Ecosystem Services 4 (2013) 4–14

Contents lists available at SciVerse ScienceDirect

Ecosystem Services

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

A blueprint for mapping and modelling ecosystem services

Neville D. Crossman[a,*], Benjamin Burkhard[b], Stoyan Nedkov[c], Louise Willemen[d,1], Katalin Petz[e], Ignacio Palomo[f], Evangelia G. Drakou[d], Berta Martín-Lopez[f], Timon McPhearson[g], Kremena Boyanova[c], Rob Alkemade[h], Benis Egoh[d], Martha B. Dunbar[d], Joachim Maes[d]

[a] CSIRO Ecosystem Sciences, PMB 2, Glen Osmond, South Australia, 5064, Australia
[b] Institute for Natural Resource Conservation, University of Kiel, Olshausenstr. 40, 24098 Kiel, Germany
[c] National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences Acad. G. Bonchev Street, bl. 3, 1113 Sofia, Bulgaria
[d] European Commission, Joint Research Centre, Via E. Fermi 2749, TP 460, Ispra, VA 21027, Italy
[e] Environmental Systems Analysis Group, Wageningen University, PO Box 47, 6700 AA, Wageningen, The Netherlands
[f] Social-Ecological Systems Laboratory, Department of Ecology, Universidad Autónoma de Madrid, Madrid, Spain
[g] Tishman Environment and Design Center, The New School, 79 Fifth Avenue, 16th Floor, New York, NY 10003, USA
[h] Netherlands Environmental Assessment Agency (PBL), PO Box 303, 3720 AH Bilthoven, The Netherlands

ARTICLE INFO

Article history:
Received 30 November 2012
Accepted 8 February 2013
Available online 7 March 2013

Keywords:
Environmental accounting
Spatial analysis
Geographic information systems
Ecosystem assessment
Standards
Indicators

ABSTRACT

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. In this paper we develop and test a 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 those beginning an ecosystem service modelling and mapping study. A secondary purpose is to provide, over time, a database of completed blueprints that becomes a valuable information resource of methods and information used in previous modelling and mapping studies. We base our blueprint on a literature review, expert opinions (as part of a related workshop organised during the 5th ESP conference[2]) and critical assessment of existing techniques used to model and map ecosystem services. 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 here will reduce the uncertainty associated with quantifying ecosystem services and thereby help to close the gap between theory and practice.

1. Introduction

Ecosystems provide various goods and services to society, which in turn directly contribute to our well-being and economic wealth (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005; TEEB, 2010; de Groot et al., 2012). Valuing the contribution of ecosystems to human well-being through economic, ecological and social (triple-bottom-line) accounting such as Green GDP (Boyd, 2007), the United Nations System of Environmental Economic Accounts (United Nations Statistical Division, 2012), the Green Economy (United Nations Environment Program, 2011), and corporate sustainability reporting (World Business Council for Sustainable Development, 2010) demands robust methods to define and quantify ecosystem services. Also, decision making and policy aimed at achieving sustainability goals can be improved with accurate and defendable methods for quantifying ecosystem services (McKenzie et al., 2011). As Troy and Wilson (2006) point out, spatially explicit units are needed to quantify ecosystem services because supply and demand for ecosystem services are spatially explicit. Furthermore, the supply and demand of services may differ geographically (Fisher et al., 2009; Bastian et al., 2012a). This heterogeneity calls for maps of ecosystem service supply and demand. Distinguishing between mapped supply and demand provides a basis for accounting to ensure demand does not exceed supply. Hence, mapping is a useful tool for illustrating and quantifying the spatial mismatch between ecosystem services delivery and demand that can then be used for communication and to support decision-making.

A number of recent studies have mapped the supply of multiple ecosystem services at global (Naidoo et al., 2008), continental (Schulp et al., 2012), national (Egoh et al., 2008, Bateman et al., 2011) or sub-national (Nelson et al., 2009, Raudsepp-Hearne et al., 2010, Willemen et al., 2010) scales. A few recent studies have mapped the demand of ecosystem services (Burkhard et al., 2012b, Kroll et al., 2012, Nedkov and Burkhard, 2012, Palomo et al., in press). Other recent studies offer frameworks for

* Corresponding author. Tel.: +61 8 8303 8663.
E-mail address: neville.crossman@csiro.au (N.D. Crossman).
[1] Current address: Department of Natural Resources, Cornell University, Ithaca (NY) 14853, USA.
[2] 〈http://www.espconference.org/previous_editions/80045/5/0/60〉.

2212-0416/$ - see front matter Crown Copyright © 2013 Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ecoser.2013.02.001

integrating the ecological and economic value-dimensions of ecosystem services to more accurately calculate monetary values of mapped ecosystem services (Daily et al., 2009, de Groot et al., 2010, Wainger and Mazzotta, 2011). There have also been a number of reviews (Egoh et al., 2012, Martínez-Harms and Balvanera, 2012), special issues of journals (Burkhard et al., 2012a, Crossman et al., 2012b) and books (Kareiva et al., 2011) on ecosystem services quantification, modelling and mapping. These products are at numerous scales and demonstrate the many and diverse ways to model and map ecosystem services. Consequently, there is much uncertainty in what is mapped and the methods used to map the services.

The inconsistency in methods to quantify and map services (Eppink et al., 2012) is a challenge for developing robust economic, ecological and social values of ecosystem services for inclusion in national accounts and broader policy and natural resource management decision-making. At a broader level of sustainability policy, there needs to be better understanding of where and what services are provided by a given piece of land, landscape, region, state, continent and globally, so that stocks of natural capital and the flow of services can be monitored and managed across spatial and temporal scales. There also needs to be better understanding of conditions and threats to the natural capital so that finite resources can be targeted to where the enhancement of services is needed most (de Groot et al., 2010). Furthermore, the recent biodiversity conservation policies based on commodification of ecosystem service production, such as payments for ecosystem services, biodiversity and wetland banking, carbon offsets and trading, and conservation auctions, depend on robust measurement on the stocks of natural capital and flow of services to provide surety to participants in these markets. The varied methods also make the commodification and trade of ecosystem service values very difficult because markets require certainty and clarity around the product being traded, both in the supply-side and the demand-side. The varied methods also make public and private sector ecosystem service accounting very difficult for the same reasons.

Recently, Martínez-Harms and Balvanera (2012) call for a standardised methodological approach to quantify and map ecosystem services, Eppink et al. (2012) suggest that an adaptable conceptual framework should be developed for ecosystem service assessments and Maes et al. (2012a) call for a consistent ecosystem service mapping approach. On a more practical level, TEEB (2010) call for extra effort in mapping: (i) the flow of services; (ii) a wider set of ecosystem services that includes cultural and regulating services, so trade-offs can be better explored, and; (iii) the connections between biodiversity and the final benefit. The conceptual framework, presented in Seppelt et al. (2012) as a blueprint for ecosystem service assessment, includes a component for describing the indicators and their calculation, but little prescriptive detail on modelling and mapping. There is clearly a need to develop a blueprint and set of standards for mapping the stocks and flows and supply and demand of a fuller suite of ecosystem services.

In this paper we develop and test a blueprint for modelling and mapping the stocks of natural capital and flows of ecosystem services, building on the Seppelt et al. (2012) ecosystem service blueprint by focusing on the specific mapping aspect. For simplicity, we use term *ecosystem services* in place of *natural capital stocks and ecosystem service flows*. In this paper we do not limit ourselves to any types of ecosystem services, but instead follow the precedent set by TEEB (2010), who valued elsewhere classified *intermediate* and *final* services as long as the services provide an indirect or direct contribution to human well-being (see Box 1). Our premise is that a review of existing techniques used to model and map ecosystem services provides the basis for the blueprint. We review the current state of the art in mapping ecosystem services, taking into account existing ecosystem service mapping tools and preceding reviews. Our review focuses on the modelling and quantification methods used to map each ecosystem service. We provide preliminary results of our review and a description of the methods used for each of the main ecosystem services mapped. We then propose a blueprint as a guide for mapping ecosystem services, followed by a completed example of the blueprint. The blueprint was developed with the input from working group participants at the 5th Ecosystem Services Partnership Conference in Portland, Oregon, August 2012. We conclude with a discussion on where our approach could be of most use, and provide some critical thought on the level of uncertainty that is inherent in any effort to map ecosystem services.

Box 1–Ecosystem service definitions.

Ecosystem services: contributions of ecosystem structure and function—in combination with other inputs—to human well-being (Burkhard et al., 2012a).

Ecosystem processes: changes or reactions occurring in ecosystems; either physical, chemical or biological; including decomposition, production, nutrient cycling and fluxes of nutrients and energy (Millennium Ecosystem Assessment, 2005).

Ecosystem structures: biophysical architecture of ecosystems; species composition making up the architecture may vary (TEEB, 2010).

Ecosystem functions: intermediate between ecosystem processes and services and can be defined as the capacity of ecosystems to provide goods and services that satisfy human needs, directly and indirectly (de Groot et al., 2010).

Intermediate ecosystem services: biological, chemical, and physical interactions between ecosystem components. E.g., ecosystem functions and processes are not end-products; they are intermediate to the production of final ecosystem services (Boyd and Banzhaf, 2007).

Final ecosystem services: Direct contributions to human well-being. Depending on their degree of connection to human welfare, ecosystem services can be considered as intermediate or as final services (Fisher et al., 2009).

Ecosystem service supply: refers to the capacity of a particular area to provide a specific bundle of ecosystem goods and services within a given time period (Burkhard et al., 2012b). Depends on different sets of landscape properties that influence the level of service supply (Willemen et al., 2012).

Ecosystem service demand: is the sum of all ecosystem goods and services currently consumed or used in a particular area over a given time period (Burkhard et al., 2012b).

Ecosystem service providing units/areas: spatial units that are the source of ecosystem service (Syrbe and Walz, 2012). Includes the total collection of organisms and their traits required to deliver a given ecosystem service at the level needed by service beneficiaries (Vandewalle et al. 2009). Commensurate with *ecosystem service supply*.

Ecosystem service benefiting areas: the complement to ecosystem service providing areas. Ecosystem service benefiting areas may be far distant from the relevant providing areas. The structural characteristics of a benefiting area must be such that the area can take advantage of an ecosystem service (Syrbe and Walz, 2012). Commensurate with *ecosystem service demand*.

Ecosystem service trade-offs: The way in which one ecosystem service responds to a change in another ecosystem service (Millennium Ecosystem Assessment, 2005).