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Ecosystem service state and trends at the regional to national level: A rapid assessment

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ABSTRACT

The concept of ecosystem services has helped rationalize humanity's dependence on and benefits from nature, pushing the paradigm of environmental sustainability from a charity in the direction of a necessity. However, globally many ecosystem services are declining despite their eminent value for society. A prime cause of this decline is allocated to land use change. While the body of empirical research showing various consequences of land use is growing, and the ecosystem service concept has helped make trade-offs more graspable, a lucid approach that neatly summarizes the extent of land use trade-offs is still lacking.

In this paper, we introduce a rapid assessment to analyze both the state and trends of selected ecosystem services associated with given land use categories. Theoretically, the assessment can be performed for any given spatial unit, but the regional to national level appears to be the most appropriate spatial resolution. Each land use-ecosystem service relationship is classified from a strong disservice to a strong service. The results are displayed in adapted flower diagrams, which legibly display information on the ecosystem services in each land use, thus clearly summarizing trade-offs associated with changing land use.

We illustrate this rapid ecosystem service assessment method by applying it to three land use categories on the spatial extent of Switzerland. We found that the simple but systematic approach is more flexible than traditional mapping approaches, i.e. it allowed us to combine a variety of spatially non-explicit but highly detailed indicators with spatially explicit indicators. Also, we were able to proceed faster than with a mapping approach, where many known and unknown spatial inaccuracies may arise have allowed. This flexible incorporation of spatially explicit and non-explicit data provides high quality information on the state and trends of ecosystem services at regional to national extents. For that reason, we are convinced that the rapid assessment method has the potential to advance knowledge of ecosystem services and land use trade-offs, especially in areas with low data availability and monitoring activity.

1. Introduction

Ecosystem services, the benefits people obtain from ecosystems, help demonstrate how humans profit from and depend on nature (Daily et al., 2009; Fisher et al., 2008). Even early, rudimentary valuation efforts made it clear that ecosystem services are of irreplaceable value for humanity (Costanza et al., 1997). However, the general condition of many ecosystem services is decreasing (MA, 2005), even though human use for them is increasing (Carpenter et al., 2009).

Humanity has altered nature to increase its benefits, to maximize certain ecosystem services, a phenomenon coined land use. Kareiva et al. (2007) point out that the net effect of this "domestication" has been positive on humans. However, often societies were (and still are) not aware of the consequences of land use trade-offs. For example, it has been argued that soil loss resulting from agriculture led to the demise of various ancient civilizations (Beach et al., 2006; Judson, 1968; Montgomery, 2007). Even today, land use change often comes with unaccounted losses of carbon sequestration, regional climate and air quality regulation, pollination services, etc. (Foley et al., 2005). While the body of empirical research showing various consequences of land use is growing, and the ecosystem service concept has helped make trade-offs more graspable for management, a lucid approach that neatly summarizes the extent of trade-offs is still wanting.

Different approaches have been developed to assess ecosystem services and to make the assessments readily available for

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managers. The most common method is the assessment based on mapping (Cowling et al., 2008; Haines-Young and Potschin, 2009). Prominent applications include the mapping of ecosystem services in Europe (Kienast et al., 2009; Schröter et al., 2005), California (Chan et al., 2006), globally (Naidoo et al., 2008), as well as the InVEST project (Daily et al., 2009; Nelson et al., 2009). While mapping is useful for certain objectives, mapping exercises are only as good as the spatial data available, i.e. for map overlays the layer with the lowest spatial and thematic quality determines the overall quality of the assessment. In many regions, fine-scale spatial data necessary for approximating ecosystem services across space and time is lacking (Eigenbrod et al., 2010). Also, the binary transfer assumption behind mapping approaches conveys a false sense of accuracy: it extrapolates the value of ecosystem services over a whole region, when in fact the values only stem from point observations or expert approximations of a specific habitat type (Nelson et al., 2009). Thus the use of proxies may lead to fatal error propagations (Eigenbrod et al., 2010). Lastly, because data quality and availability are unique for each assessment area, it is generally difficult to transfer inherently complex spatial assessment methods from one study area to another (Koschke et al., 2012).

Efforts following the Millennium Ecosystem Assessment to create and establish a set of ecosystem service indicators have missed their goals at the continental and global level (Feld et al., 2009; Layke et al., 2012; Walpole et al., 2009). For one, there are no agreed upon global indicators. While different indicator frameworks have been suggested (Feld et al., 2010; Haines-Young and Potschin, 2010; Layke et al., 2012; Staub et al., 2011; van Oudenhoven et al., 2012), it is extremely difficult to generalize indicators broad enough to apply to diverse environments but specific enough to retain conclusiveness. Also, various ecosystem services, especially cultural ecosystem services, are still ungraspable (Harrison et al., 2010). Indicators have to find the golden middle between simplifying and expressing the original, complex processes, all while maintaining maximum possible quantifiability and transparence.

In this paper we introduce a rapid method for assessing the state and trend of ecosystem services. We follow the example of Harrison et al. (2010) and evaluate the state and trends of ecosystem service capacity in our assessment area. The approach is based on a combination of spatially non-explicit but highly detailed indicators with spatially explicit indicators and lucidly illustrates land use trade-offs for decision makers. We focus our assessment on the capacity of ecosystems to provide ecosystem services, as opposed to the flux or flow of ecosystem services actually reaching society. This capacity of providing ecosystem services has been called various names, "supply" (Schröter et al., 2005), "stock" (Kienast et al., 2009; Layke et al., 2012), "potential" (Koschke et al., 2012), all of which fall into the category of biophysical assessment suggested by Cowling et al. (2008). The evaluation of the potential for landscapes to deliver ecosystem services is considered an important bridge builder between research and landscape management due to its ability to express land use trade-offs (Bastian et al., 2012; Koschke et al., 2012; Lautenbach et al., 2011).

2. Methods

The objective of our assessment is to systematically approximate the state and trends of ecosystem services at large spatial scales (regional or national level). The entity of the assessment is a land use category. The core of the assessment is the evaluation of the following questions:

(1) Ecosystem service state: What is the contribution of the land use category n to the ecosystem service m (very negative −3, negative −2, slightly negative −1, no influence 0, slightly positive +1, positive +2, very positive +3)?
(2) Ecosystem service trend: How is the ecosystem service state in each land use category developing over time (declining, increasing, constant, uncertain)?

The value of the state and trend are determined using a systematic expert approximation. That means, first a set of indicators is established. Then, based on these indicators, experts approximate the values of interest—here the ecosystem service state and trend. Systematic expert approximations are a useful tool for providing an overview of the state of socio-ecological processes or structures where scientific knowledge is not yet at a level to allow more complex mathematical, statistically supported calculations. Applications include the (MA, 2005), the Planetary Boundaries Concept (Rockström et al., 2009), and many more (Foley et al., 2005; Haines-Young et al., 2012; Harrison et al., 2010; etc.).

To illustrate the methodology behind our rapid approach for assessing the state and trends of ecosystem services in selected land use types, we applied the approach to Switzerland.

2.1. Case study region

Our case study region is Switzerland. We draw on the land use categories from Swiss Statistics, which effectively divide the country into forests, agricultural areas, alpine pastures, urban areas, water bodies, glaciers, and other unproductive areas (BFS, 2012). In this assessment we evaluate forests, agricultural areas (excluding alpine pastures), and water bodies (see Table 1). The three land uses cover almost two-thirds of the country.

2.2. The assessment

Based on the Common International Classification of Ecosystem Services (CICES, 2013), eight ecosystem services were defined as relevant and important to human well-being in Switzerland: provisioning services, biodiversity, water regulation, cultural services, climate regulation, soil preservation, mitigation of natural hazards, and air quality regulation. We found it more practical to use various CICES hierarchies (Table 2) then to adhere to one level. However, in their entirety, our selected ecosystem services cover all CICES classes except disease control and ones pertaining to marine ecosystems. Next we defined a set of quantifiable indicators for each ecosystem service and land use relationship. The indicators were selected based on the literature (Feld et al., 2010; Harrison et al., 2010; Layke et al., 2012; Staub et al., 2011; van Oudenhoven et al., 2012) and our own judgment.

The assessment method differs from existing literature - and expert-based ecosystem service evaluations such as MA (2005), Harrison et al. (2010), and Haines-Young et al. (2012) by incorporating the concept of ecosystem dis-services. Various authors noticed that an ecosystem, land use category, or other spatial entity, aside from providing benefits to humans, may also have negative effects for human well-being (Power, 2010; Zhang et al., 2007). Agro-ecosystems, for example, often contribute to air and water pollution, emit greenhouse gases, increase erosion, and come along with biodiversity loss (Swinton et al., 2007).

Considering negative effects is especially important for projects that aim at agglomerating ecosystem services from different spatial or ecological entities or demonstrating land use trade-offs. Such projects must have a mechanism whereby a positive effect on an ecosystem service may be negated on a higher agglomeration level by a negative effect in another entity. Burkhard et al. (2012) and