Ecological Modelling 295 (2015) 21–30

Contents lists available at ScienceDirect

Ecological Modelling

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

Review

'The Matrix Reloaded': A review of expert knowledge use for mapping ecosystem services

Sander Jacobs [a,*], Benjamin Burkhard [b,c], Toon Van Daele [a], Jan Staes [d], Anik Schneiders [a]

[a] Research Institute of Nature and Forest INBO, Kliniekstraat 25, 1070 Brussels, Belgium
[b] Institute for Natural Resource Conservation, University of Kiel, Olshausenstraße 75, 24118 Kiel, Germany
[c] Leibniz Centre for Agricultural Landscape Research ZALF, Eberswalder Straße 84, 15374 Müncheberg, Germany
[d] University of Antwerp, Ecosystem Management Research Group, Universiteitsplein 1C, 2610 Wilrijk, Belgium

ARTICLE INFO

Article history:
Received 21 January 2014
Received in revised form 23 August 2014
Accepted 26 August 2014
Available online 20 September 2014

Keywords:
Ecosystem services
Expert judgment
Reliability
Confidence
Decision support

ABSTRACT

Ecosystem service research covers a challenging socio-ecological complexity and simultaneously copes with a high policy demand for decision support in sustainable resource management. This stimulates proliferation of pragmatic modeling techniques, such as the matrix model: ecosystem service supply is modeled using expert estimations per land use or land cover class. The matrix models popularity proves its main strengths (efficient, fast, accessible and adaptable), but also entails risks for scientific credibility and legitimacy of its results and ecosystem service assessments in general. Some of the main methodological critiques on the matrix model can be addressed especially by including measures of confidence, traceability, reliability, consistency and validity. This review presents recommendations and encourages these to become standard practise in future applications of the matrix model and related techniques.

Additionally, we argue that an extended matrix model could provide more than only scientifically sound and politically legitimate results. It could serve as a tool to improve cooperation between natural and social sciences, experts, stakeholders and decision makers: collaborative development of the matrix model contributes to transdisciplinary ecosystem service research aimed at effective implementation and action.

Contents

* Corresponding author. Tel.: +32 496156673.
E-mail address: Sander.jacobs@inbo.be (S. Jacobs).

http://dx.doi.org/10.1016/j.ecolmodel.2014.08.024
0304-3800/

1. Introduction

1.1. Ecosystem services: an instrument for sustainable resource use

Ecosystem services (ES) are generally defined as 'the benefits which people derive from nature' (MA, 2005), or more precisely as 'the aspects of ecosystems, utilized actively or passively, to produce human well-being' (Fisher et al., 2009). All ES are generated, supported and ensured by ecosystems in all their diversity and functionality. Anthropogenic pressures lead to ecosystem changes (e.g., by land cover change, climate change), but humans also provide substantial additional inputs (such as fertilizer, energy, labor or knowledge) to the resulting supply of ES (Burkhard et al., 2012a, 2014). Numerous publications demonstrate ecosystem services to be a potentially powerful concept to guide sustainable and equitable natural resource management strategies (e.g., Costanza and Folke, 1997; MA, 2005; Müller et al., 2010; TEEB, 2010; Abson et al., 2014). Non-governmental organizations, companies, landscape planners and decision makers have embraced the concept since then. Ecosystem service-related networks are emerging at national and international levels (e.g., BEES[1], CoP-NL[2], ESCOM[3], IPBES[4], ESP[5]). The new EU biodiversity strategy 2020 urges member states to map and assess ecosystems and their services on their territories by 2014 (EU, 2011). The rising demand for ES accounting and effective decision support forms now a main driver for development of ES research. ES are being quantified and mapped all over the world (see Martínez-Harms and Balvanera 2012; Egoh et al., 2012; Crossman et al., 2013 for reviews). For an effective integration of the ES concept in decision making, it needs to be applied in a way that is credible, replicable, scalable and sustainable (Daily et al., 2009). Many critical scientists and policy makers, however, are skeptical toward the surging amount of pragmatic ES assessment tools and ES indicators (Portman 2013; Hauck et al., 2013a, 2013b). This undermines the ES-concept's potential to support knowledge-based sustainable land-use strategies (Jacobs et al., 2013a; Honey-Rosés and Pendleton 2013).

1.2. The urgency-uncertainty dilemma in ES-decision support

Ecosystem services are the benefits of ecosystems to human well-being and the concept effectively bridges the divide between social and ecological systems (Glaser et al., 2008). Since both systems are highly complex (Weaver, 1948; Muller, 2005), the characterization of the interdependencies of social-ecological systems based on the ecosystem service concept has a descriptive as well as a normative dimension (Abson et al., 2014). Understanding about ecosystem functionality, ES supply and human dependence on natural capital has improved substantially, but sound evidence is still lacking (Burkhard et al., 2012a). ES-assessments are challenged by multiple sources of uncertainty, (e.g. data scarcity, functional knowledge gaps, demand variability, social trade-offs, normative and value-laden arguments, see Jacobs et al. 2013b). This invokes immediate risks for decision making which is based on ES-assessments (Hou et al., 2013). Ecosystem service research and practise have to balance between scientifically deepened analysis in face of complexity on the one hand, and pragmatism in the context of fast global ecological resource depletion on the other (Jacobs et al., 2013b). Establishment of ES-based sustainable management strategies cannot wait for final levels of certainty and precision (Burkhard et al., 2012a).

Expert elicitation deals with the urgency-uncertainty dilemma by securing best available knowledge, validating methods and adding data (Jacobs et al., 2013b; Kienast et al., 2009). It aims at reaching (scientific) consensus in uncertain decisions for a broad range of fields, such as climate change research, scenario analysis and forecasting for policy support, probabilistic modeling (Apostolakis 1990), modeling seismic hazard and damage (SSHAC, 1997), natural disaster damage assessment (Boissonnade et al., 2000; Kaiser et al., 2013), and nuclear waste storage (Kerr 1996). These fields are – like ecosystem services – characterized by a large complexity, which generates uncertainty and risk (Keune and Dendoncker, 2013). Expert elicitation is especially well-suited for Integrative ecosystem service assessments, which are transdisciplinary and have specific data requirements. The huge amount of data needed to assess and quantify multiple ES from the biophysical and socio-economic realms are otherwise difficult to obtain with justifiable efforts (Burkhard et al., 2012b), therefore, numerous ES studies use expert-based assessment approaches (e.g., Stephenson 2008; Vihervaara et al., 2010, 2012; Kaiser et al., 2013). Specific methods include social and community ES value mapping (Raymond et al., 2009; Sherrouse et al., 2011) and participatory approaches such as participatory GIS (PGIS; Palomo et al., 2012) or public participation GIS (PPGIS; Brown, 2013; Fagerholm et al., 2012). These methods are developed and applied to harness community stakeholder knowledge within spatial landscape assessments. Expert-based approaches are also commonly applied for conservation studies, ecological studies and biophysical assessments (see e.g., Al-Awadhi and Garthwaite, 2006; Choy et al., 2009; James et al., 2010; Drescher et al., 2013; Krueger et al., 2012; Schneiders et al., 2012).

Expert elicitation is based on the assumption that through experience, education or profession, certain people have sufficient knowledge on the research subject, to officially (or legally, in the case of court decisions) rely upon their opinion. In understanding and handling complex systems, people form a mental image or model of reality (Eysenck, 2012), even described by some as the basis of human reasoning and learning (Johnson-Laird and Byrne, 2002). Explicit visualisation of the mental model to a conceptual model can enhance communication, understanding and debate (Mylopoulos, 1992). Scientific or stakeholder consensus can thus be reached, implying a certain degree of agreement (but not necessarily unanimity). Although consensus is no guarantee for a good outcome, it allows to move ahead in complex situations without being paralyzed by a lack of data, knowledge or "hard" proof.

1.3. Questioning the current use of expert elicitations in ES research

Expert estimation of ES supply per land use or land cover (LULC) class, aka "the matrix model" is one of the most popular ES assessment techniques today (see next section and Burkhard et al., 2009, 2012b, 2014). The matrix model is technically simple and quickly provides understandable and "mapable" ES data. It also allows to involve relevant experts as well as comprehensive models and measurement data (in later stages). ES-estimates per LULC class (for an example see Fig. 1) are mostly based on several data sources. These can include statistical data (Kroll et al., 2012; Kandziora et al., 2013), model results (Nedkov and Burkhard, 2012), expert knowledge (Vihervaara et al., 2010, 2012; Stoll et al., 2014), interview results (Kaiser et al., 2013; Müller et al. 2014), and monitoring or other data sources (Baral et al., 2013). Estimates are mostly put into comparable semi-quantitative units to allow

[1] Community of Practice on BElegium Ecosystem Services (http://www.beescommunity.be).

[2] Community of Practice on ecosystem services in the Netherlands (http://skbodem.nl/project/43).

[3] Ecosystem Service Community Scotland (http://escomscotland.wordpress.com/).

[4] Intergovernmental Platform on Biodiversity and Ecosystem Services (http://www.ipbes.net).

[5] The Ecosystem Services Partnership (http://www.es-partnership.org).