baldocchi and Xu 2004) and tropical areas (Murphy *et al*. 2010), and close to the range estimated for that of old-growth forests (Luyssaert *et al*. 2008). Cork harvest is a minor component of the tree C balance, representing approximately 4% of the total biomass produced between successive cork extractions, and therefore has negligible effects on ecosystem C storage (Pereira unpublished).

Both overuse and disuse affect the C balance of cork oak savannas.

In overused savannas, soil degradation and drought hamper tree regeneration and increase tree mortality, thereby reducing ecosystem C stocks (Tiessen *et al*. 1998). In unmanaged savannas, shrub encroachment shifts soil C from below- to aboveground plant biomass, increasing the risk of C losses through wildfires or other disturbances (Jackson *et al*. 2002). The reallocation of C to the shrub layer may facilitate the transition from mild surface fires to severe crown fires, and thus increase C emissions, while reducing tree growth and the potential for C sequestration (Murphy *et al*. 2010). Management for the prevention of severe wildfires

(Figure 4c) is thus crucial to avoid C losses and maintain cork production in cork oak savannas; such practices will also benefit biodiversity conservation, thereby allowing for a "bundling" approach to the implementation of PES programs (Wendland *et al*. 2010).

Mechanisms for cork oak savanna conservation and restoration

Economic incentives derived through PES schemes that encourage best management practices may contribute to the conservation and sustainable use of cork oak savannas (Figure 5). Such incentives may include product-based PES schemes (Wunder 2005) like the Forest Stewardship Council's (FSC) certification and incentives to promote forest conservation through mitigation of C emissions, as in the "Reducing Emissions from Deforestation and Forest Degradation and enhancement of carbon stocks" (REDD+)) mechanism (Stickler *et al*. 2009) or other compliance or voluntary markets of ecosystem services. To be applicable to cork oak savannas, PES programs should favor such practices as maintaining effective levels of oak regeneration, clearance of shrub understory in long rotational periods, maintenance of uneven age classes of trees, and decreasing intensity of land uses (eg Rey Benayas *et al*. 2008), particularly grazing. PES designs developed for sites in southwestern Europe will likely be different from those created for sites in northwestern Africa. In Europe, PES programs must compensate land users for maintaining management practices that generate added value products (eg FSC-certified cork) or ecosystem services; in North Africa, PES programs must be directed toward improving local livelihoods through the prevention of land overuse and degradation of ecosystem services (eg REDD+).

Forest Stewardship Council certification

The FSC is a non-governmental organization that was created to promote responsible management of the world's forests by adding market value to forest products generated according to environmental, social, and economic principles (Auld *et al*. 2008). FSC certification is based on a standard of forest management covering issues that include land tenure, use rights and responsibilities, rights of indigenous peoples, and biodiversity conservation, among others. The FSC standard for certification is flexible, to account for different conditions in different countries through collaboration of stakeholders representing environmental, social, and economic interests (Auld *et al.* 2008). The process, which is voluntary and conducted at the request of landowners, is based on an independent audit of landholder management practices. Application of FSC certification to the management of cork oak savannas in Portugal, Italy, and Spain is progressing, with 56 000 ha certified thus far, and is under development in Morocco and Tunisia (Berrahmouni *et al*. 2009).

In addition to forest management, 26 cork companies worldwide (including 10 in Portugal and seven in the US) have certified their "chains of custody" – the pathways taken by raw and processed materials and products from the forest to the consumer – with the FSC standard. This implies industry compliance in the use of raw materials originating from FSC-certified forests. As a result, FSC-certified cork stoppers are now in demand with several wine producers and bottlers in South Africa, the US, Spain (Berrahmouni *et al*. 2009), and the UK; for instance, Sainsbury, one of the largest supermarket retailers in the UK, has committed to using only FSC-certified cork stoppers in all of their bottles for store-brand wines . This sort of added market value of FSC certified cork will provide financial incentives for the responsible management of cork oak savannas, given that added benefits are expected to outweigh management costs (Berrahmouni *et al*. 2009).

REDD+ mechanisms

Approximately 15% of global C emissions result from deforestation and forest degradation in the tropics (van der Werf *et al*. 2009). The REDD+ mechanism aims to avoid C emissions through the provision of financial incentives that reduce the rate of forest clearing and degradation and by increasing C stocks through regeneration, rehabilitation, or restoration of forests in developing countries. REDD+ was recognized as a crucial mechanism for reducing C emissions at the UN Framework Convention on Climate Change meeting in Copenhagen, Denmark, in December 2009, where members agreed to set up an international fund to implement REDD+ programs (UNFCCC 2009). Early financial flows associated with REDD mechanisms reached US$6 billion, easily surpassing international conservation funding flows, which were below US$1 billion for the 10-year period 2000–2009 (Stickler *et al*. 2009).

REDD+ is designed to support large-scale ecological restoration activities (Galatowitsch 2009) that could be applied to degraded and overused northwestern Africa cork oak savannas. It could also fund management practices such as reducing overharvesting of fuelwood, which would increase C stocks and also benefit biodiversity conservation.

Promotion of more sustainable livelihoods can be achieved through the provision of direct payments or in-kind benefits to rural and local populations (Tallis *et al.* 2009). Positive social impacts can be generated from REDD+ by, for example, providing compensation or technical assistance to rural communities for the development of alternative energy and livelihood strategies that avoid the overharvesting of fuelwood (Lawlor *et al.* 2010). Restoration of degraded northwestern African oak savannas would also serve to mitigate the deterioration of ecosystem services, such as water regulation, thereby benefiting local human populations. Both FSC and REDD+ programs indirectly target biodiversity conservation as well.

Other services and possible PES schemes

Other funding sources for PES may come from user fees, taxes, or voluntary donations (Wunder *et al*. 2008). In some countries there are existing legal frameworks that could be used in the conservation of cork oak savannas. In Portugal, for instance, a public fund to promote wildfire prevention through best management practices was created through a petrol tax (US$0.007 per liter) after the country experienced severe wildfires in 2003. Public funding schemes such as this could be made available to finance best management practices (eg avoiding shrub encroachment) in cork oak savannas using, for example, FSC standards and certification as a validation tool (Lawlor *et al.* 2010).

Voluntary markets of ecosystem services, where the beneficiary of the service pays directly to the ecosystem manager providing the service, are growing substantially (Wendland *et al*. 2010). In Victoria, Australia, the government compensates landholders for habitat conservation efforts (Stoneham *et al*. 2003). Corporations with strong social and environmental responsibility policies are providing funds for biodiversity conservation, as well as targeting water-related ecosystem services. In France, Vittel Nestlé – a water bottling corporation – pays farmers with lands upstream of their facility to conduct agricultural practices that preserve water quality (Wunder *et al*. 2008). In the Iberian Peninsula, where water is scarce and likely to become scarcer (Schroter *et al*. 2005), many cork oak savannas are situated within watersheds associated with impoundments used for irrigation or located over aquifers (eg cork oak covers 36% of the main aquifer in Portugal; WWF-Mediterranean unpublished). Water-related PES schemes can potentially be implemented in cork oak savannas, but research linking the effects of management practices on water dynamics is still lacking in these ecosystems. Table 2 summarizes the main features of PES discussed above.

Conclusions

Human-shaped ecosystems with high conservation value, such as cork oak savannas, can only be maintained through sustainable use based on market viability. Lack of economic incentives to management, due in part to global market devaluation of cork, is leading to land abandonment, biodiversity losses, and degradation of ecosystem services of southwestern European cork oak savannas. In contrast, poverty-driven overuse is endangering northwestern Africa cork oak savannas. Well-designed PES schemes could provide an opportunity to promote sustainable use, conservation, and large-scale restoration of southern and northern Mediterranean cork oak savannas.

Acknowledgements

We thank C Fontaine, S Cerasoli, C Moura, R Jackson, R Ryel, L Silva, D Porej, and HM Pereira for helpful comments that greatly improved the manuscript. Funding was provided by CREOAK project (EU R&D Fund project number QLK5-CT-2002-01596) and Portuguese National Science Foundation projects POCTI/AGG/48704/2002, POCI/AGR/63322/2004, and PTDC/AGR-AAM/098790/2008.

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Table 1

Table 1. Examples of human use and main ecosystem services of five cork oak savannas in the Mediterranean Basin

Site	*Location*	*Area (ha)*	*Human use*	*Drivers*	*Indicators*	*Ecosystem services*
Akfadou, Algeria	36°41'N 04°27'E	11 000	Overuse	Overgrazing; overharvesting of fuelwood	No natural regeneration; even-aged woodlands; oak savanna degradation	Fuelwood; cork; pasture; prevention of severe wildfires
Maamora, Morocco	33°51'N 06°51'W	70 000	Overuse	Overgrazing; overharvesting of fuelwood and acorns	No natural regeneration; oak savanna degradation	Fuelwood; cork; acorns; pasture; prevention of severe wildfires
Machoqueira do Grou, Portugal	39°60'N 08°22'W	2500	Toward sustainable use	Low grazing; sustainable management (eg FSC certification)	Natural regeneration; multi-age oak savannas	FSC-certified cork; pasture; prevention of severe wildfires; *carbon; biodiversity conservation*
Parc Natural de la Serra d'Espadà, Spain	39°55'N 0°22'W	7000	Land abandonment	Shrub encroachment; no grazing	High risk of crown fires; natural regeneration	Cork; carbon; *biodiversity conservation*
Aspres and Albères, France	42°33'N 03°01'W	15 000	Land abandonment	Shrub encroachment; no grazing	High risk of crown fires; natural regeneration	*Carbon*

Notes: Drivers related to management practices and indicators to current state of the savannas are also listed. Ecosystem services include services from which people obtain direct benefits (eg cork, pasture) and others (in italics) for which they are not currently compensated (eg long-term carbon storage). Sources: personal knowledge of the authors and examples from Aronson *et al.* (2009).

Table 2

Table 2. PES mechanisms to compensate landholders for services that they can provide but are not still compensated for in cork oak savannas

Targeted	*Paid for*	*Who buys?*	*Who else benefits?*	*Who sells?*	*Mechanism*
Carbon	Best management practices; oak savanna restoration; oak regeneration	Government; corporate sector	Global community; local community	Landholder	REDD+; FSC; voluntary market; compliance market
Biodiversity	Best management practices	Government; corporate sector; conservation NGOs	Global community; local community	Landholder	REDD+; FSC; voluntary market
Water	Best management practices	Government; municipalities; water companies; downstream users	Local farmers; local community	Landholder	Voluntary market

Notes: Carbon storage, biodiversity conservation, and potential water regulation services can be targeted through payment of best management practices. These services can be bought through public (eg government) or private (eg corporations) funds benefitting the global or local communities. In North African countries, local communities, which do not hold the land but exploit the resources, must be rewarded for sustainable management practices that simultaneously enhance their livelihoods. Adapted from Wunder *et al.* (2008).

Panel 1. *Quercus suber*: a tree with a unique bark

Cork oak is a long-lived (up to 200 years or more) evergreen tree, native to the western Mediterranean Basin (Figure 1). Its outer bark is composed of a compact, elastic, and thermally insulating tissue of dead cells with highly impermeable walls (Pereira 2007). Each year, cork oak trees produce a new cork ring that is not shed naturally. This feature, extremely rare in the plant kingdom, has evolved as protection against the periodic fires common throughout the Mediterranean (Pausas 1997).

Cork is extracted without felling the tree. Once the cork is removed, the original phellogen cells die but another layer of active phellogen differentiates in the outer phloem, maintaining the production of cork. The cork oak tree is unique in its high capability to regenerate a new outer bark after harvest (Pausas 1997). The first cork harvest is conducted when the tree is approximately 30 years old. Thereafter, harvests are practiced at 9- to 12-year intervals, the time necessary for the trees to grow a new layer of bark of ca 30-mm thick.

Approximately 300 000 tons of cork are harvested annually in the western Mediterranean Basin, 70% of which is transformed into bottle stoppers. Other products include flooring, insulation material (eg for the external fuel tanks of NASA's Space Shuttle program), clothes and accessories, or decorative objects. Globally, cork is the sixth most important non-timber forest product, with an estimated annual export value of US$329 million, while processed cork products generate approximately US$2 billion in annual revenues (Berrahmouni *et al*. 2007). However, the use of synthetic stoppers and metal screw-caps increases economic competition with traditional cork stoppers and has contributed to world market devaluation of cork (Aronson *et al*. 2009), with prices declining approximately 30% between 2003 and 2009.

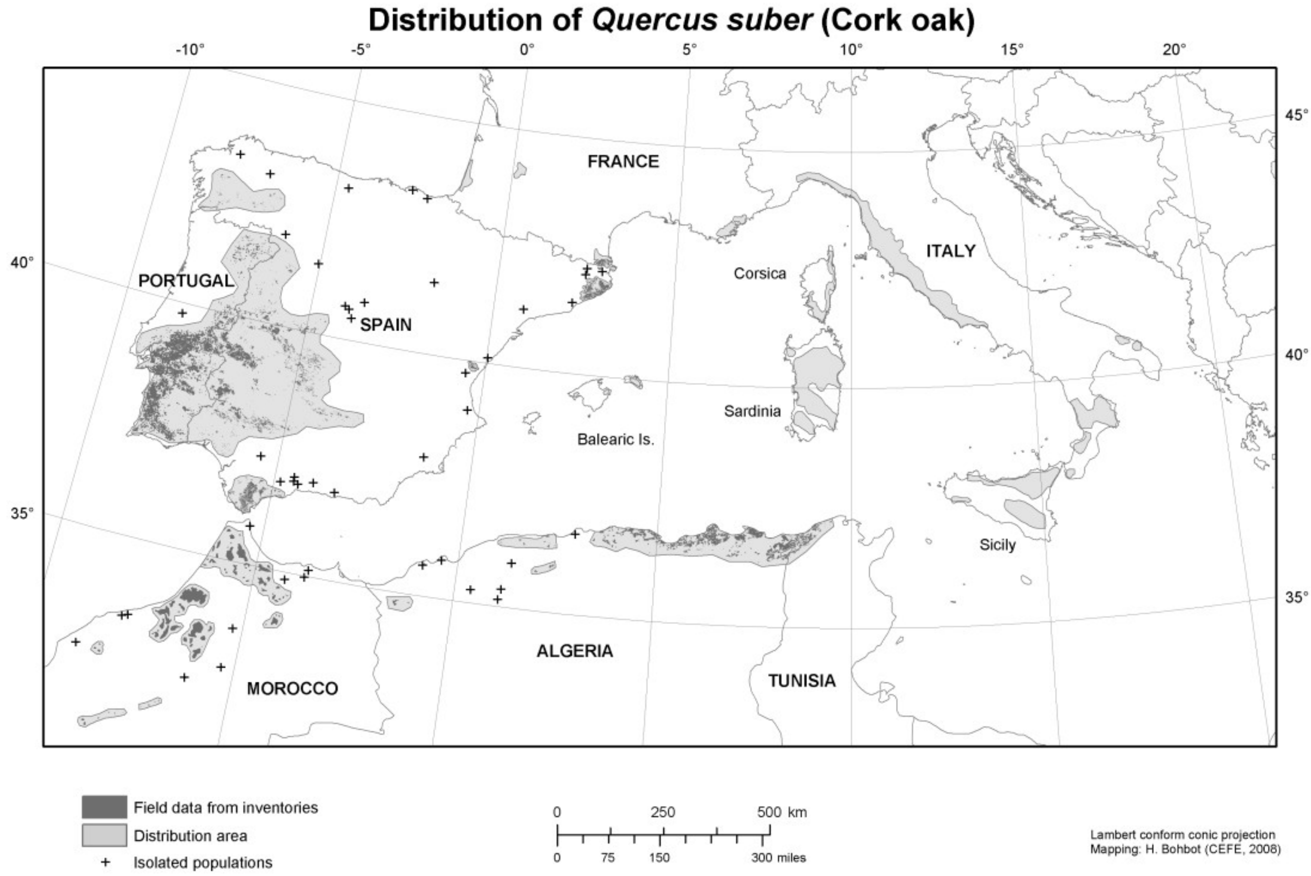

Figure 1. Distribution of cork oak in the western Mediterranean Basin. Reproduced from Aronson *et al*. (2009), Copyright © 2009 Island Press. Reproduced by permission of Island Press, Washington, D.C.

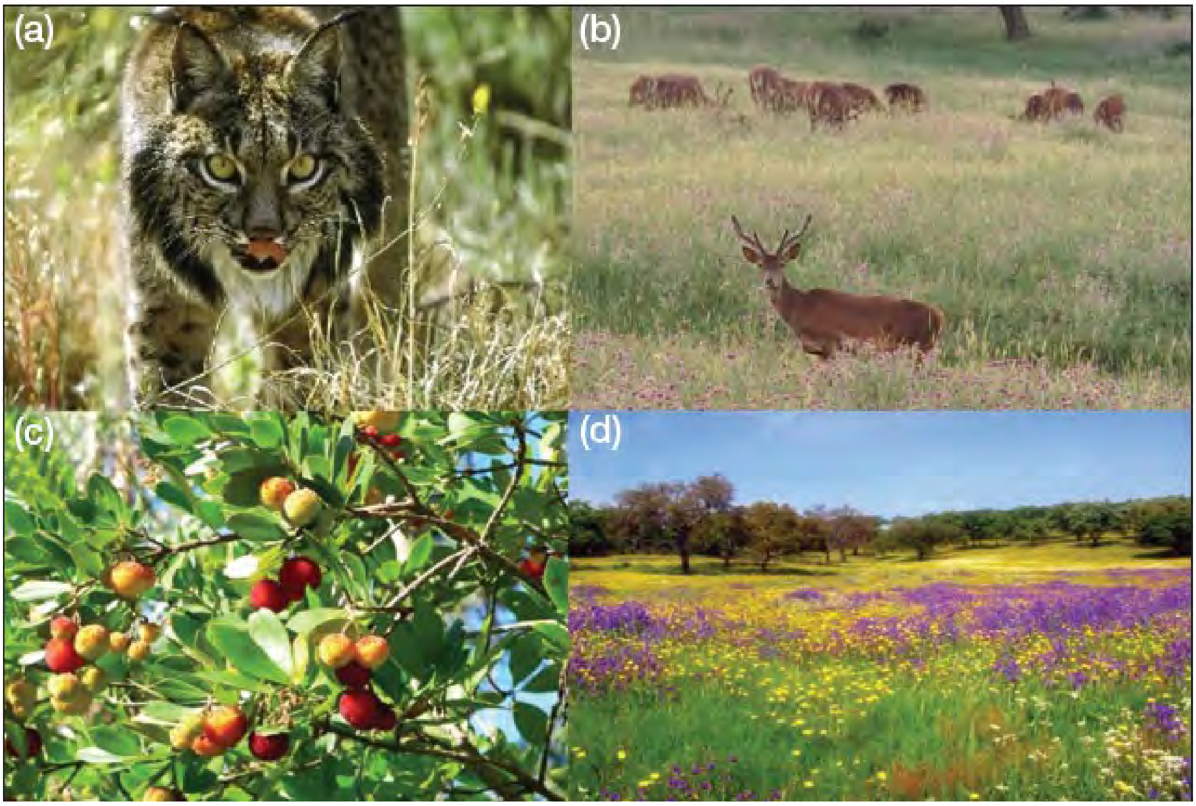

Figure 2. (a) The Iberian lynx (*Lynx pardinus*), a critically endangered feline, and (b) the North African Barbary deer (*Cervus elaphus barbarus*), which is the only deer species occurring in North Africa, both use cork oak savannas; (c) shrub species commonly occurring in these savannas include the strawberry tree (*Arbutus unedo*); (d) Mediterranean grasslands, such as this one in southern Portugal, support a high diversity of species.

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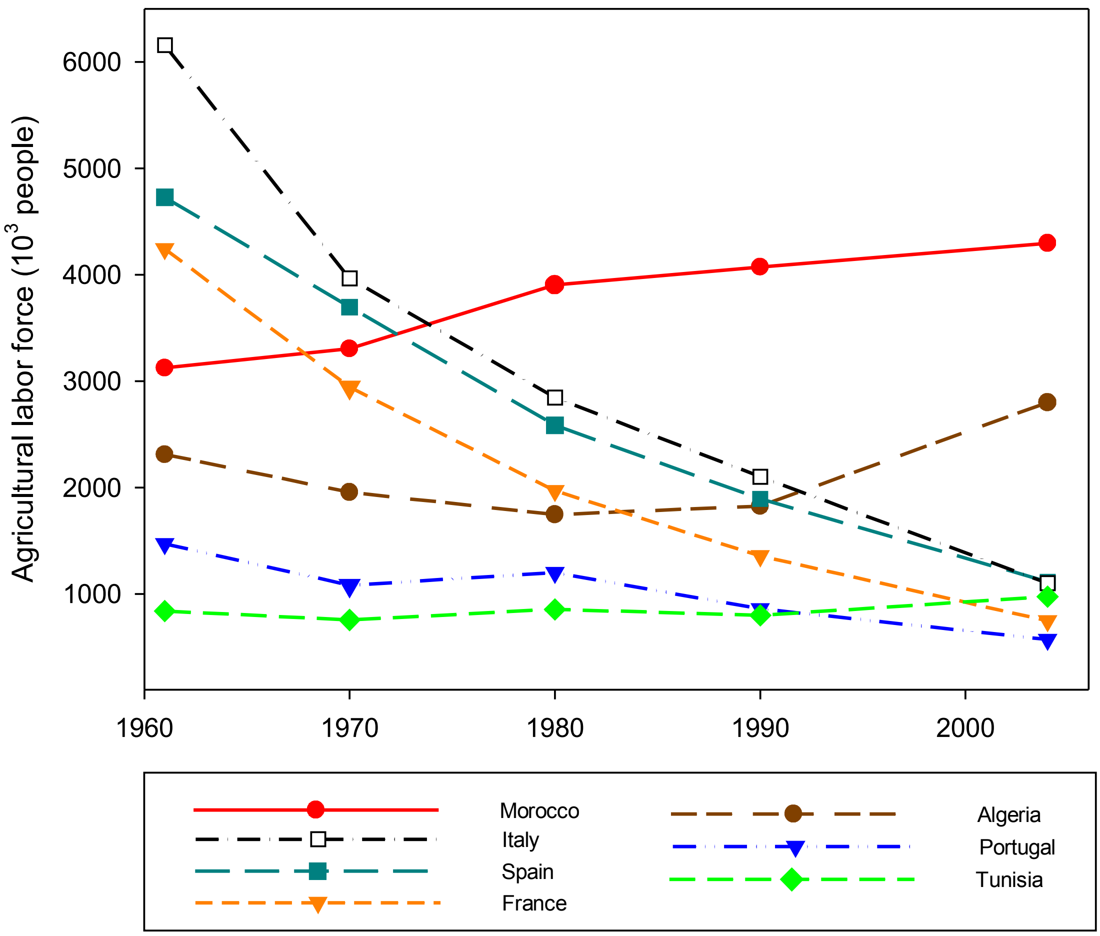

Figure 3. "Active rural population" (see main text) in countries of the western Mediterranean Basin where cork oak savannas occur, 1961–2005. Data obtained from FAOSTAT (http://faostat.fao.org/).

Figure 4. (a) Cork is extracted manually every 9–12 years. (b) After abandonment, the system undergoes shrub encroachment; this fenced plot has been unmanaged for 12 years, and a dense canopy of *C ladanifer* (averaging 2.5 m in height) has formed. (c) Cork oak savanna one year after a severe wildfire; the unburned patch was regularly cleared of shrubs by the landholder. (d) A Moroccan site displays evidence of overuse – including oak mortality, a scarcity of juvenile trees, and overgrazing. The women are harvesting acorns.

Photo credits:
(a) APCOR
(b) M Bugalho
(c) P de Jesus
(d) © WWF Mediterranean / N. Berrahmouni

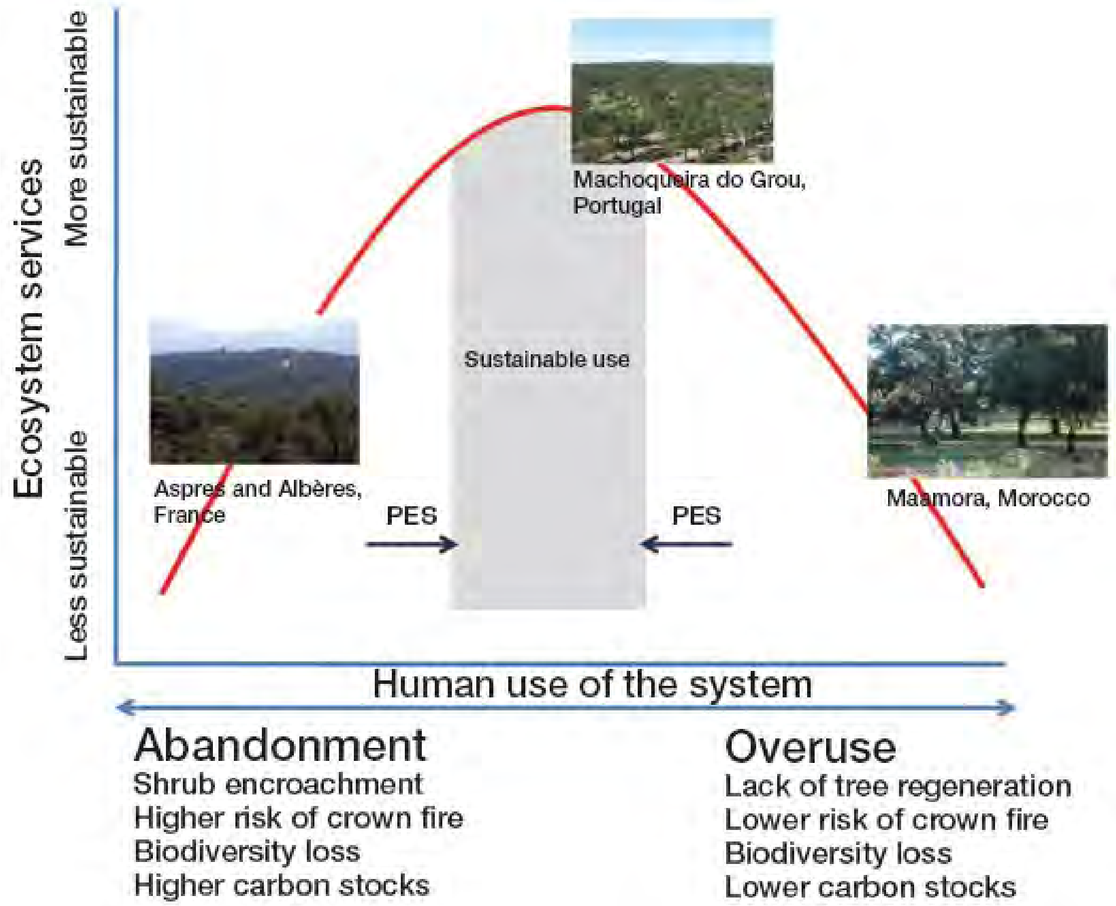

Figure 5. Ecosystem services provided by cork oak savannas depend on the intensity of human use. Both abandonment (eg Aspres and Albères, France) and overuse (eg Maamora, Morocco) are detrimental to biodiversity conservation, but a tradeoff is attained in relation to ecosystem services such as carbon storage. For example, shrub encroachment implies higher aboveground carbon storage but also higher risk of severe wildfires and carbon losses. Sustainable management of the system (eg Machoqueira Grou, Portugal, an FSC-certified site) provides sustained ecosystem services. Application of PES mechanisms may contribute to achieve sustainability.