Ecological Modelling 289 (2014) 124–132

Contents lists available at ScienceDirect

Ecological Modelling

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

Review

Ecosystem services assessment: A review under an ecological-economic and systems perspective

Tiina Häyhä[a,b,*], Pier Paolo Franzese[a,c,*]

[a] Laboratory of Ecodynamics and Sustainable Development, Department of Science and Technology, Parthenope University of Naples, Italy
[b] Stockholm Resilience Centre, Stockholm University, Sweden
[c] Industrial Ecology Programme, Department of Energy and Process Engineering, Norwegian University of Science and Technology, Trondheim, Norway

ARTICLE INFO

Article history:
Received 10 February 2014
Received in revised form 30 June 2014
Accepted 2 July 2014
Available online 26 July 2014

Keywords:
Natural capital
Ecosystem services
Economic valuation
Environmental accounting
Socio-ecological systems
Systems perspective

ABSTRACT

A comprehensive understanding of interlinked ecological-economic systems requires integration of different theoretical frameworks and assessment methods. This paper reviews the main definitions, classifications, and methodological approaches used to identify, assess, and value stocks of natural capital and flows of ecosystem services. A synthesis of the major developments in the field of ecosystem services assessment is provided and the main future challenges are outlined. The notion of value in relation to natural capital and ecosystem services is discussed exploring different economic and ecological approaches. We then propose a conceptual framework integrating environmental accounting and ecosystem services assessment to highlight three main possible windows of attention to be investigated when focusing on ecosystem services provision and exploitation: (1) sustained economic and environmental costs, (2) received benefits, and (3) generated impacts. Finally, we conclude that such an ecological-economic and systems perspective to ecosystem services assessment could play an important role in investigating the interplay between ecological and socio-economic systems, allowing a broader and more comprehensive understanding of the benefits gained from ecosystems and the costs due to their exploitation.

Contents

* Corresponding authors at: Laboratory of Ecodynamics and Sustainable Development, Department of Science and Technology, Parthenope University of Naples, Italy.
E-mail addresses: tiina.hayha@su.se (T. Häyhä), pierpaolo.franzese@uniparthenope.it (P.P. Franzese).

http://dx.doi.org/10.1016/j.ecolmodel.2014.07.002

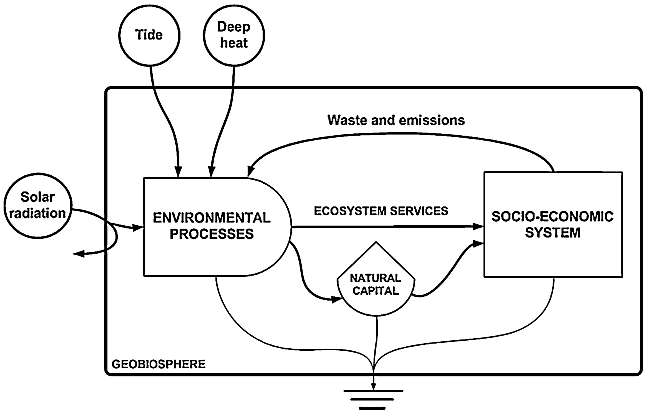

Fig. 1. Systems diagram showing an aggregated view of the interactions between environmental processes and socio-economic systems at global scale.

1. Natural capital and ecosystem services: definitions and classifications

Ecosystem services assessment is a growing research field addressing the evaluation of the benefits that ecosystems provide to humans. Since the late 1960s, the issue of human societies' dependence on nature has been discussed in the scientific literature, highlighting the ability of healthy ecosystems to provide vital services in support of human economy and well-being (Helliwell, 1969; de Groot, 1987; Odum, 1971; Westman, 1977).

Socio-economic systems are highly dependent on the ecological systems in which they are embedded and from which they gain several goods and services: food, fibers, fresh water, clean air, pollination, climate regulation, among many others (Daily, 1997). The whole human economy is supplied (and also constrained) by the availability of stocks of natural capital and flows of ecosystem services.

Concerns about the size and impact of human economy in relation to "planetary boundaries" have been discussed by Rockström et al. (2009a,b). The concept of planetary boundaries warns about overcoming tipping points over which the planet might shift into a new equilibrium state not necessarily characterized by suitable environmental conditions for human life on Earth (Lenton et al., 2007; Rockström et al., 2009a,b). A sustainable economy should therefore consider the existence of limits to growth and biophysical constraints to human activities (Boulding, 1966; Daly, 1977; Meadows et al., 2004). More recently, the concept of planetary boundaries has been extended to include social aspects through the notion of "safe and just operating space for humanity" (Griggs et al., 2013; Raworth, 2012; Rockström et al., 2013).

At global level, the environmental processes of the geobiosphere are driven by three main driving forces: solar radiation, tidal momentum, and Earth's internal deep heat flow (Brown and Ulgiati, 2010). Environmental processes generate storages of natural capital and flows of ecosystem services that directly and indirectly support socio-economic systems that, in turn, release waste and emissions in the environment. The interaction between natural and socio-economic systems has been discussed by Haines-Young and Potschin (2010) and Bastian et al. (2012, 2013), also through the concept of "ecosystem services cascade" showing how ecological structures and processes are linked to societal values. In Fig. 1 we present a systems diagram drawn by using the symbolic energy language and schematizing the interplay between environmental processes and socio-economic systems at global level.

The definition of natural capital derives from the notion of capital used in economics, in which capital refers to manufactured assets (e.g., machinery) used to produce flows of valuable goods and services (Berkes and Folke, 1992; Costanza and Daly, 1992). Different scientists have developed theoretical frameworks to explore the interplay of environment and economy based on the concepts of stock and flow. Georgescu-Roegen (1971) developed a fund-flow approach to production theory based on the distinction between funds (the agents of a production process) and flows (the elements used or acted upon by the agents). Odum (1983, 1994, 1996) studied natural and human-dominated ecosystems as composed by interconnected stocks and flows of natural and human-driven resources. Costanza and Daly (1992) also proposed a distinction between stocks and flows by stating that stocks of natural capital generate a "natural income" in terms of flows of ecosystems services. Accordingly, natural capital can be defined as stocks of natural resources generating valuable flows of different types of ecosystem goods and services.

Broadly, two types of natural capital can be differentiated: (1) renewable or active natural capital, and (2) non-renewable or inactive natural capital (Costanza and Daly, 1992). Non-renewable stocks of natural capital are depleted over time and generate yield only when extracted by humans (e.g., fossil fuels and minerals). Ecosystems also contain storages of renewable natural capital that renew themselves while generating flows of ecosystem services. A severe exploitation of ecosystem goods can reduce ecosystem's ability to produce services and, over a certain limit, can compromise ecosystem structures and functions. Maintaining structure and diversity of ecosystems is therefore an issue of great importance for a sustainable management of human activities (de Groot et al., 2003; Ekins et al., 2003; Folke et al., 2011).

In relation to a sustainable society, it is also important to remark the existence of different types of capital: natural capital (local ecosystems, biomes, sub-soil resources), manufactured capital (roads, buildings, machineries), human capital (education, skills, knowledge), and social capital (institutions, social norms and practices) (UNU-IHDP and UNEP, 2012). The concept of "weak and strong sustainability" reflects the complementarity among these four types of capital (Ekins et al., 2003). Weak sustainability assumes that technology may be able to substitute for loss of natural capital. Instead, strong sustainability builds on the assumption that natural capital is irreplaceable with manufactured capital and therefore essential to be maintained by using it in an efficient way (non-renewable natural capital) and at a rate lower than its natural rate of regeneration (renewable natural capital) (Ayres, 2007; Pearce et al., 1989). Sustainable development practices should therefore focus on qualitative rather than quantitative growth.

Table 1
Alternative definitions of ecosystem services.

Definition of ecosystem services	Source
The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life	Daily (1997)
Benefits human populations derive, directly or indirectly, from ecosystem functions	Costanza et al. (1997)
Benefits people obtain from ecosystems	MA (2005)
Final ecosystem services are components of nature directly enjoyed, consumed or used to yield human well-being	Boyd and Banzhaf (2007)
The aspects of ecosystems utilized (actively or passively) to produce human well-being	Fisher et al. (2009)
Ecosystems contribution to human well-being	TEEB (2012)
Contributions of ecosystem structure and function – in combination with other inputs – to human well-being	Burkhard et al. (2012)