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Original Articles

Ecosystem services classification: A systems ecology perspective of the cascade framework

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ABSTRACT

Ecosystem services research faces several challenges stemming from the plurality of interpretations of classifications and terminologies. In this paper we identify two main challenges with current ecosystem services classification systems: i) the inconsistency across concepts, terminology and definitions, and; ii) the mix up of processes and end-state benefits, or flows and assets. Although different ecosystem service definitions and interpretations can be valuable for enriching the research landscape, it is necessary to address the existing ambiguity to improve comparability among ecosystem-service-based approaches. Using the cascade framework as a reference, and Systems Ecology as a theoretical underpinning, we aim to address the ambiguity across typologies. The cascade framework links ecological processes with elements of human well-being following a pattern similar to a production chain. Systems Ecology is a long-established discipline which provides insight into complex relationships between people and the environment. We present a refreshed conceptualization of ecosystem services which can support ecosystem service assessment techniques and measurement. We combine the notions of biomass, information and interaction from system ecology, with the ecosystem services conceptualization to improve definitions and clarify terminology. We argue that ecosystem services should be defined as the interactions (i.e. processes) of the ecosystem that produce a change in human well-being, while ecosystem components or goods, i.e. countable as biomass units, are only proxies in the assessment of such changes. Furthermore, Systems Ecology can support a re-interpretation of the ecosystem services conceptualization and related applied research, where more emphasis is needed on the underpinning complexity of the ecological system.

1. Introduction

Ecosystem services is now widely used among scientists and policy makers to highlight the importance of the environment (including biodiversity) in sustaining human livelihoods (Convention on Biological Diversity, 2010, 1998; Costanza and Kubiszewski, 2012; Maes et al., 2016). An important milestone of ecosystem service research was the Millennium Ecosystem Assessment (MA, 2005) which made prominent the idea that human well-being depends on ecosystems, and that such linkages can be tracked and framed through the notion of ecosystem services. The MA found that more than 60% of ecosystem services is being degraded or transformed endangering future human well-being.

Ecosystem services research has since progressed at different levels—from theoretical conceptualization to practical applications (see Braat and de Groot, 2012; Egoh et al., 2012; Seppelt et al., 2011; Potschin et al., 2016 for a review). This work has been supported by several international initiatives such as The Economics of Ecosystem and Biodiversity (TEEB, 2010), the UK National Ecosystem Assessment (UK NEA, 2011) and several European Union research

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projects.[1] In addition, some organizations have supported this process with modeling tools such as the US Natural Capital Project with the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) tool. The private sector have also adopted the concept through initiatives such as the Natural Capital Coalition (NCC), the World Bank's Wealth Accounting and the Valuation of Ecosystem Services (WAVES), the accounting system developed by the London Group, which is also being adopted by the United Nations Environmental Program (UNEP).

However, there has been inconsistency in developing a framework within which such research and policy assessments are carried out. The he MA (2005) and subsequent ecosystem services literature (Boyd and Banzhaf, 2007; Fisher et al., 2009; Haines-Young and Potschin, 2012; Landers and Nahlik, 2013; Staub et al., 2011; Wallace, 2007) have developed many different conceptual and empirical frameworks and assessment of changes in ecosystems, their consequences for humans, and actions for sustainable use of these ecosystems (Albert et al., 2015). The existence of numerous ecosystem service conceptualizations and classification systems has led to a plurality in the interpretation of ecosystem services and related terminology and definitions when it comes to applications (Boerema et al., 2016). Large differences in interpretation are found in the meaning of biophysical structure, ecological functions, intermediate services and final services (e.g. Landers and Nahlik, 2013; Mononen et al., 2016; Spangenberg et al., 2014; UK NEA, 2011; TEEB, 2010). The consequence of such differences is the ecosystem service classification systems have poor correspondence of services with benefits and blurred distinctions between intermediate and final services. Among these, the Common International Classification for Ecosystem Services (CICES), proposed by the European Environment Agency, has become an important frame of reference for ecosystem services research (Maes et al., 2014). CICES and most ecosystem services literature are based on and influenced by the cascade framework proposed by Haines-Young & Potschin in 2010 (Haines-Young and Potschin, 2010; Potschin and Haines-Young, 2016). The purpose of the cascade framework is in fact to show the pathway of ecosystem services from ecological structures and processes to human well-being.

In this context, the need to develop a framework to assess ecosystem services is a priority in ecosystem services research. Although individual interpretations enrich the research landscape, the ambiguity must be addressed so that a more rigorous framework for ecosystem services can be developed and adopted. Such a framework would improve comparability among ecosystem-service-based approaches and would provide a standardized approach for ecosystem assessments at global and national scales. The further evolution of ecosystem services concepts and frameworks could draw from the field of systems ecology which can provide insights into our understanding of the different aspects of ecosystem functioning that contributes to ecosystem services. This interdisciplinary field of systems ecology adopts a holistic approach to the study of ecological and human systems. Concepts from ecological theory have been already discussed in previous literature in relation to ecosystem services, e.g. ecological integrity and complexity, resilience (Kremen, 2005; Brand, 2008). Our paper aims to systematically adopt key concepts from systems ecology to redefine ecosystem services and the related cascade framework. The contribution of our paper is to present a refreshed conceptualization of ecosystem services through the lens of systems ecology.

[1] e.g. RUBICODE (Rationalizing Biodiversity Conservation in Dynamic Ecosystems), SCALES (Securing the Conservation of biodiversity across Administrative Levels and spatial, temporal, and Ecological Scales), OpenNESS (Operationalization of Natural Capital and Ecosystem Services) and ESMERALDA (Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAking)

We firstly identify the main challenges associated with the various interpretations of the cascade framework (Section 2.1) and of the existing classification systems whose structure and meaning does depend on the chosen theoretical framework (Section 2.2). Secondly, we introduce key concepts from the discipline of systems ecology (Section 3) to address the identified challenges (Section 4). We finally conclude by discussing the contribution of our refreshed conceptualization of ecosystem services (Section 5).

2. Current challenges in ecosystem services research

2.1. Challenges with the use of the ecosystem services cascade

The cascade framework proposed by Haines-Young and Potschin (2010) links natural systems to elements of human well-being, following a pattern similar to a production chain: from ecological structures and processes generated by ecosystems, to the services and benefits eventually derived by humans. The advantage of this framework is to effectively communicate societal dependence on ecosystems.

Challenges arise when applying this cascade framework in practice, due to the simultaneous presence in the framework of bio-centered and human-centered spheres. This means that ecosystem services assessments include:

- observations from a bio-centred or holistic approach- i.e. biophysical structures and processes/functions belonging to the ecological sphere and which are considered as a whole,
- observations from a reductionist or human-centred approach- i.e. ecosystem services which are projected towards the human end-use side individually.

This challenge is evident when we try to measure ecosystem services, which are categorized and accounted for individually.[2]

In addition, different definitions of ecosystem services and in particular of the elements in the cascade framework are found in the literature: biophysical structure, process, function, service, benefit.[3] As an example, Table 1 summarizes the definitions provided in recent ecosystem services studies. For instance, ecosystem structure is often poorly distinguished from processes. Wallace (2007, p. 237) proposes that 'an important distinction [between the two] is that the former are generally tangible entities described in terms of amount, while the latter are [. . .] generally described in terms of rates'.

Furthermore, the word function is generally used interchangeably with ecological process and/or ecosystem service. According to Jax (2005), the term 'function' is often used too ambiguously. Ecosystem services are generally defined as the ecosystem processes considered useful to humans (MA, 2005; TEEB, 2010). In the same light, some studies (ref. Table 1) that have assessed, mapped or valued ecosystem services, use services and benefits as synonyms. Benefits are in some cases considered as tangible natural resources derived from provisioning services (e.g. crops, wood, water), or some regulating services (e.g. clean water for multiple uses provided by water purification). Benefits, however, can also be intangible (e.g. recreation opportunities offered by nature).

[2] Note that some authors, e.g. Mononen et al. (2016) have suggested to highlight the process-like nature of ecosystem services delivery as socio-ecological systems, thus maintaining the holistic approach on the focus.

[3] The cascade model does indeed include, after 'benefit', also the 'value' step that assigns to benefits a quantification in monetary terms. The economic valuation of ecosystem services is a field of research and applications that does not affect the specific conceptual analysis proposed in this paper. In order to keep focused on the main objectives of the paper, we thus choose not to include the 'value' box at this stage.