Ecosystem Services 26 (2017) 58–69

Contents lists available at ScienceDirect

Ecosystem Services

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

Geosystem services: A hidden link in ecosystem management

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ARTICLE INFO

Article history:
Received 14 February 2017
Received in revised form 16 May 2017
Accepted 26 May 2017
Available online 15 June 2017

Keywords:
Geosystem services
Ecosystem services
Subsurface
Environmental economics
Sustainability
Urbanization

ABSTRACT

This paper explores the representation of goods and services from the subsurface, as defined by the concept of geosystem services, in contemporary ecosystems literature. A framework is defined consistent with and complementary to the categorization defined under CICES. Following the Campbell Collaboration protocol, a systematic literature review is conducted on the representation of subsurface-related goods and services in ecosystem services research. The review shows that, in the period between 2000 and 2016, for every publication on subsurface services 140 articles on ecosystem services have been published. The results further indicate that valuation and governance studies on geosystem services are scarce. This gap stems from the exclusion of a number of abiotic goods and services from the classification as well as a lack of attention from the current scientific community to this topic. Studies to date have been performed in a limited number of English-speaking countries by researchers with backgrounds in ecology, biology, earth sciences and mining engineering. The underrepresentation of geosystem services in the scientific literature negatively impacts integrated decision making in spatial planning, environmental policy making and long term ecosystem management.

1. Introduction

The concept of ecosystem services emerged in the eighties and since then there has been a significant increase in literature regarding its economic value and importance for society (see e.g. Daily, 1997, Daily et al., 2009; MEA, 2005; TEEB, 2010; De Groot et al., 2010; Cornell, 2011). The contributions of both biotic and abiotic natural processes to human well-being through ecosystem functioning and service provisioning are crucial. Van Ree and van Beukering (2016) point to the ambiguity in the field of ecosystem services in dealing with the role of abiotic characteristics, even when natural systems are dependent on both abiotic and biotic flows. In the literature arguments have also been made to use the links between geodiversity, biodiversity, and species distribution in conservation planning (Lawler et al., 2015). This dependence of ecosystems on abiotic flows is part of the argument to explicitly distinguish and include geosystem services.

The conceptualization of ecosystem services has been driven predominantly by biological and ecological scientists, and as a result the focus in the development process has been mostly on biodiversity and biotic flows that manifest themselves at the surface of the earth. In recent years, debate emerged among scientists questioning the comprehensiveness of the ecosystem services approach. Arguments have been made that the current classification system lacks the inclusion of abiotic flows, including their interaction with biotic flows (van der Meulen et al., 2016). By excluding these flows, potentially important economic values and impacts are omitted and critical trade-offs between biotic ecosystem services and abiotic resources are ignored (Brouwer et al., 2013). As a result, important positive and negative contributions of the subsurface are not taken into account in resource management.[1]

Gray et al. (2013) state that there is a mismatch between the application of geoscience and how ecosystem services are approached. The services that are derived from geosystems can appropriately be labelled as ‘geosystem services’. Geosystem services are defined as “the goods and services that contribute to human well-being specifically resulting from the subsurface”

[1] An example of an important positive contribution of the subsurface, but which also requires careful consideration when aiming for sustainable development, is the use of hard rock phosphates used in fertilisers (Cordell et al., 2009). Another example that also shows the need to carefully consider positive and long term negative impacts can be found in mining and mineral extraction including oil and gas exploration. For example, the Groningen gas case in the Netherlands shows that the subsurface contributed hugely to economic wellbeing but simultaneously let to significant social impacts resulting from man-made geohazards (Koster and van Ommeren, 2015).

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http://dx.doi.org/10.1016/j.ecoser.2017.05.013
2212-0416/

(Van Ree and Van Beukering, 2016). This part of nature, although not directly visible to the human eye, is responsible for important contributions to human well-being. The alleged underrepresentation of geosystem services in ecosystem assessment, which leads to undervaluation of nature as a whole, is problematic as it negatively impacts decision making in spatial planning, environmental policy making and long term ecosystem management.

Making geosystem services explicit in ecosystem services assessments provides a more integrative and inclusive description of the (global) ecosystem and specifies the impact that mankind has on nature's shape and functioning. Substantiating that there is an actual gap in expanding upon the contributions from the subsurface is an important first step in fixing this omission. Therefore, the present study conducts the first ever systematic literature review on geosystem services to show whether and how the subsurface has been addressed under the concept of ecosystem services to date.

The paper starts with distinguishing and categorising goods and services derived from the subsurface in Section 2. Section 3 describes the methodology used for the systematic literature review, translating the identified goods and services into specific keywords applied in the search. Section 4 presents the results and the frequency by which specific subsurface goods and services are addressed in contemporary literature. Section 5 ends with conclusions and a discussion.

2. Background

The notion of the importance of nature to man and ecosystems services has evolved over decades through the International Biological Program, the Convention on Biodiversity (Earth Summit in Rio in 1992) as well as the EU Biodiversity Action Plan and Strategies (European Commission, 2011) linked to the UN Decade on Biodiversity. The widely accepted definition introduced by Daily (1997)[2] pioneered the conceptualization of ecosystem services. By accepting and assigning a monetary value to nature, economists then showed that much of societies' wealth was made possible through these services. As a result, economic valuation studies became a common tool to inform environmental policy. However, comparability of welfare indicators suffered from lack of uniform definitions and interpretations of ecosystem services. This ambiguity is reflected in the emergence of the three classification systems of ecosystem services: (1) (MEA, 2005; Lele et al., 2013); (2) The Economics of Ecosystems and Biodiversity (TEEB, 2010; De Groot et al., 2010); and (3) the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2013).

Being the most recent classification system, CICES attempted to merge the natural science and economic perspective into a new system which is still under development. By stating that "ecosystem outputs are regarded as things fundamentally dependent on living processes, and so abiotic outputs from nature are not regarded as an ecosystem services for the purpose of CICES", CICES omits abiotic nature in its entirety. An exception is made for water, which is included in CICES despite the argument that it is an abiotic output. The same holds for several cultural services revolving around physical settings, which are also included in CICES (Haines-Young and Potschin, 2013). An example of such cultural services is the preservation of remnants from human settlements and implements used in daily life through burial in non-degrading wet and anaerobic conditions. The physical presence of fossils is another example. Notwithstanding the decision to exclude abiotic services in CICES, the authors do recommend to "continuing the dialogue" and even propose to define a "separate but complementary classification that covers abiotic outputs. Both should retain the same underlying logic" (Haines-Young and Potschin, 2013). Therefore, in spite of the recognition that abiotic outputs ought to be classified and valued, it remains largely unaddressed in CICES.

The focus of natural resource management in dealing with the subsurface is mostly on the extraction of groundwater and mining of mineral resources, and thus mainly concerned with stocks, flows and impacts of exploitation on a single asset. It should furthermore be noted that 95% of biodiversity is in the subsurface (mostly the pedosphere) when just looking at the number of species (invertebrates, fungi, bacteria although this fact is often overlooked (Bardgett and van der Putten, 2014; Gardi & Jeffery, 2009). There is a significant amount of literature describing the functionality of the subsurface (see e.g. De Mulder et al., 2012), however, authoritative and multidisciplinary assessments on the scarcity of mineral, fossil and abiotic resources are lacking (UNEP, 2010; UNEP, 2011).

The geosystem services concept explicitly addresses abiotic services stemming from the subsurface and thereby provides a solution to the above-mentioned missing link in the contemporary ecosystem services approach (van Ree and van Beukering, 2016). Van Ree and van Beukering (2016) conclude that a more integrative, inclusive and consistent framework is needed to distinguish ecosystem services from geosystem services as complementary concepts.

The systematic literature review followed the procedures as laid down in the Campbell Collaboration protocol (2016). This protocol requires:

- Clear inclusion and exclusion criteria;
- Explicit research strategy; and
- Systematic coding and analysis of included studies.

Minor deviations of the protocol occurred in systematic coding, as this was done by a single reviewer instead of two researchers working independently and comparing results. Furthermore, a meta-analysis involving statistical techniques to process data was not deemed possible, and this review is qualitative rather than quantitative.

Fig. 1 shows the conceptual framework of goods and services to be identified in the wider ecosystem, including the distinction between biotic and abiotic services. Separating 'geosystem services' from 'ecosystem services', as presented in Fig. 1, enables the inclusion of all functions of the subsurface in society. Note that geosystem services are not limited to abiotic components of ecosystems. The geosystem also contains living material (e.g. stygofauna and bacteria), which is very important in the functioning of the subsurface (e.g. in biodegradation of groundwater contaminants), albeit at a significantly lower intensity than in surficial ecosystems (see e.g. Stein et al., 2012). As represented by the outermost column at the right side of Fig. 1, the share of abiotic services in the subsurface is expected to be significantly larger compared to abiotic services that are delivered by the surface. When exploring different types of services, the MEA categorization is adopted (since it was designed from a natural science perspective) distinguishing provisioning, regulating, supporting and cultural services. The depth (or environmental compartment) from which the services are obtained forms the distinguishing criterion between ecosystem services and geosystem services. With respect to the subsurface it is the pedosphere that is the transition zone between the two. The strong decline in biological activity below this soil zone delineates the boundary.

Table 1 shows an elaborate overview of the uses of the subsurface by humans, as reported by De Mulder et al. (2012), using the

[2] Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life.