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Mapping forest ecosystem services: From providing units to beneficiaries

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ABSTRACT

Some of the main research questions in the assessment ecosystem services include how to integrate ecological and social information into the analysis and how to make it spatially explicit. We mapped six ecosystem services delivered by forests in the Sierra Nevada Mountains (south-east Spain) from the supply- to the demand-sides, taking into account the influence of protected areas on the capacity of supply services. Semi-structured interviews and geographical information system sources were used to map the supply-side, whereas 205 face-to-face questionnaires were distributed to assess and map the demand-side. Our results show the existence of consistent ecosystem service bundles in terms of both the supply- and demand-sides, particularly between erosion control–recreational hunting and between mushroom harvesting–nature tourism. We found a spatial scale mismatch for the erosion control, with its supply at the local scale and its demand at the regional–national scales, with implications at the institutional scale at which it should be managed. Consequently, mapping both the supply- and demand-sides is essential for environmental decision making because it can indicate where management interventions should be focused, either by defining high-priority areas for protection or defining the institutional scale at which these services should be managed.

1. Introduction

The ecosystem service concept is currently the focus of both scientific activities (Fisher et al., 2009; Vihervaara et al., 2010; Seppelt et al., 2011) and environmental policy actions, e.g., the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the targets of the Convention of Biological Diversity (CBD) for the year 2020. Despite the increasing scientific and political attention on ecosystem services, several research areas need to incorporate the ecosystem service framework into environmental conservation programmes. One of the most important gaps in scientific knowledge is related to the spatial distribution of multiple ecosystem services from a multidisciplinary approach, which involves the use of biophysical and socio-economic information (Anton et al., 2010). As the evaluation of ecosystem services addresses the complex relationships between humans and ecosystems ((MA) Millennium Ecosystem Assessment, 2005; Bennett et al., 2009; Martín-López et al., 2009), attempts to define the spatial analysis of ecosystem services should include both the capacity of the ecosystems to deliver services to society, i.e., the supply-side, and the social demand for using a particular ecosystem service in a specific area, i.e., the demand-side (Tallis and Polasky, 2009; De Groot et al., 2010; Haines-Young and Postchin, 2010; Bastian et al., 2012). The capacity of ecosystems to supply particular services that benefit people is usually considered to be a service-providing unit (SPU), i.e., the ecosystem structures and processes that provide a specific ecosystem service at a particular spatial scale (Luck et al., 2009; Harrington et al., 2010). If the capacity of a SPU is changed, the satisfaction of social demands for the ecosystem service might be affected (Burkhard et al., 2012). The ecosystem service beneficiaries (ESBs) are those stakeholders who benefit from and demand of the ecosystem services or someone who is or may be involved or affected positively by a given environmental or management public policy (modified from Harrington et al. (2010)) (Fig. 1). Box 1 shows the definitions of the key concepts used in this study.

Despite the importance of the spatial identification and delineation of SPUs and ecosystem service demands, its integrated analysis remains a key challenging research issue (Anton et al., 2010; De Groot et al., 2010; Reyers et al., 2010; Seppelt et al., 2011), and few studies have spatially analysed both sides of ecosystem service assessment (e.g., van Jaarsveld et al., 2005; McDonald, 2009; Burkhard et al., 2012; Kroll et al., 2012). In fact, the identification of supply-demand mismatches across landscapes is also one of the key

Abbreviations: ESBs, ecosystem service beneficiaries; MCA, multiple correspondence analysis; PCA, principal component analysis; SPUs, service-providing units.

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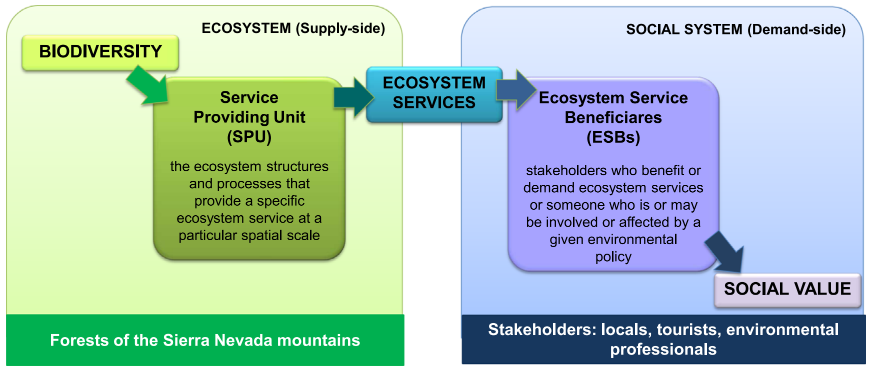

Fig. 1. Framework for mapping ecosystem services considering both the ecological capability to deliver them (supply-side) and the use and value by stakeholders (demand-side). Modified from Haines-Young and Postchin (2010).

Box 1–Definitions of key concepts for mapping ecosystem services.

Ecosystem services: direct and indirect contributions of ecosystems to human well-being (De Groot et al., 2010).
Service-providing units (SPUs): the ecosystem structures and processes that provide a specific ecosystem service at a particular spatial scale (Harrington et al., 2010; Luck et al., 2009).
Ecosystem service beneficiaries (ESBs): stakeholders who benefit from and demand of the ecosystem services or someone who is or may be involved or affected positively by a given environmental or management public policy (modified from Harrington et al., 2010).
Hotspot: an area that provides large components of a particular service, delineated here as the richest 5% of grid cells for each service (Bai et al., 2012; Egoh et al., 2009; Chan et al., 2006).

issues to be addressed in specific environmental and conservation strategies, as in the case of the new European Biodiversity Strategy to 2020 (Maes et al., 2011) or the National Strategic Plan of the Natural Heritage and Biodiversity of Spain ((MARM) Ministerio de Medio Ambiente y Medio Rural y Marino, 2011). As mapping tools allow an ecosystem to be analysed for the supply of ecosystem services in a suitable way while also taking into account the social demand for those services, the spatial visualisation approach constitutes a powerful tool for supporting environmental and landscape decision making (Sherrouse et al., 2011; Burkhard et al., 2012; Kroll et al., 2012; Gulickx et al., 2013).

Within this context, the main purpose of this study is to explore the spatial mismatch between the delivery of ecosystem services by forest ecosystems and the use and valuation of them by the beneficiaries. In Spain, forest ecosystems occupy an important extension, represent the habitat of terrestrial biodiversity and provide a diverse flow of ecosystem services (e.g., timber, harvesting, beekeeping, climate regulation, erosion control, and recreational activities) ((EME) Millennium Ecosystem Assessment of Spain, 2011). For this objective, we specifically: (1) mapped SPUs and explored the role of forests in determining ecosystem service hotspots, (2) analysed the social value of ecosystem services and determined the spatial scale at which these ecosystem services were valued by different ESBs, (3) identified the existing ecosystem service trade-offs and synergies in both the supply-side (i.e., SPUs) and the demand-side (i.e., ESBs), and (4) analysed the relationship between different conservation strategies (i.e., National Park, Natural Park, and non-protected areas) and the capacity of forests ecosystems to supply services. For these objectives, we mapped the ecosystem service supply and demand by forests in a semi-arid Mediterranean mountain, i.e., the south-east of Spain. This study is part of a wider research project on ecosystem services in south-east Spain in which different approaches, from biophysical to social, have been used (Castro et al., 2011; García-Llorente et al., 2011a, 2012a).

2. Study area

The study area is located in south-east Spain and covers 8 municipalities in the Granada and Almería provinces (58,627 ha and nearly 10,000 inhabitants). A socio-demographic profile of each municipality present in the study area is represented in Table 1.

This location corresponds to the socio-economic administrative limit of the main ESBs of the forest ecosystem services delivered by the eastern part of the massif of the Sierra Nevada Mountains (Fig. 2), which has been declared a Natural Park (1989) and National Park (1999). Both designations refer to different conservation strategies: the National Park designation involves a strict conservation level, whereas Natural Park implies a medium conservation level that allows traditional and cultural management practices.

The ecosystem services delivered by the forests of this area have been recognised in relation with the provision of services, such as timber or fruit harvesting (Arias Abellán, 1981). In the last decades, intense reforestation was conducted with the aim of fostering regulating services, such as erosion control and hydrological regulation. The diverse community of Mediterranean shrubs (i.e., *Cistus* spp., *Genista* spp., and *Rosmarinus* spp.) and trees species (e.g., chestnuts (*Castanea sativa*) and almonds (*Prunus dulcis*)) have also sustained the service of beekeeping. In addition, the presence of certain species of wildlife (i.e., Iberian wild goat (*Capra pyrenaica*), wild boars (*Sus scrofa*), red-legged partridge (*Alectoris rufa*), and Iberian hares (*Lepus granatensis*)) supports recreational hunting. Finally, the ecological value of the area increases the significance of nature tourism (Vacas Guerrero, 2001).

3. Methodology

We mapped both the supply and demand-sides of ecosystem services by delineating SPUs and identifying the spatial scale at which ESBs demand forest ecosystem services. We selected those ecosystem services that are relevant in the study area (García-Llorente et al., 2012a,b), which were also previously identified as important in forest systems (Naidoo and Ricketts, 2006; Harrison et al., 2010; Chiabai et al., 2011; (EME) Millennium Ecosystem Assessment of Spain, 2011; Maes et al., 2011), as follows: