Ecosystem Services 23 (2017) 18–29

Contents lists available at ScienceDirect

Ecosystem Services

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

Physical and monetary ecosystem service accounts for Europe: A case study for in-stream nitrogen retention

Alessandra La Notte[a,*], Joachim Maes[a], Silvana Dalmazzone[b], Neville D. Crossman[c], Bruna Grizzetti[a], Giovanni Bidoglio[a]

[a] *European Commission - Joint Research Centre, Directorate D – Sustainable Resources, Via Enrico Fermi 2749, 21027 Ispra, VA, Italy*
[b] *Department of Economics and Statistics, University of Torino, Campus Luigi Einaudi, Lungo dora Siena 100, 10153 Torino, Italy*
[c] *CSIRO Land and Water Flagship, Waite Campus, 5064 Adelaide, South Australia, Australia*

ARTICLE INFO

JEL codes:
Q56
Q57
Q25

Keywords:
Ecosystem accounting
Ecosystem services
Water purification
Capacity
Sustainable flow
Actual flow

ABSTRACT

In this paper we present a case study of integrated ecosystem and economic accounting based on the System of Environmental Economic Accounting — Experimental Ecosystem Accounts (SEEA-EEA). We develop accounts, in physical and monetary terms, for the water purification ecosystem service in Europe over a 20-year time period (1985–2005). The estimation of nitrogen retention is based on the GREEN biophysical model, within which we impose a sustainability threshold to obtain the physical indicators of capacity – the ability of an ecosystem to sustainably supply ecosystem services. Key messages of our paper pertain the notion of capacity, operationalized in accounting terms with reference to individual ecosystem services rather than to the ecosystem as a whole, and intended as the stock that provides the sustainable flow of the service. The study clarifies the difference between sustainable flow and actual flow of the service, which should be calculated jointly so as to enable an assessment of the sustainability of current use of ecosystem services. Finally, by distinguishing the notion of 'process' (referred to the ecosystem) from that of 'capacity' (pertaining specific services) and proposing a methodology to calculate capacity and flow, we suggest an implementable way to operationalize the SEEA-EEA accounts.

1. Introduction

Integrated assessments of economic, social and environmental impacts are key to supporting public and private sector decisions related to land and water resources. An essential part of integrated assessments is the identification of the links between ecosystem functions and processes and human wellbeing, a task to which theoretical frameworks, principles, definitions and classifications have been devoted by numerous studies (e.g. Millennium Ecosystem Assessment, 2005; The Economics of Ecosystems and Biodiversity, 2010; Daily et al., 2009; Diaz et al., 2015).

A number of policy initiatives have incorporated ecosystem service quantification and valuation. For example, the *Europe 2020* strategy has the manifest intention of mainstreaming environmental issues into other policy areas (European Commission, 2011a, 2011b) by preserving the resource base (defined as the capacity of ecosystems to provide services that, in turn, provide benefits to human beings) required to allow the economy and society to function (European Commission, 2011a). The *EU Biodiversity Strategy to 2020* (European Commission, 2011b) includes ecosystem services alongside with biodiversity, to highlight the key role of ecosystems in biodiversity protection. In particular Action 5 of the Strategy requires that ecosystem service assessment and valuation be integrated into accounting and reporting systems, so as to relate environmental assets to other statistics and data on environmental, economic and social characteristics already used by analysts and policy makers. At all levels, a fully integrated economic and environmental analysis is increasingly recognised as crucial for policy design and implementation.

To meet this call, national statistical offices and international agencies have been working on ways to make national accounting and reporting systems more inclusive of ecosystems.[1] Traditional national economic accounts based on the System of National

* Corresponding author.
E-mail address: alessandra.la-notte@jrc.ec.europa.eu (A. La Notte).

[1] See for example *Wealth Accounting and Valuation of Ecosystem Services* (http://www.wavespartnership.org/waves/).

http://dx.doi.org/10.1016/j.ecoser.2016.11.002
Received 3 February 2016; Received in revised form 28 October 2016; Accepted 2 November 2016
Available online 29 November 2016
2212-0416/

Accounts (SNA), developed 50 years ago when little thought was given to environmental damage, do not consider ecosystem assets and services. Although there have been some revisions,[2] the SNA does not yet account for the degradation and depletion[3] of natural resources. Over the last 40 years a number of efforts have been made to develop methods that integrate traditional macroeconomic indicators with environmental information (Hecht, 2007). In the early 1990s the statistical unit of the United Nations proposed a single System for Integrated Environmental and Economic Accounting (SEEA) (Bartelmus et al., 1991) as a way to standardize different frameworks and methods. The original 1993 SEEA handbook (UN, 1993) focused on the adjustment of existing macro-indicators. The subsequent SEEA 2003 framework comprised four categories of accounts, made up of several environmental accounting modules (UNSD, 2003). More recently, the SEEA Central Framework (SEEA-CF), which covers the main component of the physical environment (air, water and land), is being adopted as an international statistical standard (UN 2014a).

Natural resource accounts, however, only tell part of the story, because ecosystems are a lot more than just land and water. An ecosystem is an interconnected and interacting combination of abiotic (land, water) and biotic (biodiversity) components, and the depletion of its stock - the natural capital - may cause the loss of multiple services now and in the future. This is the reason why ecosystem accounts, aimed at monitoring the capacity of ecosystems to deliver services, are the focus of increasing attention within economic-environmental accounting (Schröter et al., 2014; Remme et al., 2014; Busch et al., 2012; La Notte et al., 2011).

The Land and Ecosystem Accounting framework (LEAC) is an early attempt at ecosystem accounting (Weber, 2009; EEA, 2006, 2010 and 2011). In LEAC the consumption of natural capital, considered as the asset, is measured as the restoration cost required after intensive exploitation and/or insufficient maintenance. However, the LEAC framework does not incorporate direct measurement of ecosystem services. A white cover version of the SEEA-Experimental Ecosystem Accounts (SEEA-EEA) was released in June 2013 and officially published in 2014 (UN, 2014b), developed and recommended by the United Nations, European Commission, World Bank, OECD and FAO. The SEEA-EEA is an experimental accounting framework to be reviewed in light of country experience and conceptual advances. The framework is intended for 'multidisciplinary research and testing' (UN, 2014b) and urgently calls for applications and case studies. SEEA-EEA Technical Guidelines were released in April 2015 and made available for global peer review in December 2015 to support national efforts at ecosystem accounting(UNEP et al. 2015).

The Technical Guidelines state that central in applying the SEEA-EEA framework to 'support discussion of sustainability' is the concept of *capacity* (ref. Section 7.44 UNEP, 2015). The notion of capacity is important to assess the integrity/degradation of the ecosystem in relation of how ecosystem services are used and managed. However, some aspects of the notion of capacity in the SEEA-EEA have not been tackled in a definitive way. Specifically: i) whether to attribute the notion of capacity to the ecosystem as a whole or to each individual ecosystem service, and ii) whether to consider ecosystem service supply independent of service demand. There is the need to address these questions because some assumptions regarding capacity are required in order to set up a complete and consistent accounting system.

Our paper investigates these two questions by applying the SEEA-EEA to the regulating ecosystem service of water purification in Europe, using in-stream nitrogen retention as a proxy for water purification. To our knowledge this is the first application of SEEA-EEA based approaches to ecosystem services measurement at a continental scale.

We begin with a brief introduction to the SEEA-EEA framework (Section 2.1), followed by the description of how the water purification ecosystem service is quantified here to be consistent with SEEA-EEA principles (Section 2.2). The results (Section 3) are expressed in terms of the SEEA-EEA procedure. The challenges raised by our case study and discussed in Section 4 aim at developing a notions of capacity able to link the accounting principles of stock and flows with ecosystem services, considering that the definition of capacity as join concept between ecology and economy is still a matter of debate.

2. Methods

2.1. Accounting for regulating ecosystems services: concepts and definitions

The SEEA-EEA framework contains ecosystem service accounts and ecosystem asset accounts for individual services and assets. As in all conventional accounting frameworks, the basic relationship is between stocks and flows. Stocks are represented by ecosystem assets. Ecosystem assets are defined as 'spatial areas containing a combination of biotic and abiotic components and other environmental characteristics that function together' (UN, 2014b). Ecosystem assets have a range of characteristics (such as land cover, biodiversity, soil type, altitude, slope, and so on). In accounting there are two types of flows: the first type of flow concerns changes in assets (e.g. through degradation or restoration), the second type of flow concerns the income or production arising from the use of assets. The accounting for ecosystem services regards the second type of flow although consistency is needed with the flow representing changes in ecosystem assets. According to the SEEA-EEA (UN, 2014b), the flows can be within an ecosystem asset (intra-ecosystem flow) and between ecosystem assets (inter-ecosystem flows). The combination of ecosystem characteristics, intra-ecosystem flows and inter-ecosystem flows generates ecosystem services that impact on individual and societal wellbeing.

In the SEEA-EEA tables are grouped in ecosystem assets and ecosystem services. Accounts for ecosystem assets record changes in the stocks, for example using area estimates. Accounts for ecosystem services record the flow of ecosystem services and their use by beneficiaries. Accounting for the capacity of an ecosystem to generate services is critical for determining whether the flow of an ecosystem service for human benefit is sustainable. By means of indicators describing ecosystem condition or quality, it should be possible to assess how changes in the stock of ecosystem assets affect such capacity. Indeed, the SEEA-EEA Technical Guidelines include within the ecosystem accounts an 'ecosystem capacity account' that should be compiled. As far as we are aware, however, there are no examples of ecosystem capacity accounts.

In order to make ecosystem capacity accounts operational, there needs to be clear definitions of key concepts and methods based on robust scientific knowledge on ecosystem functioning as well as on the relationships between ecosystem capacity, ecosystem service flows, and their benefits to humans. Edens and Hein (2013) define ecosystem services, within the context of ecosystem accounting, as the input of ecosystems to production or consumption activities. They make a strong link to economic activities by identifying the direct contribution of ecosystems to the production process. This form of accounting is feasible for provisioning services, where natural/ecological processes are combined with other kinds of capital inputs to produce goods. It is however difficult to apply to the other categories of services (cultural, regulating and maintenance). Edens and Hein (2013) acknowledge that the impact of regulating ecosystem services is external to direct economic activities or to people, stating that 'regulating services can only be understood by analysing [...] the specific mechanism through

[2] The first release was published in 1953. Revisions took place in 1968, 1993 and 2008.

[3] Depletion of natural assets recorded in SNA refers only to those natural assets that constitute economic goods. However, SNA does include some natural resources such as energy resources. For those resources the SNA include a measure of depletion in the balance sheets, but not in production or income accounts.