

Temporal scales, ecosystem dynamics, stakeholders and the valuation of ecosystem services



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ABSTRACT

Temporal dimensions are highly relevant to the analysis of ecosystem services and their economic value. In this paper, we provide a framework that can be used for analyzing temporal dimensions of ecosystem services, we present a case study including an analysis of the supply of three ecosystem services in a Dutch national park, the Hoge Veluwe, over a time span of around a century, and we analyze the implications of temporal scales for ecosystem services analysis and valuation and ecosystem management. Our paper shows there can be major shifts in the values attributed to specific ecosystem services at time scales of decades or less. Changes in values at these time scales and are not commonly included in cost benefit analysis of ecosystem management options or natural capital accounts. Yet – given the long time lapse with which ecosystems may respond to management – these changes are highly relevant. We argue that ecosystem managers using cost benefit analysis should be aware of both uncertainties and of temporal changes in ecosystem values, and – to deal with unexpected changes in ecosystem services values – consider management strategies that target multiple ecosystem services.

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1. Introduction

In recent years, there has been a strong increase in interest in the analysis and valuation of ecosystem services (e.g. Millennium Ecosystem Assessment, 2005; Daily and Matson, 2008; Bateman et al., 2013; Diaz et al., 2015). Ecosystem services analysis and valuation has been applied, for instance, to raise awareness on the economic benefits provided by ecosystems and to analyze the costs and benefits of different ecosystem management options (Turner et al., 2010). There is also an increasing interest in examining how ecosystem services can be linked to national accounts in order to develop ecosystem accounting approaches (UN et al., 2014). In an earlier article, we examined spatial scales and stakeholders in relation to ecosystem services (Hein et al., 2006). Increasingly, studies have addressed the spatial scales of ecosystem services, for instance by mapping ecosystem services (e.g. Nelson et al., 2009; Schröter et al., 2014) or by linking spatial scales to stakeholder interests (e.g. Willemen et al., 2010).

Studying the *temporal* dynamics of ecosystem services supply is important given that ecosystems and their capacity to supply

ecosystem services, as well as the demand for ecosystem services may change over time (Rounsevell et al., 2010). In ecology, a broad range of studies have been published on ecosystem dynamics and the complexities therein (e.g. Scheffer et al., 2001; Rustad, 2008; Carpenter et al., 2011). The importance of ecosystem dynamics for analyzing ecosystem services has been explored in for instance Carpenter et al. (2006) and, for coastal ecosystems, Koch et al. (2009). In an economic context, preferences and demand for ecosystem services may change over time, and future benefits need to be discounted in order to analyze the net present value of management options (Boithias et al., 2016). In natural capital accounting, the asset value of an ecosystem is influenced by changes in flows of ecosystem services as well as price changes over time (UN et al., 2014). Temporal dynamics are reflected in the various frameworks for ecosystem services assessment that have been produced to date, such as the MA (2005), TEEB (2010), Ecosystem Accounting (UN et al., 2014) and IPBES frameworks (Diaz et al., 2015).

Understanding and quantifying temporal changes in ecosystem services flows and values as a function of ecosystem dynamics and economic drivers is, however, not straightforward. In many valuation studies, data and methodological constraints mean that general assumptions have to be made regarding the dynamics of

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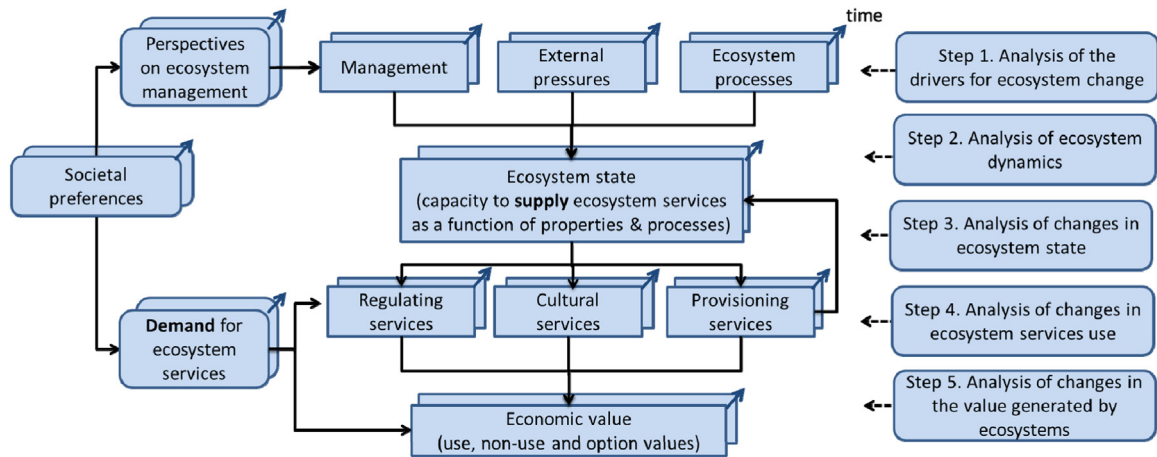


Fig. 1. Considering temporal dynamics in ecosystem services assessment and modelling.

ecosystem use, ecosystem processes, and values that can be attributed to ecosystem services (TEEB, 2010). Often, such assumptions are based on current ecosystem management practices and assuming constant prices for ecosystem services (Grêt-Regamey et al., 2013). Clearly, the longer the time frame, the more difficult meaningful assumptions on ecosystem uses and dynamics become.

The objective of this study is to analyze the implications of temporal changes in ecosystems and the services they provide for ecosystem valuation and ecosystem management. On the basis of a literature review, we develop a general framework that points to the main aspects of ecosystem services modelling and assessment that require consideration of temporal changes, and we carry out a case study on the temporal variation of ecosystem services supply in the Hoge Veluwe National Park in the Netherlands. For this park, we analyze the supply and value of three ecosystem services over a time frame of around a century. Because of limitations in the availability of historical data, we express economic value through proxy indicators that reflect changes in value over time. Based on our findings, we distill a number of lessons for the consideration of temporal aspects in studies supporting ecosystem management.

We first present the framework and subsequently analyze two critical components of assessing the temporal dynamics of ecosystem services supply: the dynamics of societal preferences and complex ecosystem dynamics. Note that our framework is not meant to substitute for the elaborate frameworks on ecosystem services analysis provided in, for example MA (2005), TEEB (2010), UN et al. (2014) and IPBES (Díaz et al., 2015). We also do not intend to provide a detailed analysis of temporal considerations in economic valuation (for which we refer to for instance Frederick et al. (2002)). The specific purpose of the framework is to elicit those elements that require consideration of temporal scales in ecosystem services assessment. Subsequently we present our case study that focusses on one specific provisioning, one regulating and one cultural services supplied by the national park 'Hoge Veluwe', and how this supply has changed over the course of around a century. Finally, we analyze the implications for ecosystem management.

2. Temporal scales of ecosystem services

2.1. Analyzing the temporal dimensions of ecosystem services

Three types of ecosystem services are generally distinguished (Millennium Ecosystem Assessment, 2003, TEEB, 2010; Haines-Young and Potschin, 2013), i.e. provisioning services (involving the

goods that can be harvested in an ecosystem), regulating services (reflecting that ecosystems can regulate essential ecological and climatologic processes) and cultural services (non-material benefits provided by ecosystems). In a welfare-based valuation approach, the economic value of the ecosystem services can be expressed in terms of producer and consumer surplus (e.g. NRC, 2004, Bateman et al., 2011). In an accounting approach to valuation, the focus is on the value of production (of ecosystem services, by the ecosystem) as measured on the basis of exchange values (Obst et al., 2015). For provisioning services, exchange values can be obtained through observed market prices but for regulating and cultural services non-market valuation approaches are needed (UN et al., 2016). Since the ecosystem accounting valuation approach only considers values related to production (expressed through indicators such as value added or resource rent, see for the definitions and Remme et al. (2015) for an example) and not to consumption, the values in ecosystem accounting will usually be lower than the full welfare-based value (Nordhaus, 2005). Note that ecosystem accounting records both annual flows of ecosystem services and the net present value of ecosystem assets on the basis of the discounted value of the expected flow of ecosystem services from an ecosystem asset (UN et al., 2014). The latter requires consideration of ecosystem dynamics and expected ecosystem services flows over a period of typically 20–25 years in the future.

In most ecosystems, ecosystem services supply and the value of these services are likely to change over time, as a function of a set of ecological, institutional and economic factors. Such changes are relevant in view of the need to ensure that future ecosystem users also have the possibility to use ecosystem services, and would be reflected in, for example, medium to long-term ecosystem management plans, scenario analysis of ecosystem uses, or analysis of the net present value of an ecosystem on the basis of the sum of the discounted net values generated by the ecosystem over time (Millennium Ecosystem Assessment, 2003; Daily and Matson, 2008).

We propose the following framework for identifying and analyzing the temporal dimensions of ecosystem services supply, see Fig. 1 below. Our framework specifies the various aspects in ecosystem services assessment and modelling where temporal dimensions are relevant. The figure contains five steps that facilitate a systematic analysis of the temporal dimension of ecosystem services supply. These steps are described below.

Step 1. Analyze the drivers for ecosystem change. We distinguish the following drivers for ecosystem change: ecosystem processes (e.g. succession), external pressures (e.g. climate change), and ecosystem management (which may shift as a function of changing visions on ecosystems). For example, visions on ecosystem

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