Sustainability of Water Quality and Ecology 1–2 (2013) 3–9

Contents lists available at ScienceDirect

Sustainability of Water Quality and Ecology

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

# Modelling ecosystem services – Challenges and promising future directions

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ARTICLE INFO

*Article history:*
Received 29 April 2014
Received in revised form 21 May 2014
Accepted 27 May 2014
Available online 5 June 2014

*Keywords:*
Ecosystem services
Trade-offs
Modelling
Optimization
Resources management
Recommendations

ABSTRACT

This paper reviews briefly the current studies on modelling ecosystem services and identifies their current strengths and weaknesses, such as methodological varieties, missing quantification of processes and trade-offs, and insufficient use in resources management. By discussing promising examples, the paper provides five key recommendations to improve these shortcomings.



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## 1. Modelling and assessing ecosystem services can support resource management

Ecosystem services are defined as the benefits that humans obtain from ecosystems (Daily, 1997). Employing the ecosystem service concept is supposed supporting the development of policies and instruments that integrate social, economic and ecological perspectives. Modelling plays an important role as various feedbacks and interactions between ecosystem functions and services need to be quantified. Already Faucheux et al. (1996) found that "...addressing the goal of ecological sustainability requires a large measure of scientific assessment and modelling". The process of integrated ecological-economic modelling can help to build understanding, solicit input from a broad range of stakeholder groups,

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http://dx.doi.org/10.1016/j.swaqe.2014.05.003
2212-6139/

and maintain a dialogue. In the process of adaptive management, integrated modelling and consensus building are essential components (Gunderson et al., 1995; Costanza and Folke, 1997). These statements underpin the important role that models play for the analysis, assessment and finally also for the implementation of the concept. Carpenter et al. (2009) found that "...future assessments modeled on the Millennium Assessment would benefit from concerted effort to understand effects of biodiversity in social-ecological context, improve quantitative modelling across a range of social-ecological topics, address nonlinear and abrupt changes, and improve assessment and communication of uncertainty". Nelson and Daily (2010) provide an overview of existing methods and tools to calculate and express ecosystem service provision and value on landscapes.

## 2. But how far is modelling and assessing ecosystem system services from being used in resources management?

But how far are we with respect to these statements? Daily et al. (2009) point out that "if we can help individuals and institutions to recognize the value of nature, then this should greatly increase investments in conservation, while at the same time fostering human well-being. In practice, however, we have not yet developed the scientific basis, nor the policy and finance mechanisms, for incorporating natural capital into resource- and land-use decisions on a large scale". Seppelt et al. (2011) state that the prolific use of the term 'ecosystem services' in scientific studies has given rise to concerns about its arbitrary application. The authors conducted a quantitative review of recent literature and showed the diversity of approaches and revealed a lack of consistent methodology, which is confirmed by the study of Crossman et al. (2013). The authors point out that the inconsistency in methods to quantify and map ecosystem services challenges the development of robust values of ecosystem services in national accounts and broader policy and natural resource management decision-making. A higher model transparency (e.g., transparency related to model assumptions) also could benefit robustness of national accounts more than a uniform modelling approach would do. In addition – and as prerequisite for sound environmental modelling (Jakeman et al., 2006), data and model uncertainties have to be taken into account, since including uncertainties can in some cases facilitate decision making. Burkhard et al. (2013) hold that new methods to aggregate data, indicators, maps and models without losing relevant information are needed to improve ecosystem service assessments. They state that indicators and models have to be more robust and sensitive to changes and that there is a dearth of indicators for ecosystem functions, regulating and intangible/cultural ecosystem services – however, by searching journal papers with the keywords "ecosystem services" and "indicators" (2010–2014!) over 14,000 articles appear (access in science direct at April 10, 2014), which makes a need for methodological blueprints obvious.

With regard to these shortcomings, Seppelt et al. (2011) derived four facets that characterize the holistic ideal of ecosystem services research: (i) biophysical realism of ecosystem data and models; (ii) consideration of local trade-offs; (iii) recognition of off-site effects; and (iv) comprehensive but critical involvement of stakeholders within assessment studies. The authors suggest that these four facets should be taken as a methodological blueprint for further development and discussion (see also Seppelt et al., 2012). They should critically reveal and elucidate what may often appear to be ad-hoc approaches to ecosystem service assessments. Based on the quantitative review, they provide guidelines for further development and discussions supporting consistency in applications of the ecosystem service concept as well as the credibility of results, which in turn can make it easier to generalize from the numerous individual studies.

In addition, Crossman et al. (2013) develop and test a helpful blueprint to give guidance on modelling and mapping ecosystem services. The primary purpose of this blueprint is to provide a template and checklist of information needed for an ecosystem service modelling and mapping study. A secondary purpose was to provide a database of completed blueprints that becomes a valuable resource of methods and information used in previous modelling and mapping studies. While any study that models and maps ecosystem services will have its unique characteristics and will be largely driven by data and model availability, a tool such as the blueprint presented by these authors will reduce the uncertainty associated with quantifying ecosystem services and thereby help to close the gap between theory and practice.

There are promising attempts to combine concepts such as Integrated Water Resources Management, Integrated River Basin Management or Integrated Natural Resources Management and related Decision Support Systems with the ESS concept, since they have similar objectives (but also similar problems with regard to integration, implementation, data availability, uncertainty, consistency of methods (models), etc.; Jewitt, 2002; Volk et al., 2010; McIntosh et al., 2011; Hering and Ingold, 2012). These integrated management concepts all emphasize linkages between land-use and hydrological systems, ecosystems and human health, and between political and scientific aspects of water management. The water-related integrated modelling and management approaches could learn how to better address trade-offs among land and water use, and ecosystem protection, the ecosystem services approach could benefit from the more process-oriented modelling mostly applied in the former mentioned resources management approaches – depending on the question to answer (see also Vigerstol and Aukema, 2011).

In a nutshell, insufficient use of the ecosystem services concept in resource management is caused by the important deficits of modelling ecosystem services adequately:

- Missing discussion on how much integration is needed for ecosystem services modelling.
- Very diverse, heterogeneous model systems are used, covering a range from relatively simple systems to very complex models – no model selection guideline or protocol available.