Ecosystem Services 32 (2018) 22–40

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Information content of global ecosystem service databases and their suitability for decision advice

Stefan Schmidt[a,*], Ralf Seppelt[a,b,c]

[a] UFZ – Helmholtz Centre for Environmental Research, Department Computational Landscape Ecology, 04318 Leipzig, Germany
[b] iDiv – German Centre for Integrative Biodiversity Research, 04103 Leipzig, Germany
[c] Institute of Geoscience & Geography, Martin-Luther-University Halle-Wittenberg, 06099 Halle (Saale), Germany

ARTICLE INFO

Keywords:
Policy instruments
Information supply
Information demand
Database synthesis
Standardization

ABSTRACT

Databases have the potential to facilitate the integration of ecosystem service (ES) information into decision advice by collecting and condensing big data volumes in a standardized form. In this article we examined how ES databases support policy instruments to take nature's benefits into account in decision-making. We analyzed 29 databases with global coverage containing information of 36,112 studies, projects and methods within more than 600,000 entries. We identified 93 indicators of information demand for six major policy instruments and matched database entries with these indicators. Findings showed databases contain information for most of the policy instruments. However, ES databases were limited regarding geographic representativeness, highlighting major information gaps in society's poorest nations. We propose steps forward towards optimized knowledge exploitation and suggest five priority areas for mainstreaming ES information into decision-making: (i) quantitatively recognize nature's value, (ii) develop prioritization schemes based on ES valuation, (iii) sensitive stakeholder engagement, (iv) support information access and capacity building to establish ES-based decision-making and (v) consider long-term returns of interventions in ES. These priority areas contribute to formalize standards for the documentation of knowledge on ES and provide a baseline for the establishment of ontologies that facilitate knowledge accessibility for decision-making.

1. Introduction

Current policies and markets struggle with the consideration of nature's benefits for human well-being and fully accounting for environmental impacts, while the exploitation of natural resources and degradation of nature is accelerating (UNEP, 2016). The ES framework has the potential to both awaken the public to its dependency on nature and to engage different research disciplines and non-scientists in shaping and achieving societal goals. There is evidence that achieving societal goals, such as the UN Sustainable Development Goals, strongly depends on ES (Ranganathan et al., 2008). All economic activities are ultimately linked to and influenced by trends in ES supply (Millennium Ecosystem Assessment, 2005b). The ES framework is unique and promising for decision-making due to its integrative approach of estimating and valuing: (i) the diverse ways in which nature underpins human well-being, (ii) the human impact on ecosystems, and (iii) the welfare effects of potential ecosystem management policies (Daily et al., 2009; COP, 2010). Entry points for incorporating an ES approach into existing decision-making processes occur at all sectors and levels of governance, for instance national accounting systems (PRI & UNEP FI, 2011; Bartelmus, 2014), corporate disclosure policy (IPIECA, 2016; Natural Capital Coalition, 2016), public payment systems (Porras et al., 2008a), cooperation between public and private sector (Waage et al., 2012), landscape planning (Hauck et al., 2013) and other large-scale decision contexts (Guerry et al., 2015). Consequently, there is a demand for ES knowledge that can feed into information and decision-support frameworks underpinning the development, implementation and assessment of policies which deal with or are directly related to the use of natural resources or land (Schaefer et al., 2015; Bouwma et al., 2017).

The number of ES studies is fast-growing and rapid advances in information technology, globalization, and increasing networking cause an information overload (Hey et al., 2009; Abson et al., 2014). This involves a number of challenges such as to be aware of, access, and process the ever-growing data volume. Not all data and information is readily available or accessible (IPBES, 2016). Existing data and information resources are widely distributed, heterogeneous, and difficult to combine (IPBES, 2016; Olander et al., 2016). Moreover, literature provides evidence of a science-policy gap, i.e., limited interactions, infrequent exchanges of information, and different objectives that hinder coordinated science and policy processes (Weichselgartner and

* Corresponding author.
E-mail address: stefan.schmidt@ufz.de (S. Schmidt).

https://doi.org/10.1016/j.ecoser.2018.05.007
Received 9 October 2017; Received in revised form 11 May 2018; Accepted 14 May 2018

Kasperson, 2010). The science-policy gap causes a lack of expertise in ES applications among decision-makers and contributes to skepticism about the suitability of the ES tools for the purpose of usage in and informing of decision-making (van den Hove and Chabason, 2009; Laurans et al., 2013; Guo and Kildow, 2015; Polasky et al., 2015). Guidelines and standards for an improved operationalization of the ES framework are steadily developed, e.g. for assessment practitioners (Ash et al., 2010; Haines-Young and Potchin, 2010; Seppelt et al., 2012), development planning (Kosmus et al., 2012), the business sector (Bartelmus, 2014; Natural Capital Coalition, 2016), as well as policy and decision makers more generally (Ranganathan et al., 2008; DEFRA, 2015). Guidance and overviews of ES databases that document and combine existing data and information on the relationships between ecological supply, social demand and effects of management options on ecosystems and human well-being are missing (McComb et al., 2006; IPBES, 2016; Olander et al., 2016).

Through databases large amounts of diverse data can be collected and organized in a standardized form. Databases are important prerequisites to provide easy accessible and consistent knowledge, increase rigor and specificity of the ES framework, and support further implementation mechanisms such as Decision Support Systems (DSS). Databases provide the potential to improve methods and semantics of data collection and measurement through scrutiny of other data users as well as allow the scientific community to reach consensus on methods and semantics (Fienberg, 1994). Building upon a prior work avoids duplications, allows us to use data in ways that the original investigators had not envisioned and increase progress. Developing databases and archiving data results in a greater utility of the data, ensures the availability of data in future, and maximize the impact and benefit of research funding (ICPSR, 2012). Databases provide an important resource for training and are a powerful force for inclusion and removing barriers to participation across all education backgrounds and at all ages (NSB, 2005).

Databases vary greatly in size, scope, standardization, usage, accessibility, and other characteristics. Three functional types of databases can be distinguished (NSB, 2005): research, resource, and reference collections. A research collection is the product of one or a few investigators or scientifically focused projects, e.g., a database on quality of ES studies (Seppelt et al., 2011). Usually these lack standardized data policies (file formats, meta-data, access policies, etc.), are not broadly shared or discoverable and, therefore, they are little used beyond their original application. For research collections funding is low and assured for only short terms. They are at the greatest risk of loss through a lack of maintenance. Resource data collections are developed for a specific science and engineering community, such as the database on monetary valuation studies of ES called the Environmental Valuation Reference Inventory (EVRI, 2016). They typically conform to community standards or often bring communities together to develop appropriate standards where a need exists. In many cases resource collections migrate to reference collections. Reference collections are intended to serve the general science and education community. For instance, the Socioeconomic Data and Applications Center is one of the Distributed Active Archive Centers (DAACs) in the Earth Observing System Data and Information System (EOSDIS) of the U.S. National Aeronautics and Space Administration (NASA). Often, standardization in reference collections sets the bar for a large segment of the community, effectively developing a universal standard. Budgets for reference collections are often large and are provided over a long term from one or more funding sources. Reference collections of ES have been entirely absent until today.

Given the information demand on ES knowledge for decision-making and the diversity of ES databases, we here investigated how information demand on ES for decision-making can be fulfilled by knowledge on ES provided in publically available databases. We conducted systematic reviews of literature driven by three research questions:

(1) Which databases on ES analysis and methods exist?
(2) What information is demanded to integrate ES into decision-making?
(3) How is this information demand addressed by the existing databases?

Two separate literature reviews were conducted. The first identified databases containing studies or projects of ES. Based on the second review we developed a systematic taxonomy of indicators representing the information demand. In order to narrow down the manifold demand for information on ES in different areas of governance and identify application contexts in decision-making, we focused on a set of policy instruments for safeguarding nature. Methodologies of both reviews are described in Section 2. In Section 3, we present characteristics of databases, policy instruments, and indicators of information demand. Also, results are presented on how well information supply from databases matches information demand indicators from policy instruments. In Section 4, we discuss options to improve the documentation of ES knowledge in databases and present recommendations to facilitate mainstreaming of ES information into decision-making. This is followed by a conclusion in Section 5.

2. Review processes: data and methods

We first searched the Web of Science™ for publications with 'ecosystem service*', or 'ecosystem valuation*' in the title to obtain a comprehensive overview of ES studies potentially holding information on ES databases. In the last 25 years, 1848 studies were retrieved (S1 Fig). From these peer-reviewed publications we identified 279 that used or reported on databases containing information about ES. We then traced back references in selected publications and directly talked to authors (39 authors) in order to find and review available databases (229 databases). Only those databases were included, which (i) provided in-depth information on ES, i.e., data entries with detailed reference to ES, and (ii) contained case studies with investigation areas that are distributed across the globe (in total 29, see Table 1). The latter criterion ensures a more comprehensive overview of socio-ecological systems, avoids biases due to local peculiarities, and increase relevance for a broader audience. The purpose of the study was not to create a complete list of ES databases, but rather to provide a first overview of the diversity of information contained in ES databases.

In a second step, considering the vast scope of information demand on ES in decision-making, we focused on specific application contexts. These were exemplified by policy instruments that consider nature's benefits for human well-being and help to reform market and policy failure. We used the following six policy instruments suggested by TEEB (2011):

(A) Extending accounting systems through nature-based indicators;
(B) rewarding benefits through payments and markets;
(C) reforming environmentally harmful subsidies;
(D) addressing environmental degradation through regulation and pricing;
(E) regulating use through protected areas and recognition of their values;
(F) direct public investment in ecological infrastructure and restoration.

We then specified the information demand for each policy instrument by reviewing publications contained in the 29 databases. Because of the vast number of publications (35,949), we selected a set of 715 publications by using the search terms: 'decision*', 'polic*' and 'guid*' for searching in title, abstract and keywords. For the selected publications a full text review was conducted and those discarded which not directly refer to the six policy instruments. We found 64 publications (S1 Table) and synthesized indicators that represent information