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Review of decision support tools to operationalize the ecosystem services concept

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ABSTRACT

The ecosystem services concept provides a valuable framework for analyzing and acting on the linkages between people and their environment. By making the values of nature explicit, it allows discussions about trade-offs between services and thus a prioritization of management options. The integration of the ecosystem services concept into decision making remains however challenging. Based on a thorough literature review of 68 tools for integrating ecosystem services into decision making, we analyze the current state, gaps and trends in the operationalization of the ecosystem services concept. We evaluate how well various policy sectors are covered with the tools and highlight gaps where more development is needed. While for some policy sectors such as agriculture or forestry several tools have been developed to support the integration of nature's benefits into concrete decisions, tools are missing where the link between policies and ecosystem services is less evident for example regarding cultural services related to land use policies as well as services supported by soils. Furthermore, the successful implementation of tools requires a good understanding of decision-making processes to bridge gaps in the science-policy interface. Based on the analysis of the application of tools in case studies, we evaluate the establishment of tools over time in different policy sectors and the frequency of their application.

1. Introduction

Current land-use changes clearly diminish the capacity of ecosystems to sustain their productivity in the long run, from the local to the global scales (Foley et al., 2005). Securing the sustainable provision of the services they provide presents a major challenge to decision makers (Cardinale et al., 2012): competing interests for natural resources need to be balanced, yet the impact of land-use practices are often difficult to predict (Carpenter et al., 2009). But while land-change science has made considerable advances in understanding land-use change and thus in understanding human-environment systems, the generated knowledge is often not suitable for decision making (Turner et al., 2007). Particularly, the uncertainties related to global change call for more value judgement in decision making (Polasky et al., 2011), involving personal, subjective attitudes. Open dialogues about critical trade-offs as well as mutual learning processes between scientists, decision makers and stakeholders involved (Owens et al., 2004) have been suggested to support the integration of value judgement in decision-making processes. Participatory processes have been shown to enhance the quality of decisions by allowing the evaluation of multiple and often competing decision criteria, but such processes need to be well designed (Reed, 2008). Based on their experience from ecosystem services (ES) assessments, Rosenthal et al. (2014) emphasized the importance of iterative stakeholder engagement to enable a more informed dialogue.

The ES concept is seen as an opportunity to guide sustainable resource management as it makes the services of nature explicit and thus allows the analysis of trade-offs and impacts of different management options. The ES concept integrates ecological, economic and social aspects by focusing on the values of nature for humans, thus providing a suitable framework to tackle complex problems related to sustainable resource use humanity is facing today. Recently, efforts have increasingly been made to operationalize the ES concept, for example under the EU Biodiversity Strategy (European Commission, 2011) and the MESEU project which supports its implementation, under several EU FP7 research programs such as OpenNESS, OPERAs, or GreenSurge as well as EU H2020 projects such as ESMERALDA, but also worldwide, for example with the guidance for U.S. Federal agencies to integrate ES into decision making (Donovan et al., 2015). According to the glossary developed by the OpenNESS project, operationalization is defined as “the process by which concepts are made usable by decision makers” (Potschin et al., 2014). Blueprints

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have been proposed to make ES assessments more consistent (e.g., Seppelt et al., 2012, Crossman et al., 2013), while acknowledging for the diversity needed to address different aspects of human-environment systems. Despite the vast increase in ES studies in recent years, it has been shown that the outputs of these assessments, especially the maps, are not yet suitable for decision making for five reasons (Martínez-Harms and Balvanera, 2012; Schägner et al., 2013): First, today's, ES assessments are often conducted with simplistic approaches that are strongly relying on available land-use/ land-cover data. This approach allows the identification of general trends, yet the poor fit between land-use based proxies and ES limits the application for the analysis of spatially explicit ES assessment (Eigenbrod et al., 2010) and the formulation of site-specific policy recommendations (Schägner et al., 2013). Second, precision and accuracy of ES assessments and related uncertainties are rarely addressed (Seppelt et al., 2011), yet crucial for decision makers. Third, the consideration of the demand side and/or the monetary valuation of ES presents a major challenge (Wolff et al., 2015) requiring the integration of different disciplines, which is still lacking in most studies (Schägner et al., 2013). Martín-López et al. (2014) show substantial differences in the outcome of a study if different value dimensions are considered, from biophysical to socio-cultural to economic. Fourth, research is focusing on key ES and yet information on many other services is scarce but essential for sound decision making (e.g., Martínez-Harms and Balvanera, 2012). Finally, ES assessments insufficiently account for political and organizational aspects of decision making (Laurans and Mermet, 2014). They often span across several administrative structures, i.e., address different policy aspects, which are often covered by different governmental ministerial or departmental units such as spatial planning and forestry (Primmer and Furman, 2012). Such institutional challenges, including limited capacities of relevant policy units or dispersed authorities, complicate the operationalization of the ES concept (Scarlett and Boyd, 2015). There are recommendations for a better implementation of ES into decision making spanning from the further development of policy instruments and financial mechanisms to a better understanding of the decision-making process and a better representation of methods and results to a more interdisciplinary research (Daily et al., 2009; de Jonge et al., 2012; Laurans et al., 2013; Ruckelshaus et al., 2015). Adelle et al. (2012) stress the role of policy appraisal to inform decision makers rather than providing the "best" solution. Owens et al. (2004) illustrate critical points in policy appraisal such as the discussion if objective, value-free knowledge exists or the misleading, oversimplified assumption of decision makers as a uniform entity rather than individuals representing different interest groups. They discuss the potential of tools such as multi-criteria decision analysis to handle subjectivity.

Efforts are made in model development to better support environmental decision making. Jakeman et al. (2011) identified "the need to diagnose elements that lead to successful process, training for professional and technical competencies, and increased access to stable platforms and interchangeable models and modelling tools" as key challenges of integrated modelling for environmental decision support. These models can be embedded in decisions support systems (DSS) that "enhances a person or group's ability to make decisions" (Power et al., 2015). While progress has been made in the development of DSS, the selection of appropriate ES tools for a specific decision process further complicates the implementation of such tools, as there is no clear guidance available. Guidance for the selection of tools for sustainability assessments has been discussed in the literature and partly also covers ES tools, see for example de Ridder et al. (2007), Ness et al. (2007) or Gasparatos and Scolobig (2012). While these studies are comprehensive, providing a clear classification scheme, they seem to be too broad to provide guidance for ES assessments. The ValuES project (http://aboutvalues.net/) offers an online navigation through a decision tree for the selection of ES tools illustrated with case studies. It is easily understandable also for people who are not familiar with the ES concept or assessment methods, thus offering a good starting point. Recently, the Restoration Ecosystem Services Tool Selector (RESTS) framework has been published guiding the user through a set of 13 ES assessment tools suitable for forest restoration. While the current version is using a spreadsheet, a web-based version is in progress (Christin et al., 2016). Bagstad et al. (2013) evaluated 17 ES tools according to their suitability to support decision making by applying them in a case study. This analysis provides valuable information about time requirements, availability, scalability and generalizability of the tools. However, comprehensive information about the use and robustness of ES tools in different policy sectors is missing but crucial to better guide the selection of tools and their implementation into decision making. This paper presents a thorough literature analysis of scientific articles integrating ES into decision support tools. Our results show the establishment of ES tools over time in different policy sectors and the frequency of their application. We extract from the articles various information, such as the types of ecosystems and services the tools address as well as the scales they are applied at. The analyses provide guidance for the selection of tools in different policy context. We discuss the further development of tools and policy appraisal needed to support the operationalization of the ES concept.

2. Methods

To describe the current state of the operationalization of the ES concept for decision making, we conducted a broad literature review of scientifically published studies. We followed the recommendations for systematic reviews of the PRISMA statement originally suggested for reviewing medical studies but also applicable to other disciplines (see Liberati et al., 2009). The search for the relevant articles was conducted in two main phases by two reviewers to enhance reliability as illustrated in Fig. 1. An initial screening of articles was done by reviewer 1 in July 2015 by searching the academic search engines Google Scholar, Web of Science and Science Direct for the keywords "decision support tool ecosystem services", "decision support tool ecology", "decision support platform ecosystem services" and "decision support model ecosystem services". The search resulted in an initial selection of 84 articles, from which we further selected only articles describing a tool which a) is used for assessing several ES and/or biodiversity to allow trade-off analysis, b) use tools that are operational, i.e., provide some type of user interface and c) are written in English. We hereby refer to a rather broad definition of a tool in the sense of a tool to quantify and value ES. As we only consider tools with a user interface, we excluded studies only describing conceptual models, general methodological approaches or frameworks.

To capture trends in the use of the tools, we also considered tools that were very recently developed and not yet published, as well as tools that do not explicitly mention the term "ecosystem services," but which were nevertheless considered to address the theme (e.g., clearly describing ES, such as water purification or erosion control). As a result, 26 tools from the 84 articles were included in the final review by reviewer 2 according to the three selection criteria. 11 of the articles were review articles from which the original sources for the tools described were also checked. This resulted in 17 additional tools included in the review. Because the initial search did not capture a wide sample of tools, a second article search was conducted in December 2015 by reviewer 2 in Web of Science by using the keywords "ecosystem services" AND "tool". From this search, 18 tools were added to the final review. Aiming to provide a full picture of available ES tools and their application, we included tools developed under the EU OPERA's project which are in the process of publication. While the database search covered two tools of the OPERA's project (mDSS, TESSA), six additional OPERA's tools considered suitable for this review (BackES, ToSIA, Streamline canvas tool, Scenario toolbox, Our Ecosystem webmapping tool and CBA-typology) were also included as well as one from the MESEU project (QUICKScan). Three of them have