The Evolution of Natural Capital Accounting: From Origins to System of Environmental-Economic Accounting

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Abstract. The valuation of natural capital has become an increasingly important issue in the environmental debate and in public policies, given the growing awareness that human well-being depends on the health of terrestrial ecosystems and their services. Natural Capital Accounting (NCA) proposes a solution to measure and value the ecosystem services provided by natural systems, integrating them into economic decision-making processes. However, the wide range of ecosystem resources and services that our natural environment provides is often overlooked or taken for granted, leading to unsustainable practices and the degradation of natural resources. This research proposes an analysis of the evolution of natural capital accounting over time, examining the origins, significant developments and achievements of the approach, with a focus on the methodologies and tools applied. The System of Environmental-Economic Accounting (SEEA) is an important tool for putting this recognition into practice, providing a standardized and coherent approach to measuring and evaluating natural capital. SEEA enables the identification of trade-offs and synergies between economic and environmental objectives and supports the development of policies and practices that promote sustainable development, ensuring the sustainable and equitable use of natural resources. The paper highlights the potential of the SEEA approach to provide useful results and support effective decision-making, emphasizing the importance of considering natural capital as a key element that can be integrated into policy strategies and spatial planning.

Keywords: Natural Capital Accounting (NCA) · Ecosystem Services (ES) · System of Environmental-Economic Accounting (SEEA)

1 Introduction

The growing awareness that human well-being depends on the health of terrestrial ecosystems and their service [1, 2] has developed a new accounting perspective focused on natural capital. Indeed, the valuation of natural capital is an increasingly important issue in the environmental debate and in public policies and urban and territorial

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planning. Despite the wide range of ecosystem resources and services that our natural environment provides, their value is often overlooked or taken for granted, which can lead to unsustainable practices and the degradation of natural resources. Natural Capital Accounting (NCA) proposes an integrated framework to measure and value the ecosystem services provided by natural systems, integrating them into economic decision-making processes [3–7]. In general terms, by assigning an economic value to the components that make up natural capital, such as forests, wetlands, and biodiversity, we can recognize the benefits they provide to society and make informed decisions about their use and management. This, in turn, can contribute to promoting more sustainable practices and ensuring the long-term resilience of ecosystems and the communities that depend on them. Additionally, recognizing the benefits of natural capital can contribute to a greater sense of community and shared responsibility for environmental issues. The System of Environmental-Economic Accounting (SEEA) is an important tool for putting this recognition into practice, providing a standardized and coherent approach to measuring and evaluating natural capital. Ultimately, the SEEA can help identify trade-offs and synergies between economic and environmental objectives and support the development of policies and practices that promote sustainable development, ensuring the sustainable and equitable use of natural resources.

This research proposes, through a review of the literature, an analysis of the evolution of natural capital accounting over time, examining the origins of the approach, its most significant developments and achievements. In particular, we will focus on the discussion of methodologies and tools retrieved in scientific literature and widely adopted to measure natural capital and to integrate this information into traditional accounting systems. The paper is organized as follow: the first section for the analysis of scientific literature, in the second section the SEEA tool is explored in depth.

Conclusions remarks how natural capital accounting can also determine compensation policies that, based on a deterministic approach, can be transposed into land-use regulations.

2 Natural Capital Accounting: An Overall Perspective

However, the concept of capital is understood as a quantity of materials or information existing at a given time, we define by Natural Capital Committee [8] as: “Natural Capital comprises the entire stock of natural assets – living organisms, air, water, soil and geological resources – that provide goods and services of direct or indirect value to human beings and are necessary for the survival of the environment from which they are generated”.

The elements of natural capital fall into two broad categories: biotic (living) components and abiotic (non-living) components. All levels of biodiversity in terrestrial and marine ecosystems are counted within the biotic components, while soil and subsoil (minerals, metals, fossil fuels), water and atmosphere are part of the abiotic components. The last can be both renewable (water, solar energy) and non-renewable (minerals, fossil fuel energy).

Recent researches on Ecosystem Services [9–14] allow us to propose a strong connection between NCA and ES as an operative dimension for applied research. It is

necessary to refer also to the definitions proposed through other disciplinary perspectives. The origin of the concept of capital is to be found in economics. This genesis, in fact, can be found in the writings of economist Alvin S. Johnson, the first to distinguish between artificial and natural capital [15]. Like other forms of capital, natural capital is a stock and not a flow [16]. Costanza and Daly in 1992 [17] defined natural capital as "stocks of natural assets that yield a flow of valuable ecosystem goods or services into the future". The consideration that ecosystem service flows are generated from natural capital has been consolidated over time by different authors [17–21], but their definition and classification is still debated. Regarding the ES definition Fisher et al. [22] indicate that the literature does not have an official and commonly accepted definition, although the one most familiar appears [23] to be the definition provided by Millennium Ecosystem Assessment (MEA) in 2005 [24] that sees ecosystem services as "the benefits that people obtain from ecosystems." Several authors [25, 26] have criticized this definition as too vague arguing that "ecosystem services" are not the same thing as "benefits", as the latter derive from the union of the services offered by nature with other forms of capital. Even the classification is not unique, among the most important worldwide is the one proposed by MEA that divides ES into four broad categories, as follows: 1) provisioning services; 2) regulating services; 3) supporting services; 4) supporting services. However, the scientific literature agrees on the importance of ecosystem services for to the support of human activities, but their importance is often ignored because their value is not easily identified, as they are not tradable on the market. NCA is precisely an approach aimed at measuring, managing and valorising natural capital and its services and is central not only to environmental sustainability, but also to economic, social and spatial sustainability [27, 28]. The last is a transversal dimension of sustainable development, part of a holistic approach to sustainability that takes into account the impact of mankind on the planet. The core definition of sustainable development first introduced in 1987 by the United Nations World Commission on Environment and Development [29] was expanded in 1994 by the International Council for Local Environmental Initiatives, which defines sustainable development as "development that provides ecological, social and economic opportunities to all inhabitants of a community, without creating a threat to the vitality of the natural, urban and social systems that depend on these opportunities". Public decision makers are becoming increasingly aware of the importance of ensuring a more sustainable development, and this is manifested through increased attention to natural resource values. The value of natural capital and its services can hardly be identified through pure economic evaluations alone; it is often necessary to consider nonmonetary approaches. Other authors [30] emphasize the importance of identifying beneficiaries as a dimension for assessing the intensity of the ecosystem service provided. In fact, the main difficulties are due to the confusion that arises over the object of valuation. Costanza et al. in 1997 [18] are among the first to point out that it is not exactly the ecosystem service that is valued, but it is the change in that service or natural capital and that only at a smaller scale will these coincide, whereas as also reported by Toman in 1998 [31] any attempt to estimate the "total value of the world's ecosystem services and natural capital would be a serious underestimate of infinity". Fisher and Turner in 2008 [25] also state that it is the benefits (from combinations of different types of capital) that directly affect human well-being that are valued, so economic valuation rather than

the ecosystem and its services is concerned with the effects that human actions have on them and how these services are employed [23]. In addition, further debates have arisen over which methods to use in valuation. Exchange-value-based methods for ensuring a correct estimate of natural capital benefits have often been criticized. Despite uncertainties about the most appropriate methodology to implement, recent debates on the application of NCA have resulted in different approaches to develop this system in order to integrate it systematically into decision-making processes [32]. Among them is the approach adopted by the United Nations in 2012: System of Environmental-Economic Accounting (SEEA).

3 System of Environmental-Economic Accounting

Many countries are approaching an NCA based on the SEEA [33]. Indeed, SEEA has considerable potential to support decision-making, but despite this, its practical application in public policy delineation is complex [34]. The SEEA was created to overcome the difficulties of conventional Systems of National Accounts (SNA), which are unable to fully and comprehensively consider environmental resources. The purpose of this approach is mainly to combine environmental, economic and social information into single framework that can develop policy relevant indicators to support holistic decision-making. The SEEA framework follows an accounting structure similar to that of the SNA. The choice to use concept, definitions and classification consistent with the SNA is to facilitate the integration of environmental and economic statistics. In 2012 the UN Statistical Commission adopted the SEEA Central Framework (SEEA CF) as an international statistical standard [35]. Measurements provided by it are shown in Table 1.

Table 1. Measurements provided by SEEA Central Framework.

Measurements	Description
Environmental flows	The flows of natural inputs, products and residues between the environment and the economy and within the economy, both in physical and monetary terms.
Stocks of environmetal assets	Stocks of indiviual goods, such as water or energy goods, and the way they change over an accountig period due to economic activity and natural process, both in physical and monetery terms.
Environment-related economic activity	Monetary flows associated with environmet-related economic activies, including expenditure on environmental protection and resource management, and the production of "environmental good and services".

Following the adoption of SEEA CF, the statistical community experimentally proposed SEEA Experimental Ecosystem Accounting (SEEA EEA), designed as a complementary framework to SEEA CF. The conception of the link between the economy

and the environment changes. For while SEEA CF considers how the economy uses natural goods, SEEA EEA instead focuses on ecosystems and the services they provide to economic and human activities. In addition, the SEEA EEA expanded the set of flows considered in the SEEA CF to include ES that provide benefits. Experimentation with the SEEA EEA has found interest in the international community with different projects [36]: Wealth Accounting and Valuation of Ecosystem Services (WAVES), Mapping and Assessment of Ecosystems and their Services (MAES), Integrated System for Natural Capital and Ecosystem Services Accounting (INCA) and Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES). Following a review developed between 2018 and 2020, in 2021 SEEA Ecosystem Accounting (SEEA EA) was approved by UN Statistical Commission. SEEA EA covers two types of accounts in monetary and physical terms: stock accounts and flow accounts. Figure 1 shows that SEEA EA measures [37]: 1) ecosystem extent (usually in spatial units); 2) ecosystem conditions over time; 3) accounts on flows and utilization of ecosystem services in physical terms (for example, tons of sequestered carbon); 4) accounts recording the value of ecosystem services (in monetary terms); 5) ecosystem goods accounts in monetary terms that record the net present value of all ecosystem services provided by an ecosystem good.

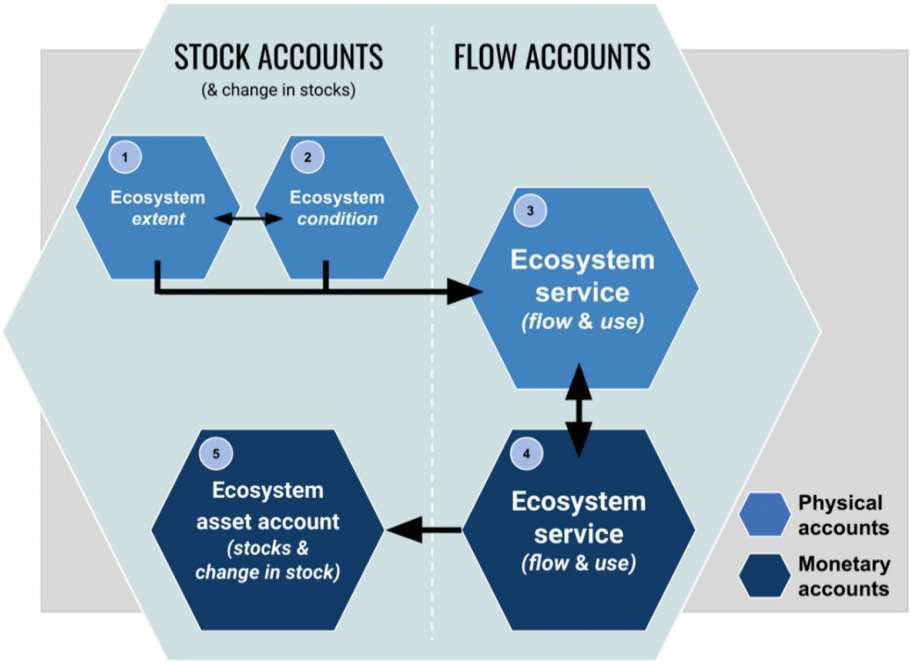

Fig. 1. Connections between the ecosystem accounts. Source: UN [37]

Regarding the monetary valuation of ES flows, the SEEA EA applies the valuation principles of SNA. Ecosystem asset account (in monetary terms) describes both the value of beginning and ending stocks and changes during an accounting period. Variations are

understood as changes in value due to ecosystem conversion, degradation, or improvement, or price changes. Additionally, SEEA EA adopts a spatial approach, since the benefits a society receives from ecosystems depend on where those assets are located in the landscape in relation to the beneficiaries. This approach identifies the location and size of ecosystem resources, the ecosystem services provided and the location of beneficiaries [38–41]. In fact, SEEA EA can be implemented at different spatial scales such as sub-national or national level [42, 43]. As of 2020, 34 countries have compiled ecosystem accounts and another 13 are outlining plans for implementing the SEEA EA. Among them, the European Commission has made public accounts regarding the extent, condition and services provided by ecosystems for the entire EU territory.

4 Final Remarks

The importance of ecosystem services in the scientific world has generated the need to have an effective tool that can provide useful results in research and that will reinforce the proper monitoring and management of ecosystem assets and their flows. SEEA has all the potential to be an excellent tool useful in informing decision making at various stages and supporting numerous policy choices. This approach not only allows natural capital to be considered as a key element to be integrated into policy strategies and spatial planning [44], but also highlights its importance through the economic aspect. Indeed, the framework was created to highlight the impact of the economy on the environment and the environment on the economy. These necessary trade-offs between the environmental, economic, social and also spatial spheres (given the characteristic of the SEEA EA to be a spatial approach) are highlighted through the different indicators that can be generated from the reports provided by the international standard. The difficulties highlighted in the NCA, i.e., unambiguously defining and classifying ecosystem services, identifying tools capable of providing their value (not only in monetary terms) were critical basis for the development of this approach, indeed SEEA can be considered the result of the ongoing effort to have natural capital accounting effectively and efficiently integrated into a decision-making process both at national, regional or local level. In particular, the challenge for its application concerns the local level where it is difficult to find data both on ES and environmental variables and with respect to value streams. New data analytics has to be selected in order to support the quantitative assessment in the territorial perspectives [45–47]. However, the circumscribed identification of beneficiaries and consequently their involvement provides a broadening of the audience of stakeholders involved in the management of environmental protection processes. The possible identification of impacts resulting from production processes that use local environmental resources allows for the maturation of a greater awareness with respect to the scarcity of natural resources and increases the feeling of their protection [7, 48, 49]. The research perspectives looks at: (i) delving into the SEEA framework; (ii) defining significant case studies; (iii) developing a discussion with potential stakeholder beneficiaries of the tool to verify its applicability within decision-making processes involving them.

This paper sought to highlight the process that led to the emergence of SEEA from the NCA and the potential of this tool to support improved policy making that includes the environmental, economic, social, and spatial (referring to recent experience in NUA

downscaling [50–53] dimensions necessary for effective implementation of the cardinal principles of sustainable development [54].

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