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Exploring ecosystem services assessment through Ecological Footprint accounting

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ABSTRACT

Ecosystem services are the benefits that humans derive from Nature. In the last decades, research efforts have been made to better understand the connections between the natural sphere and the human sphere as well as to propose novel approaches to measure the value of ecosystem services. While economic valuation has so far been the most commonly used approach – expressing ecosystem services' value in monetary units – recent efforts have focused on alternative qualitative or biophysical accounting approaches to express the value of ecosystem service in physical units.

The role of Ecological Footprint accounting as a biophysical approach for measuring the value of ecosystem services through a surface-equivalent unit is here investigated. This accounting tool allows keeping track of both the human demand on, and the Nature's supply of, a precise sub-set of ecosystem services thus being able to make an ecological balance at the country level. A comparison between Ecological Footprint and economic valuation analyses is finally performed, for the forest ecosystem type, to highlight complementarities and correlations of these different approaches.

Contents

1. Introduction

Ecosystem services are Nature's benefits to people. These include provisioning services such as food and fresh water; regulating services such as climate control; supporting services such as soil formation and photosynthesis; and cultural services such as recreation, spiritual and educational values (Costanza et al., 1997; MEA, 2005; TEEB, 2010). Interest in the understanding, modelling, valuation and management of ecosystem services has grown rapidly in the sustainability debate since 2005, when it gained broader attention following the publication of the United Nations' Millennium Ecosystem Assessment (MEA, 2005; Braat and de Groot, 2012; Costanza and Kubiszewski, 2012). Since then, a few international initiatives have been undertaken for assessing the connection between Nature and the human society and economy,

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Table 1
Overview of key quantitative biophysical accounting methods for the assessment of Ecosystem Services.

Method name	ESs accounted	Description	References
Change in stock/ quantities	P	Increasing/decreasing quantities of an ecosystem good indicate increasing/decreasing values	Remme et al., (2014)
Ecological integrity	All	The higher the ecological integrity (defined as the basic requirements for the stability of biotic communities), the higher the value of that ecosystem for that service	Johnston et al., (2011)
Biodiversity indexes	All	The higher the biodiversity (measured through indexes such as the Living Planet Index or the Red List Index), the higher the service value of that ecosystem	Obrist and Duelli, (2010)
Ecological Footprint	P, R	The area and productivity of ecosystems within a territory (i.e. the biocapacity) used as proxies for the ecosystem service value of that territory	Galli et al. (2014), Galli et al. (2012) This study
Changes in efficiency	P, R	The more efficient an ecosystem is in producing goods and services (in terms of resource use per service unit), the higher its value	McCarthy et al., (2011)
Emergy	All	The more equivalent solar energy is embodied in the ecosystem components, the higher is the ecosystem service value	Coscieme et al., (2014)
Eco-exergy	All	The higher the level of genetic information and biomass in the ecosystem, the higher the ecosystem service values	Jørgensen, (2010)

Note: letters P and R reported in the second column refers to "provisioning" and "regulating" ecosystem services, respectively, while "all" refers to the whole set of ecosystem services according to the CICES classification (see Haines-Young and Potschin, 2013).

including the Economics of Ecosystems and Biodiversity (TEEB, 2010), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES – see Díaz et al., 2015), the System of Environmental-Economic Accounting (SEEA – UN et al., 2014a,b) and the Common International Classification of Ecosystem Services (CICES – Haines-Young and Potschin, 2013).

Ecosystem functions and biodiversity constitute the natural capital stock that yields the ecosystem service flows into the future (Costanza and Daly, 1992). However, ecosystems cannot provide any benefit to people without the presence of people (human capital), their communities (social capital), and their built environment (built capital) (Costanza et al., 2014a). Humanity depends on the biosphere for its well-being and a relational order exists between the different forms of capital, with built and human capital embodied into social capital, and social capital embodied, in turn, into natural capital (Wackernagel et al., 2002; Pulselli et al., 2015).

Two main approaches exist to understand and measure the value of ecosystem services: 1) a monetary valuation approach, requiring that ecosystem services are assessed in monetary units; 2) a biophysical accounting approach, based on quantitative empirical measurements.

Monetary valuation is the most developed approach to assess the value of ecosystem services. It constitutes a way to include the value of ecosystems and biodiversity in cost-benefit analyses and allows including the costs of environmental degradation in macroeconomic "beyond-GDP" type of indicators (Costanza et al., 1997; Costanza et al., 2014a,b). As such, the economic assessment of the value of ecosystem services represents an effective way to communicate to policymakers, the business sector (Hanson et al., 2012), and the general public the importance of environmental conservation (TEEB, 2010). Through environmental economics methods, which aim at weighting in monetary terms the use and non-use values of ecosystem services, it is possible to track a wide basket of ecosystem services, although these evaluations often depend on the variability of market prices as well as individual preferences (De Groot et al., 2012; Christie et al., 2012).

Given the complexity of Nature and the high degree of approximation of the economic-based approach, a few scientists and researchers have recently suggested (e.g., Costanza et al., 2014a) that research efforts should be focused on alternative analyses based on more spatially explicit and dynamic methods, to capture the intrinsic value of natural capital and its capacity to deliver goods and services to humans. Such an alternative to monetary valuation is envisaged by qualitative and biophysical accounting methods aiming at expressing the value of ecosystem services in other than monetary units (i.e. land, energy, productivity, etc.) (e.g. Burkhard et al., 2012; Burkhard and Maes, 2017).

Accordingly, the aim of this paper is to analyze such an alternative, biophysically-based, approach for the assessment of ecosystem services. Specifically, we discuss here the possibility of using Ecological Footprint accounting as a biophysical measure for the assessment of ecosystem services. A comparison between the results obtained from economic valuations and those obtained from the Ecological Footprint assessment is also provided to highlight advantages and limitations of both methods.

2. The biophysical evaluation of ecosystem services: Ecological Footprint accounting

The ability of biophysically-based methodologies such as LCA (Koellner and Geyer, 2013; Othoniel et al., 2016), Emergy analysis (Coscieme et al., 2014; Pulselli et al., 2011, 2015), Water Footprint (Vanham, 2016), biodiversity assessments (Schneiders et al., 2012), as well as accountings of economic (Costanza et al., 1997; Fisher et al., 2008) and other human-derived forms of capital (Jones et al., 2016) to track ecosystem services has been widely investigated in the last decades. Such methodologies can be either qualitative or quantitative (see Table 1 for an overview of existing approaches).

Qualitative approaches are mainly based on descriptive assessment of ecosystem services provision at a certain spatial scale without any actual measurement or quantification, such as descriptive tables and color-coded maps illustrating the potential of particular areas to provide ecosystem services (see Burkhard et al., 2009). Conversely, proper biophysical accounting methods include the use of physical units to quantify the flows of ecosystem services from the environment to human socio-economic systems (i.e. raw materials and resources) or even quantify the capacity of ecosystems to provide goods and services (UN et al., 2014a). The value of grassland for milk production, for instance, can be expressed in tons of milk per year rather than using the market value of that same amount of milk. The chosen unit of measure largely depends on the objective of the evaluation as well as on users' considerations about the most effective way to communicate results to a specific audience, in a given context.

One of the major drawbacks of biophysical evaluations is represented by the fact that a common physical unit of measure is hardly associable to the different kinds of services. In other words, these methods often fail in aggregating different multiple services from