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Development of a new framework for non-monetary accounting on ecosystem services valuation

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ABSTRACT

To appropriately support green development practices, there is an urgent need to improve Ecosystem Services Valuation (ESV) accounting approaches. This paper establishes a non-monetary accounting framework for ESV, which classifies the ES into direct services (directly related to the stock and flow), indirect services (through the functioning of ecosystem processes that produce the direct services) and existence services (cultural services and global benefit). New framework tries to (1) construct system emergy flow diagram and merging calculation method to avoid double counting; (2) propose new methods for biodiversity and climate regulation; and (3) bridge the non-monetary and economic values. Taking the forest ecosystem in Jing-Jin-Ji urban agglomeration as a case, this study made a detailed calculations of 9 ecosystem services and compared the Em¥ with economic values based on Emergy Money Ratio. The results show that emergy can be used to record environmental debt and establish a balance sheet to state the economic conditions and the environmental contribution to economic development. However, emergy is not an alternative method to the economic assessment, but a complementary and systemic approach to highlight the donor-side value of ES. The new framework is needed to realize the return of wealth including all "stakeholders" of nature.

1. Introduction

The traditional measure of progress, economic activity, still predominates. However, critiques to Gross Domestic Product (GDP) as a measure limited to economic performance which excludes both social and human welfare, entered the global debate. This dispute highlights the need for better measurements of progress, which can inform different policies and public perceptions (Daly, 1996; Pulselli et al., 2011; Fioramonti, 2017). A change of perspective, from economic to ecological, is putting ecosystem services at the core of sustainable development framework. However, this has become a controversial and difficult topic, depending on the different understandings about their connotation and implications (Fioramonti, 2013, 2017).

Ecosystem services, as a term, first appeared in 1981 (Ehrlich and Ehrlich, 1981). However, the concept of translating the work of the environment into economic benefit is much older. For example, there are the cases of economic ornithology, i.e. the quantification of economic benefit of bird species as pest control being done in the 1800s (Whelan et al., 2015) and more holistic approaches, acknowledging the role of the environment in supporting the human economy, as proposed in the 1970s (Kapp, 1970; Georgescu-Roegen, 1971; Odum, 1971; Daly, 1977).

In the 1990s, ecologists began to systemically quantify the dependence of humans' survival and development on ecosystem services. Daily (1997) suggested that ecosystem services functions, which support ecological process to maintain human being's survival, refer to natural environment conditions. Costanza et al. (1997) defined ecosystem services as the ecological characteristics, functions, or processes, that directly or indirectly contribute to human wellbeing (MEA, 2005; Costanza et al., 1997). This definition refers to the benefits that people

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derive from ecosystem goods and services.

Several researches stemmed out from the publication of these papers, as well as policies, and further developments of previous ideas (Almeida et al., 2017; Costanza et al., 2017). However, the paper by Costanza et al. (1997) also sparked controversy and criticism, due to its methods and results (Bockstael et al., 2000; Hueting et al., 1998; Norgaard and Bode, 1998; Pearce, 1998). In 2005, the United Nations published the Millennium Ecosystem Assessment (MEA) report, which assessed that about 60% of world ecosystem are still in the state of degradation (MEA, 2005). After that, Germany and the European Commission initiated "The Economics of Ecosystems and Biodiversity" project (TEEB) (Costanza et al., 2017). These programs tried to establish a complete monetary accounting framework for ecosystem services. However, both the uncertainties and complexity of methods make ESV and ecological protection practices difficult to effectively carry out.

Both market systems for trading ecosystem goods or services and promotion of enterprise sustainable behavior rely on policies and regulations, which should support both environmental protection and green development. In parallel, they depend on public welfare activities such as financial subsidies and donations from nonprofit organizations, conducted by governments and non-governmental environmental organizations. Therefore, it is difficult to truly form a long-term market based mechanism, which consciously supports ecosystem and environment protection.

Green development is now considered a solution for pursuing economic growth and development while preventing environmental degradation, loss of biodiversity and unsustainable use of natural resources (OECD, 2011). However, in order to be effective, it requires a better accounting process of ESV (Alkemade et al., 2014). After year 2008 financial crisis, green development is recognized as a way, which can bring new opportunities for economic growth. This leaded to the definition of several policy innovations to promote green development (Redclift, 2011). Among them, market mechanisms, based on resource pricing, were widely studied (Fenichel et al., 2016). In parallel, the basic procedure for ecosystem services value accounting was also assessed (Ouyang et al., 2016).

Green development is not without criticism, suffering from a lack of a consistent framework, as well as a general lack of consideration of "strong sustainability" (Georgeson et al., 2017) In fact, while green development practices are likely "less bad" (i.e.: less impactful on natural ecosystems or resources), they may not meet the definition of true (i.e.: strong) sustainability practices, that do not have significant negative impacts on ecosystems, do not deplete natural resources and can be continued indefinitely into the future (López-Hoffman et al., 2017; Georgeson et al., 2017). ESV based on economic methods was criticized for not considering the sustainability of the resource conferring the benefit. Moreover, a higher difficulty depends on the use of different accounting systems necessary to address both human preference for ESV and biophysical quantities to gauge sustainable resources use (Ulgiati et al., 2011; Liu et al., 2014b; Costanza et al., 2017).

The method proposed in this paper will help to bridge this gap, through an ESV accounting approach, using units, that can also be used to quantify resource sustainability. Complexity and uncertainty in accounting methods still exist, dependent on three aspects: ES classification systems; ESV accounting techniques; and Total ESV calculation (MEA, 2005; Costanza et al., 2017). To address these issues, this paper will overview the available ESV methods, their advantages and limitations. Then, a new framework for non-monetary ESV accounting will be defined, by integrating and bridging these methods, based on their potential to solve the three issues. As a case study, an ESV assessment for the forest ecosystem in Jing-Jin-Ji urban agglomeration will be performed to validate the new framework. This study is a critical way for policy makers to guide green development, establishing an ecologically-oriented urban outlook, promoting the implementation of integrated ecological civilization reform, ecological civilization construction and the sustainable development of cities, all of which should be based on assessment of ecosystem services valuation.

2. Literature review

2.1. Literature review on ecosystem services classification systems

First, a taxonomy of ecosystem services studies is desirable, as a premise to better ESV definition. Daily (1997) divided ES into 13 types, while Costanza et al. (1997) included 17 services. Other classification systems were developed later. Table 1 summarizes these classifications.

MEA (2005) divided ES into four categories: provisioning, regulating, supporting and cultural services. It was adopted, but then modified in TEEB (2010). In particular, it established the core of the most recent classifications, detailing their economic aspects. The Common International Classification of Ecosystem Services (CICES) was developed to provide a hierarchically consistent and science-based classification to be used for natural capital accounting purposes (Haines-Young and Potschin, 2012). However, there are some controversies on these classifications during the accounting processes:

(1) Many studies directly sum up all the monetary ESV to obtain the total value. However, one ecological process can support more than one ecosystem services (as co-products). For example, both NPP increase and carbon sequestration are the products of photosynthesis, while the biomass produced by photosynthesis is a part of raw material for soil building. If NPP increase and carbon sequestration values are added together, it will result in double-counting. Meanwhile, some cultural services may partially overlap with others, i.e., tourism and recreation values, culture and educational value. Direct summation of these two values would overestimate cultural services value.
(2) There is still a lack of proper methods to value the supporting services, such as biodiversity and climate regulation. Obviously, they are long term and global impacts. A new method should use to explain the trans-scale mechanism and localized effect sharing, which should sweeten the deal for local politicians.

Therefore, while double-counting should be avoided, a systematic and comprehensive classification systems is needed to assess all types of ESV.

2.2. ESV accounting techniques

ESV accounting techniques mainly include monetary (Bockstael et al., 2000; Costanza et al., 1997; Lerouge et al., 2017; Obeng and Aguilar, 2018) and non-monetary methods (Brown et al., 2006; Campbell and Brown, 2012; Dong et al., 2012). Monetary methods asses the economic value of ESV from the consumer side. In strict economic terms, they represent the aggregate willingness-to-pay either for the stream of received services or as compensation for their loss (Costanza et al., 2017). This approach quantifies values based on human preferences. Revealed and stated preferences are the two main conventional economic methods (Costanza et al., 2017; Unai Pascual et al., 2010). Revealed preference involves the analysis of individual choices in real-world settings and infers a value from those observed choices (Costanza et al., 2017). Stated preference relies on individuals' responses to hypothetical scenarios, which involve ecosystem services and include contingent valuation and structured choice experiments (Fioramonti, 2014). These two methods are both based on human perceptions or preference. Thus, there is the risk of measuring ESV in terms of each individual's perceived wellbeing (Bockstael et al., 2000; Freeman et al., 2014). As a consequence, individuals might give no value to ES, if they don't know or don't understand the role and the influence of a certain service on their wellbeing (Norton et al., 1998). Moreover, the sources of human welfare also include social capital,