Ecosystem Services 19 (2016) 1–5

Contents lists available at ScienceDirect

Ecosystem Services

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

Abiotic flows should be inherent part of ecosystem services classification

E.S. van der Meulen [a,*], L.C. Braat [b], J.M. Brils [a]

[a] Deltares, P.O. Box 177, 2600 MH Delft, The Netherlands
[b] 1931XH, 494, Egmond aan Zee, The Netherlands

ARTICLE INFO

Article history:
Received 19 October 2015
Received in revised form
24 March 2016
Accepted 25 March 2016
Available online 4 April 2016

Keywords:
Abiotic
Biotic
Flows
CICES
Ecosystem services
Classification

ABSTRACT

Although ecosystems comprise both biotic and abiotic structures and processes, the role of abiotic output receives less attention and is addressed inconsistently in ecosystem services (ES) classification systems. The authors explore the nature and position of abiotic ecosystem output from: 1) a theoretical perspective on ecosystems, ecosystems services and natural capital; 2) a practical perspective on applying the ES concept in environmental policy, spatial planning and ecosystem management. From a theoretical point of view, excluding abiotic flows in ES frameworks such as CICES is inconsistent with the principles of the ES concept. Consequently, abiotic flows with (high) societal relevance may in practice be neglected or selectively addressed; many of them are related to sediment and the subsurface part of ecosystems. This impedes the integration strength of the ES concept. Given the large contributions to the economy and the societal costs of non-sustainable use of abiotic flows, it also impedes holistic, consistent and transparent information provision to decision makers. The authors urge to include abiotic flows as inherent part in ecosystem services classification systems such as CICES. This makes the application of the ES concept more holistic and consistent and will optimize it's integration power for practical planning and decision making.

1. Introduction

An ecosystem is an interacting complex of biota and their abiotic environment. Ecosystem services (ES) are the goods and services that humans derive from ecosystems, actively or passively. Although ecosystems comprise biotic and abiotic elements, the focus in ES assessment frameworks and classifications is biased towards ES for which biota dominate as service providing agents. The role of abiotic structures and processes gets less attention and is addressed inconsistently in classification systems. The classifications of ES used in the Millennium Ecosystem Assessment (MA, 2005) and in The Economics of Ecosystems and Biodiversity (TEEB, 2010) projects have not explicitly addressed the position of services which are produced from abiotic structures and processes in ecosystems. Brouwer et al. (2013) also observe that most existing ecosystem assessments focused only on biotic ES. The Common International Classification of Ecosystem Services (CICES; Haines-Young and Potchin, 2013) at first did not specify the position of abiotic ecosystem outputs. However, in second instance the authors reacted to criticism with a satellite table, and stated that '*the long term goal should be a combined classification that integrates outputs across ecosystems and from other natural resources*'.

The concept of Natural Capital (NC) relates ecosystem structures and processes to ES and NC accounting is making its way to countries' economic accounting systems (Obst et al., 2015). In descriptions of the NC concept, abiotic assets (structures) and flows have already been incorporated (see e.g. Petersen and Gocheva, 2015; Brouwer et al., 2013). There is debate about the inclusion and position of energy sources (assets) and flows, such as the sun and solar radiation respectively. The relevant point here is that abiotic aspects of ecosystems are recognized as being part of the wider concept of NC and are linked to ES and thus considered potentially relevant for human welfare and wellbeing.

In this paper we explore the nature, position and contribution of abiotic structures and processes in ES applications. We discuss both depletable and non-depletable abiotic flows. Non-depletable sun based energy flows (sunlight, wind, rain), moon based (tidal energy) and geothermal energy are not produced by what is defined in ecological textbooks as ecosystems (see e.g. Odum, 1971), but their contributions to human society are to some extent modified by the ecological structure in the biosphere and by

* Corresponding author.
E-mail address: suzanne.vandermeulen@deltares.nl (E.S. van der Meulen).

http://dx.doi.org/10.1016/j.ecoser.2016.03.007
2212-0416/© 2016 Published by Elsevier B.V.

humans, e.g. via land use.

We propose to include abiotic flows (goods and services) in future versions of ES classification systems. We focus on the CICES classification system since this is a commonly used international reference. We discuss the nature and position of abiotic ecosystem output from two perspectives: 1) a theoretical perspective on ecosystems, ES and consistency in the concepts of ES and NC and related classification systems; 2) the practical perspective of applying the ES concept in environmental policy, spatial planning and ecosystem management.

2. Nature and position of abiotic flows in ecosystems from a theoretical perspective

Ecosystems are a dynamic complex of plant, animal, and micro-organism communities together with the non-living environment, interacting as a functional unit (see e.g. Odum, 1971). Abiotic (physico-chemical matter and energy flow) processes have always been implicitly part of the ecosystem, as no biotic process in ecosystems can take place without energy from sun, moon or earth and without interaction between biota and their abiotic environment. For example: photosynthesis of organic molecules requires sunlight energy, water, carbon dioxide and various soil or sediment chemicals which act as plant nutrients. The combined forces of sun, wind and rain produce biomass via the photosynthetic processes and also, often modulated by biotic structures and processes, flows of useful abiotic materials such as sand, clay and gravel derived from sediment. Sediment is an essential, integral and dynamic part of river basins and provides very important ES to society; see examples below (Brils et al., 2014).

The ES concept is in essence an anthropocentric concept, i.e. it pertains to the benefits of ecosystems for humans. From that point of view, it is logical to include the abiotic structures and processes, which are used by, and are useful to humans, in the debate. For millennia, mankind has utilized sediment as a source of construction material and land and water act as carrier of human activities. The carrier concept was already included in early classifications of ES in the 1970s, when services were still called functions of the natural environment for society (Braat et al., 1979). Carrier services include for example the role of rivers for transportation and the capacity of the geological substrate for carrying buildings. This role of land and water in human economies has historically been recognized, as is evident from legal and economic debates about public and private land (and water). The subsurface part of our environment provides storage capacity (e.g. water, waste) and information (preservation of signs that mark cultural and natural developments) besides the already mentioned raw materials in the form of sand, clay, gravel and (fresh) water. The combination of natural characteristics and processes and technology leads to 'new' ES being used by people such as in the application of aquifer thermal energy storage. Finally, there is a whole different category of abiotic sources to economies via the contribution of volcanic eruptions bringing new loads of useful chemicals to the world's ecosystems and humans to work with. Of course, these additional services generally also involve additional economic and social costs, which need to be included in the decision processes. As Costanza (2008) also explained, processes can also be ES or not, depending on the context of the ES assessment. This also applies to abiotic processes.

Some abiotic aspects were already explicitly recognized in ES classifications, e.g. in the 'provisioning service' (drinking, irrigation or industrial) water production from surface or groundwater. They were also explicit in ecosystem functions (formerly, in the MA classification, called 'supporting services'), such as nutrient cycling and soil formation. This involves interactions between micro-organisms and geo-chemical materials and processes. The regulating ES of water purification is included in the CICES classification as 'bioremediation by microorganisms', as 'filtration by ecosystems' and 'maintenance of physical, chemical, biological (in this case, water-) conditions'. These services are provided by biota in interaction with their abiotic environment but also by abiotic processes such as filtration. Also in the section of cultural services, soils are mentioned as example medium for intellectual and representative interactions (a.o. scientific research, heritage). The relevance of sediment is acknowledged under the division 'mediation of flows'; the example provided in the CICES-class 'buffering and attenuation of mass flows' is 'transport and storage of sediment by rivers, lakes, sea'. Some examples provided in the CICES-list emphasize the role of complete ecosystems, such as the functions of wetlands or dunes for flood protection.

Abiotic flows that are not addressed in the main list of ES in the CICES classification, but included in the satellite table are for example abiotic nutritional substances (such as salt), metallic and non-metallic materials (e.g. ores, building materials), renewable and non-renewable energy sources and cultural settings. The carrier services of ecosystems are not explicitly included in the CICES- classification. Although under the section of cultural services, 'physical use of land-/seascapes in different environmental settings' refers to recreational boating, and the satellite table with abiotic outputs also includes a section 'physical and intellectual interactions with land-/seascapes', non-recreational (e.g. commercial) shipping has no explicit position in the system.

Many abiotic resources are depletable on a 'human time scale' (i.e. 1–50 years), even if they are renewable at geological time scales (i.e. millennia). Abiotic outputs such as mineral resources are the result of both biotic and abiotic processes, many of which take place on such geological time scales. These aspects, and the fact that some processes, especially in the subsurface or under water, are taking place out of human view, may result in a general lack of awareness from both the general public and policy makers.

3. The role of abiotic flows in societal decision making regarding ecosystem management

Next to the theoretical, scientific argument to pay attention to the role of abiotic aspects in ES provision, there is also the socio-economic argument to assess their relative contribution to economic, cultural and social benefits and values in society. It is relevant because in some cases there are competing interests between using abiotic resources in alternative ways, e.g. sediments for construction, for river management or for agriculture. Regional water managers see integration of policy domains as one of the main contributions of the ES concept to their work. Based on results of ES concept pilot applications it is expected that the concept supports collaboration between stakeholders (e.g. in the case of river restoration). This integration cannot be complete if abiotic flows and related stakeholders are neglected or only selectively addressed.

In the case of NC accounting, many abiotic aspects of ecosystems are included in ES. To prevent double counting, processes that enable services but that are not used directly by humans (called supporting services in the MA and ecosystem functions in TEEB), are not valued separately. Some abiotic resources and processes, however, are directly being used and should be accounted as ES. Fig. 1 shows the sun, moon and earth based energy sources. These energy flows can be modified by terrestrial and aquatic ecosystems with their geological substrate and soils. The #1 arrows represent the energy flows and stocks