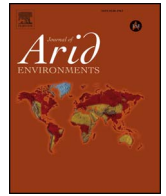




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What has ecosystem service science achieved in Spanish drylands? Evidences of need for transdisciplinary science

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ABSTRACT

Ecosystem service science has gained relevance among scientists, managers, and policy-makers worldwide as a way to communicate societal dependence on ecological life support systems. However, a major barrier to effective implementation of ecosystem services research is their lack of operationalization for land management and planning. This study conducted an in-depth analysis of ecosystem service studies conducted across Spanish arid and semi-arid ecosystems in order to identify achievements as well as to provide insights and failures of the ecosystem services application for decision making. We analyzed relevant studies in terms of ecosystem services studied, value dimensions and methodological approaches used, and their application for land planning and the level of stakeholders' engagement included. We also performed an author consultation to explore the impact of publications on environmental policies. Findings show that most studies were conducted from a socio-cultural dimension and more than 90% of the studies included some of the types of stakeholder engagement. However, the implementation of ecosystem service research findings by decision-makers is very limited, highlighting a management-application gap. We call for promoting transdisciplinary scientific collaboration that includes the scientific, public, and policy-making communities when developing ecosystem service research. Recommendations to foster transdisciplinary include: a) enhancement of continued policy-scientific communication in early phases of research such as co-designing of goals, b) promotion a culture of shared responsibility among multiple stakeholders to launch real action at the administration level for specific environmental problems, and c) train and work more closely with managers and decision-makers to integrate the ES framework into the day-to-day management of natural spaces.

1. Introduction

Global dryland ecosystems cover approximately 40% of the world's terrestrial surface (Stringer and Dougill, 2016) and host more than 38% of the world population (White and Nackoney, 2003). Dryland ecosystems are characterized by water scarcity and high climate variability with great seasonal extremes and unpredictable rainfall patterns. Despite being a harsh ecosystem, the adaptation of endemic species to these arid conditions has resulted in high biodiversity within drylands worldwide (Davies et al., 2012). In these ecosystems, biodiversity plays an important role in providing ecosystem services (ES) that are essential to human well-being as well as population and societal development (MEA, 2005). Particularly in the Mediterranean basin, global change

threatens these multifunctional landscapes that have coevolved with human development throughout recent centuries (Nieto-Romero et al., 2014). In this region, the arid and semi-arid ecosystems of the Iberian Peninsula have been especially sensitive to land use change and climate change, representing how these global changes can expand and affect dryland ecosystems worldwide.

Since the Millennium Ecosystem Assessment (MEA) was commissioned by the United Nations in 2001, the assessment of ecosystem services (ES) has become one of the main areas of conservation and environmental land-use planning. One of the MEA chapters focused on dryland ecosystems recognizing the importance of those ecosystems in the supply of ES and the maintenance of human well-being (Safriel and Adeel, 2005). Since then, review studies on dryland ES have been rarely

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conducted. For instance, Wangai et al. (2016), motivated by the clear need to increase the knowledge of ES application in Africa, reviewed ES research focusing on spatial distribution, criteria, and methodologies in these studies. They found a general increase of the number of ES studies in Africa; however, the studies were biased toward specific regions such as South Africa and these results cannot be extrapolated to drylands ecosystems because of the wide climatic complexity of Africa (Wangai et al., 2016). Other reviews have highlighted the role of protected areas in supplying critical ES in drylands (Dudley et al., 2014) or showed the vulnerability of these ecosystems facing climate hazards (Middleton and Sternberg, 2013). Overall, however, we need to acknowledge that dryland ES studies are scarce (Shoyama et al., 2017).

In an international context, the arid and semi-arid ecosystems in the Iberian Peninsula have gained attention over the last decade from an ES perspective due to the GLOCHARID program (Environmental indicators for monitoring and assessing environmental effects of Global Change in arid and semiarid ecosystems of southern Spain; <http://www.caescg.org/proyecto-glocharid/>). This program has produced multiple studies covering different ES research questions from many different value dimensions (Castro et al. 2011, 2013, 2014, 2015; García-Llorente et al., 2016; López-Rodríguez et al., 2015; Quintas-Soriano et al., 2014, 2016a,b). The arid and semi-arid region mainly covers the provinces of Almería, Granada, and Murcia in SE Spain, and it is considered the most arid region of continental Europe (Armas et al., 2011). The warm, dry Mediterranean has average annual temperatures between 12 and 15 °C and annual average rainfall between 200 and 350 mm per year. Traditionally, the arid and semi-arid ecosystems of the Iberian Peninsula were considered as poor areas in terms of productivity; on the other hand, this region has recently been included among the 25 worldwide biodiversity hotspots and recent research has emphasized the need to preserve ES related to groundwater resources for the maintenance of the capacity to provide ES (provisioning, regulating and cultural services) that support the local economy (Castro et al., 2015; Quintas-Soriano et al., 2014). This region has been described over the last few decades as particularly sensitive to the impacts of climate and land use change. Driven by the intensification of greenhouse horticulture, urban expansion, and rural abandonment, the sensitivity of the region has resulted in ES deterioration (Nieto-Romero et al., 2014; Martín-López et al., 2016; Quintas-Soriano et al., 2016a).

Consequently, Spanish arid and semi-arid ecosystems represent a unique social-ecological context in which to study the complex dynamics between ES supply and demand, the drivers of global change, and the resulting implications on human wellbeing. The goal of this study is to conduct an in-depth analysis of ES studies conducted across Spanish arid and semi-arid ecosystems in order to identify achievements as well as to provide insights and failures of the ES application for decision making. In order to document and characterize ES knowledge research conducted in this region, we examine these research efforts using the ES framework as well as the level of application in environmental policies. To do so, we reviewed the literature on (1) the diversity of ES studied in Spanish arid and semi-arid ecosystems using the ES framework, (2) the value dimensions used in each study, and (3) the diversity of methodologies and valuation techniques. Then, we used an online questionnaire with the corresponding authors of selected publications to (4) analyze the perceived stakeholder engagement and impacts of ES science on environmental policies after their studies were published. We finally discuss gaps in the implementation and limitations found in this region while providing recommendations to better implement ES into land management and planning. Our sub-objectives are to highlight all the ES research performed in semiarid Spain providing an overview of methods, approaches, and dimensions used, and to evaluate the level of application of those studies for environmental policies.

2. Methods

2.1. Selection of studies

We revised peer-reviewed articles indexed in the ISI Web of Science (<https://www.accesowok.fecyt.es/>) about ES valuation. We defined ES valuation as the process of analyzing, assessing or understanding ES values and how these values are comparable in relation to coexistences, synergies or trade-offs (Gómez-Baggethun and Martín-López, 2015). Studies selected from 2011 to 2016 were conducted across Spanish arid and semi-arid ecosystems (Armas et al., 2011) using the ES framework. The revision included terms related to the object of valuation (e.g., ES or ecosystem goods), the type of value dimension and techniques (e.g., socio-cultural or economic dimensions), and the location of the case study (e.g., Spanish drylands or Spanish semi-arid ecosystems). Other studies that employed the ES framework but did not perform a strict ES assessment were excluded (i.e., non-empirical studies). In addition, studies performing biophysical assessment without applying the ES framework were also excluded. To avoid double counting, we searched for original articles in journals (Cossarini et al., 2014) and studies were screened to determine relevant articles for this study. Overall, 22 articles out of a total of 56 met these selection criteria. Appendix A lists the studies that were incorporated in the review.

2.2. Data collection

A database from selected papers was compiled including publication characteristics (i.e., number of authors, journals, or study case characteristics), value dimensions (biophysical, socio-cultural or economic), valuation techniques, and ES categories (provisioning, regulating and cultural). Data gathered in this review were analyzed using descriptive analysis. Selected studies were analyzed and categorized using the supply-demand framework (Castro et al., 2013, 2015; Martín-López et al., 2014) and the integrated valuation framework of ES (Gómez-Baggethun et al., 2014). Fig. 1 shows the groups of methodologies and approaches found in the review based on three value dimensions and on the supply-demand and the integrated valuation frameworks.

2.3. Data compilation from online survey

To test the level of the application into existing environmental policies, we administered an online survey to the corresponding authors. The survey included seven questions regarding three main topics: a) the reliability of the application into Spanish environmental policies, b) gaps and limitations found for communicating research findings with managers and stakeholders, as well as c) the perceptions of the impact of their research in land management policies (See Appendix B for more information).

3. Results and discussion

3.1. ES knowledge of Spanish drylands

Our review reveals an increasing attention on Spanish arid and semi-arid ecosystems in the last decade. A total of 22 studies were found focused on ES valuation in this region using different value dimensions. This level of attention is connected to: the promotion of a worldwide network to study global change processes in mountains (GLOCHAMORE; <http://mri.scnatweb.ch/en/projects/glochamore/>); and the creation of the Andalusian Center for the Assessment and Evaluation of global change (CAESCG; <http://www.caescg.org>) promoting the GLOCHARID project to design a system of environmental indicators for monitoring and assessing environmental effects of global change in arid and semiarid ecosystems of Andalusia. In addition, this region has connected itself as a case study with many international initiatives at the European level, such as the BESAFE ([2](http://besafe-</p>
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