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Evaluation of forest ecosystem services in Mediterranean areas. A regional case study in South Spain

María Anaya-Romero [a,*], Miriam Muñoz-Rojas [b,c], Beatriz Ibáñez [d], Teodoro Marañón [d]

[a] Evenor-Tech, Centro de Empresas Pabellón de Italia, 5ª planta, pasarela NO-SO, C/ Isaac Newton, 4. Parque Científico y Tecnológico Cartuja, 41092 Sevilla, Spain
[b] The University of Western Australia, School of Plant Biology, Crawley, 6009 WA, Australia
[c] Kings Park and Botanic Garden, Kings Park, Perth, 6005 WA, Australia
[d] IRNAS, CSIC, Avenida Reina Mercedes 10, 41012 Sevilla, Spain

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ABSTRACT

An ecosystem services approach entails the development of a set of evaluation tools in order to quantify the benefits and vulnerabilities of each ecosystem. In this context, the current research explores the conceptualization of different evaluation tools for representative forest ecosystem services in Mediterranean areas.

Mediterranean forests provide a wide range of ecosystem services, nevertheless they have to confront various threats such as deforestation, fires, and urban/industrial development. The Mediterranean region has suffered intense changes in land use over the past several decades such as intensification of agricultural and urban development, while marginal croplands have been abandoned and reforested. Thus, the dynamics of land use change have become an important driving force for the potential impact on ecosystem services. Quantifying the magnitude of land use change is therefore essential to estimate its consequences on ecosystem services.

Taking this into account, the general aims of this research are (a) to evaluate the state and trends of forest ecosystem services at regional scale in Andalusia (South Spain), (b) to contribute to the methodology for accounting three main forest ecosystem services: carbon storage, protection of soil erosion, and cork oak provisioning, and (c) to assess how theses ecosystem services are affected by drivers of change, such as land use change. In this sense, the main results are the methodologies for the standardization and harmonization of the types of forest ecosystems using the mappings of land use (LULCMA), obtaining an objective quantification of the balance of surface supplying forest ecosystem services, and monitoring over time.

1. Introduction

The concept of ecosystem services (ES) has been discussed by scientists and stakeholders for decades (Long, 1972; Costanza, 1997; De Groot et al., 2002; Boyd and Banzhaf, 2007; Fisher et al., 2009; Braat and de Groot, 2012; Schwilch et al., 2016). This concept has been broadly used since the United Nations (UN) launched the Millennium Ecosystem Assessment (MEA), 2005, in which ecosystem services were defined as "*the benefits that human obtain from ecosystems*" (MEA, 2005). A more recent definition of ES states that they "are the direct and indirect (flux of) contributions of ecosystems to human well-being" (Braat and de Groot, 2012). The aim of the MEA was to provide decision makers and the public with scientific information about the effects of global change drivers on ecosystems worldwide, and the consequences of ecosystem degradation for human well-being (Schröter et al., 2005). Other frameworks to improve or complement the MEA are the Economics of Ecosystems and Biodiversity (TEEB, 2010) and the Common International Classification of Ecosystem Services (CICES, Haines-Young and Potschin, 2013). Within the European context several Directives, such as the European Biodiversity strategy, the Habitats Directive, the Water and the Soil Framework Directives and the Marine Strategy Framework Directive, include action programs related with the maintenance and improvement of ecosystem services.

Interdisciplinary efforts are required to quantify and map the most important ecosystem services in a region or country (Naidoo et al., 2008; Maes et al., 2013). Research at local and regional scale on ecosystem services will provide us with a better understanding

* Corresponding author.
E-mail addresses: m.anaya@evenor-tech.com (M. Anaya-Romero), miriammunozrojas@gmail.com (M. Muñoz-Rojas), bibanez@irnase.csic.es (B. Ibáñez), teodoro@irnase.csic.es (T. Marañón).

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of the socio-ecological system and will help to guide local policy-makers to implement ecosystem services when planning for conservation and sustainable development (Egoh et al., 2007; Vihervaara et al., 2010). Several countries in Europe have already published national ecosystem assessment. The country cases are Wales (UK), Flanders and Wallonia (Belgium), Spain, Austria, Switzerland, the Wadden Sea (The Netherlands), and several Balkan countries (European Commission, 2014). After the Spain´s national ecosystem assessment was completed (EME, 2011), and following a similar framework, a regional-level assessment was carried out in Andalusia, South Spain (García-Mora et al., 2013). The goal was to develop an internationally recognized instrument to include ecosystem services in decision-making for sustainable management of natural resources. Forest ecosystem services have been particularly considered in this regional assessment because of their socio-economic and cultural values (Marañón et al., 2012a).

Forest ecosystems are suppliers of some of the most fundamental services to humans and play a key role in the conservation and improvement of global ecosystem services to foster human well-being at world´s scale (Nasi et al., 2002; Campos et al., 2005; FAO, 2011; Cudlín et al., 2013). Forests provide timber and non-timber products, regulate air quality, climate and hydrology, contribute to soil formation, primary production and nutrients recycling, control pests, and support social benefits such as spiritual, landscape and educational values (De Groot et al., 2002). Humans have been exploiting forest resources for centuries; however, assuring their sustainability along with their exploitation under current scenarios of global change, is a major challenge (Balmford et al., 2002; Rey Benayas et al., 2009; Ford, 2011). Therefore forest ecosystem services, and how they are maintained under global change, should be integrated into management programs (MEA, 2005; Egoh et al., 2007; Daily and Matson, 2008; Chan et al., 2011).

Changes in land use have been recognized as main drivers of global change affecting ecosystems and their services (Foley et al., 2005; Metzger et al., 2006). In particular, land use changes have altered the quantity and quality of forest ecosystems during the last decades (Metzger et al., 2006; Padilla, 2010). Furthermore, deforestation and agricultural intensification have largely affected the global warming process through increasing emissions of CO_2 (Houghton et al., 1999; Lambin et al., 2001). Forests comprise the largest carbon pool of all terrestrial ecosystems; they store more than 80% of all terrestrial aboveground carbon (C) and more than 70% of all soil organic C (Dixon et al., 1994). In the study area, previous studies reported a C sequestration rate of 0.23 Mg ha^{-1} in forest areas, with a total carbon stock of 35.24 Tg in sclerophyllous vegetation and transitional woodland-scrub (Muñoz-Rojas et al., 2011). Therefore they play an important role in the mitigation of climate change (UNFCCC, 1995; IPCC, 2014).

Soil erosion control and sediment retention are key services provided by terrestrial ecosystems (MEA, 2005). Vegetation cover in general and forest cover in particular protect soil from erosion by diminishing the direct action of water and by acting as a mechanical support for soil retention. In addition, vegetation may improve soil porosity, increase organic matter, and increase and stabilize the aggregates. Climate change models predict an increase in soil erosion rates because of the decrease in the amount and increase in the intensity of precipitation and changes in the amount of biomass (Zhang et al., 2005; Anaya-Romero et al., 2015).

The general aims of this research were to evaluate the state and trends of forest ecosystem services at a regional scale in Andalusia (South Spain), and to identify the main drivers causing changes in those ecosystem services. This work was based on the contribution of the forest ecosystem´s team to the interdisciplinary Millennium Ecosystem Assessment in Andalusia (Marañón et al., 2012a). The particular objectives were: a) to evaluate the state and trends of three key forest ecosystem services: storage of carbon stocks, protection of soil erosion, and cork oak provisioning, b) to contribute to the conceptualization of evaluation tools for accounting those three main forest ecosystem services and c) to assess how these ecosystem services are affected by drivers of change, mainly land use change.

This kind of methodologies could be applied for the assessment on the forestation programs in Mediterranean regions, which have been promoted in most cases as a result of European Union (EU) policies. Several EU regulations have provided subsidies to encourage the afforestation of agricultural land and improvement of woodlands (Tassone et al., 2004).

2. Material and methods

2.1. Study area

The study area was Andalusia which covers about 87,500 km^2 and is located in southern Spain (Fig. 1). Climate is of mediterranean-type, characterized by warm and dry summers, and cool and wet winters. Annual rainfall regime ranges from semi-arid (< 170 mm per year) to high rainfall (> 2000 mm per year). Western Atlantic areas are more rainy and humid, while the eastern portion has a dry mediterranean-type or even semi-arid climate. Average annual temperatures vary between < 10 °C and 18 °C, although coastal areas show milder temperatures. Elevation ranges between sea level and 3.479 m.a.s.l. (Mulhacen Peak in Sierra Nevada). Main soil types in the area are Inceptisol (27%), Entisol (11%), Alfisol (20%), Vertisol (18%), Mollisol (7%), Ultisol (4%), and Aridisol (3%) (Anaya-Romero, 2013). Currently, 50% of land is dedicated to forestry uses (including shrublands and grasslands) while 44% is agricultural land (Bemerjo et al., 2011). Considering these environmental conditions, Andalusia was selected as the study area, and representative of the Mediterranean region.

Andalusia is a region of high floristic richness, which comprises the northern part of the Baetic-Rifean plant diversity hotspot (Médail and Quézel, 1999). The varied orography, climate, soil types and history of human management contribute to the diversity and distribution of tree species and the composition of forests (Blondel and Aronson, 1999; Urbieta et al., 2011). Oak species are dominant in forest ecosystems (22% of surface), mainly Holm oak (*Quercus ilex* ssp. *ballota*) and cork oak (*Q. suber*), although more than half (57%) of the non-agricultural lands are treeless shrublands. During the last century foresters have extensively planted pine (several species) and eucalyptus. Within the forested area of Andalusia we have separated a singular savanna-like formation locally called “dehesa”. The tree canopy cover fraction of “dehesas” is between 5% and 75%, and the main tree species are oaks (Holm and cork oaks); the well-developed herbaceous layer is grazed by different livestock species, such as cattle, pig and sheep (Joffre et al., 1999). “Dehesas” and forests (*sensu lato*, including shrublands) will be considered separately in this study because they differ in their ecosystem services.

2.2. Land use classification and functional units

This study was conducted at regional (total area of Andalusia) and sub-regional scales. For the sub-regional scale we used the ecological and management units (EMU) defined for the Andalusian region (CMA, 2004). These EMUs, similar to ecoregion units, are homogeneous units used for the analysis and management of the regional environment and characterized by their climate, geomorphogenesis, soil, hydrology, vegetation and socio-cultural factors. We selected three representative and contrasting EMUs as