Oak trees and woodlands providing ecosystem services in Southern Spain

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Introduction

The concept of ecosystem services, meaning the benefits people obtain from ecosystems, has gained widespread acceptance among scientists, managers and politicians since its use in the Millenium Ecosystem Assessment (MEA, 2005). Trees, woods and forests provide direct provisioning services (timber, fuel, food, meat), indirect regulating services (air and water quality, mitigation of climate change, soil protection), and cultural services (recreation, aesthetic, landscape, historic and cultural values) all of them contributing to human well-being.

The analysis and evaluation of the variety of ecosystem services provided by trees and woods make people aware of how dependent we are, in so many ways – food, economy, culture, psychology – of this natural capital. The study of the trends of ecosystem services and the drivers promoting their changes can be used as a valuable tool for a better management of trees and woods avoiding their degradation.

The research on ecosystem services has increased during the last decade impelled by diffusion of the MEA report (Vihervaara et al., 2010). For example, in 2010 up to 148 papers were published in indexed journals, with the keywords “ecosystem services” and “forest” representing about 20% of the total number of papers on ecosystem services.

In this work we present an overview of the main ecosystem services provided by oak trees, woodlands and forests in southern Spain, and the main conclusions obtained from the evaluation of their trends and drivers of change (see Marañón et al., 2012).

Oak trees and woodlands in southern Spain

Oak woodlands and forests occupy about 1,200,000 ha in the Andalusian region, southern Spain (figure 1). Dominant tree oak species are the evergreen *Quercus ilex* subsp. *ballota* (Holm oak) and *Q. suber* (cork oak); the semi-deciduous *Q. pyrenaica*, *Q. faginea* and *Q. canariensis* are also abundant in the region. The arborescent shrub *Q. coccifera* (Kermes oak) is frequent in shrublands whereas the prostrated *Q. lusitanica* is rare (Urbieta et al., 2011).
During the last 50 years, most of the oak woodlands (82%) have remained whereas about 183,000 ha have been transformed into agricultural and urban areas (Bermejo et al., 2011). In general, the total area occupied by woodlands and shrublands in southern Spain, representing about 40% of the total, has varied little in 50 years but the relative composition has changed strikingly, mainly through extensive plantations of pines and eucalyptus.

**Provisioning services**

Oak trees and woodlands provide raw materials like cork, wood and fuel, and fodder for wild and domestic animals. Forested basins are sources of good quality fresh water. Woodlands are also reservoirs of tree genetic resources (*Quercus* genotypes adapted to local conditions) and local races of domestic animals breed in oak sylvopastoral systems. Singular provisioning services of these oak woodlands are cork and the high-quality meat produced in “dehesas” (savanna-like oak woodlands).

About 40,000 tons/year of cork are extracted from *Q. suber* trees in Andalusia, representing 60% of the total Spanish production (figure 2A). The high price of this oak-produced commodity started with the large-scale industrialisation of cork stoppers for wine bottles in the nineteenth century and it has contributed to the conservation and sustainability of cork oak forests (Marañón and Ojeda, 1998; Urbieta et al., 2008; Carvalho and Graça, 2009).
Every single tree of *Q. suber* more than 20-30 years old has marks of the cork harvest through stripping off its bark (figure 2B). That harvest is done manually every 9-10 years after the cambium layer regenerates producing a new cork layer (Carvalho and Graça, 2009). Thus, almost all cork oak trees in this region are “culturally modified trees” (Samojlik, 2012) because of this provisioning service.

Despite its unquestionable economic value, several sylvicultural practices associated with cork extraction, such as shrub-clearing, may interfere with current objectives of conservation and sustainable use of biodiversity in cork oak woodlands (Pérez-Ramos *et al*., 2008).

The oak-savannas known as “dehesas”, with scattered Holm oak (*Q. ilex* subsp. *ballota*) trees and mostly annual grasslands, have been traditionally managed to raise free-range animals and produce high-quality meat, in particular from the local race of Iberian pigs feeding on acorns (figure 3). The beneficial effects of single oak trees on this semi-arid environment are many and inter-related. For example, the amelioration of extreme temperatures, reduction of water loss and photo-inhibition, and enrichment of topsoil nutrients by pumping from deeper layers. Oak trees modify the composition, biomass and diversity of the herbaceous communities and generate a higher landscape-scale diversity (Marañón *et al*., 2009). This silvopastoral system provides habitats for wild animals from both woodland and grassland habitats, contributing to a higher biodiversity at the landscape scale (Díaz, 2009).
Figure 3. Native races of Iberian pigs feeding on acorns of Holm oak (*Q. ilex* subsp. *ballota*) in a “dehesa” silvopastoral system (Photo: T. Marañón).

**Regulating services**

Oak trees and woodlands provide a climate regulating service by their capacity to sequester carbon and therefore to mitigate the effects of climatic change. They regulate the quality of air and water and contribute to soil formation and protection from erosion. Other regulating services are the reduction of risks from flooding, and the increase of biological control and of pollination by insects associated with oak ecosystems.

Oak trees and woodlands in southern Spain sequester about 0.23 Mg (equal to metric tons) of C ha\(^{-1}\) year\(^{-1}\) building a total storage of about 5,000 Mg of carbon (figure 4). Shrublands (including those dominated by *Q. coccifera*) are the greatest carbon reservoir in the region, followed by pine forests, oak woodlands and silvopastoral “dehesas” (figure 4). The effectiveness of this regulating service has globally increased during the last 50 years to 17 Tg (million tons) mainly due to pine plantations and the intensification of agriculture; however the carbon stored in oak woodlands have decreased by about 462 Mg (Muñoz-Rojas *et al*., 2011).
Forests and shrublands protect soil from erosion. About 11% of Andalusian lands are affected by “very high” soil erosion rates (losses above 100 Mg ha\(^{-1}\)) and 15% by “high” soil erosion rates (losses between 50-100 Mg ha\(^{-1}\); figure 5). Oak trees and woodlands intercept rainfall and protect soil from wind and water erosion, and with their strong roots maintain the soil structure in particular on steep slopes.

Figure 4. Changes in carbon stocks during the period 1956-2007 in different types of forests and shrublands in southern Spain.

Figure 5. Bare soil exposed to erosion in Tabernas Desert (Almería, South Spain). Source: SEISnet Soil Data Bank (www.evenor-tech.com).
Cultural services

Oak trees and woodlands belong to the cultural and historical heritage of southern Spanish people. They are also important for their physical and psychological well-being. Urban populations are increasing their demand for cultural services provided by oak woodlands, mainly for recreation, ecotourism, and to enjoy their aesthetic and spiritual values. At the same time, the abandonment of rural areas is giving rise to a loss of cultural services associated with local knowledge and cultural identity, as well as a deterioration of cultural diversity in silvopastoral landscapes.

During the last decades, a better scientific knowledge and improved environmental education has changed the perception and attitude of people towards nature and about oak trees and woodlands in particular. More than 20% of the regional area is under some kind of environmental protection. Public efforts have been directed to increase the knowledge and sensitivity of school children for trees and woodlands (e.g., see JA, 2006, figure 6A). Singular trees have been inventoried based on their “singular shape, old age, exceptional size, landscape value, history or popular tradition, or rareness” and their descriptions and locations have been disseminated (JA, 2003, figure 6B).

![Image A](image1.png)

![Image B](image2.png)

Figure 6. (A) Key to identify five oak species in a field guide for school children (JA 2006). (B) Cover of the inventory of singular trees and woods for the province of Cádiz (JA 2003).

A remarkable case is the conservation conflict with the centennial oaks in Doñana Park. They are used by colonies of water birds to nest and represent “icons” for bird conservation (figure 7). However, the trees are declining through multiple causes, including the effects of the bird colonies (García et al., 2011).
Figure 7. Decline of centennial cork oaks (*Q. suber*) in Doñana National Park (Photo: T. Marañón). In the upper left corner insert, a sticker of the Doñana National Park depicting an iconic cork oak (*Q. suber*) supporting bird nests.

**Trends and drivers of changes**

The general trends of ecosystem services provided by trees and woodlands in southern Spain during the last 50 years have been either stable for some services or increasing for other services associated with a greater wooded area and density. However, some services have declined, such as those related to the reservoir of local breeds of livestock grazing on woodlands. Cultural services associated with rural populations, like the local ecological knowledge and the cultural identity attached to trees and woods, have also declined due to the abandonment of small villages (Marañón *et al.*, 2012).

Land use change is the main driver affecting oak trees and woods and their services. During the last 50 years, about 20% of the forested area in the region has been transformed for other uses, mainly intensive agriculture and urbanisation. On the contrary, the last 30 years have seen shrub colonisation of abandoned marginal agricultural lands and afforestation of cultivated lands subsidized by the Common Agricultural Policy (Bermejo *et al.*, 2011). A kind of land use change is the increasing pressure from herbivores due to there being the highest livestock density in “dehesas” (partly thanks to the subsidies) and the highest density of red deer in oak forests (by a higher valuation of the game industry). As a result, oak regeneration is being limited region-wide (Urbiet (*et al.*, 2011).
The invasion of exotic organisms, frequently related to the global trade of forest products, can be a major driver of change. For example, the oomycete *Phytophthora cinnamomi* introduced from Asia is having a negative effect on oak roots and contributing to massive mortality, mainly of Holm oaks (*Q. ilex* subsp. *ballota*) and cork oaks (*Q. suber*), and thus threatening the persistence of the oak “dehesa” system and its services (Carrasco *et al.*, 2009).

Climate change has had a moderate effect on oak trees and woodlands during the last decades but it is expected to increase in the future. Plant species with cold-tolerance that grow in higher altitudes (for example in the Sierra Nevada, around 3,500 m) would be displaced by other less-tolerant but better competitor species (including oaks), with the effects of global warming. Theforeseen reduction in precipitation would especially have an effect on the Tertiary relics, like *Rhododendron ponticum* subsp. *baeticum*, already with limited natural regeneration (Mejías *et al.*, 2007).

Air, water and soil pollution have local effects on growth and composition of forests near chemical industrial or mining areas. A remarkable case is the pollution of about 4,000 ha of agricultural lands in the Guadiamar valley after a mine spill in 1998. The area has now been cleaned, remediated and afforested with native trees and shrubs, including oaks (Dominguez *et al.*, 2008).

Socio-economic changes, rural depopulation, trade globalisation and the global transport of organisms are indirect drivers affecting oak trees and woodlands through land-use change, climate change, the action of exotic pathogens or pollution (direct drivers).

The Andalusian society has responded to the socio-ecological changes in the last decades by modifying the tools and strategies of managing oak woodlands, and forests in general. The challenge for the future is to stop degradation of forest systems and promote the sustainability of their services. Among the adequate tools are environmental legislation, payments for ecosystem services, clean technologies, adaptive management in collaboration with local people, and environmental education.

**Conclusions**

The evaluation of ecosystem services has proved to be a useful tool for understanding and managing oak trees and woods in southern Spain.

Singular provisioning services, such as cork and high-quality meat, contribute to the conservation and sustainable management of cork oak forests and holm oak savannas (*dehesas*). Regulating and cultural services are increasingly valued by the public.

Changes in land-use during the last 50 years represent the main direct driver affecting the extension and composition of oak forests.

As an indirect driver, socio-economic conditions have changed drastically in Southern Spain during the last 50 years, inducing changes in land use and in population settlements.
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(abandonment of rural areas). Andalusian society has experienced strong cultural and political changes, reflected in their perception and attitude towards oak trees and forests, and therefore in their management and legislation.

There is a need to develop methods in adaptive management and decision support systems to solve conflicts and to favour synergies between different ecosystem services.

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