Vietnam Journal of Agricultural Sciences

ISSN 2588-1299

VJAS 2019; 2(1): 434-449
https://doi.org/10.31817/vjas.2019.2.3.04

The Framework of Ecosystem Services for Economic Valuation Purposes: A Review

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Abstract

Although humans need ecosystems and ecosystem services for their survival and well-being, most of the global ecosystems and the services that they provide have declined and/or degraded rapidly over the past few decades. In order to find the ways to sustainably use natural resources, substantial efforts have been made to measure and value the ecosystem services. The term 'ecosystem service' was interpreted in different ways in the literature. For making correct decisions in natural resource management, a consistent way of defining and classifying ecosystem services is needed for valuation purposes. This paper argued for the need to divide ecosystem services into intermediate and final services.

Keywords

Ecosystem service, ecosystem function, ecosystem benefit, ecosystem value

Introduction

Humans need ecosystems and ecosystem services for their survival and well-being. Ecosystems provide all the basic materials for human life and well-being, such as food, water, and fresh air. In addition, human living conditions are closely linked to the conditions of ecosystems because our living environment is crucially regulated by ecosystems. Furthermore, nature enriches our spiritual lives by providing areas for recreation and enjoyment (Millennium Ecosystem Assessment, 2005). However, most of the global ecosystems and the services that they provide have declined and/or degraded rapidly over the past few decades (Balmford *et al.*, 2002; Millennium Ecosystem Assessment, 2005; Postel and Thompson, 2005). Since the 1980s, with the notion of sustainable development, the importance of ecosystem services for human well-being and innovative ways for better natural resource management have been emphasized. Several milestone studies include: (i) the work of Costanza *et al.* (1997) on the 'The value of the world's ecosystem services and natural capital'; (ii) the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005); and (iii) the UK National Ecosystem Assessment

Received: November 23, 2018
Accepted: April 6, 2019

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(UK NEA, 2011). Besides these, there are a substantial number of studies that have been developed around the concept of ecosystem services and their implications (Daily, 1997; Groot *et al.*, 2002; Boyd & Banzhaf, 2007; Wallace, 2007; De Fisher *et al.*, 2009; De Groot *et al.*, 2010; Haines-Young & Potschin, 2010).

Although the term ‘ecosystem service’ is very common in natural resource management literature, it can be interpreted in different ways. Recently, papers have cited several common definitions that include the concepts proposed by Daily (1997), Costanza *et al.* (1997), and De Groot *et al.* (2002), and of special note, the broad definition provided by the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) and the terms of The Economics of Ecosystems and Biodiversity (TEEB) (TEEB, 2010). Although these definitions share many similar traits, they have some critical differences that will be described in detail in the next section. The problem of different definitions of ecosystem services arises when we start to measure and monitor ecosystem services, especially, when we try to evaluate and apply a market-oriented mechanism for natural resource management. If we do not have a consistent definition of ecosystem services, then people will not understand what we say about ecosystem services, and they will not believe in our study results and policy recommendations. Therefore, this paper aims to review three major themes that have recently emerged in the literature in order to provide a consistent framework of ecosystem services for valuation purposes. These themes comprise: (i) the concept of ecosystem services; (ii) a classification system for valuation purposes; and (iii) the total economic value of ecosystem systems.

The Concepts of Ecosystem Services for Economic Valuation: The Linkages between Human Welfare and Ecosystems

The concept of ecosystem services for economic valuation reflects links between human welfare and ecosystems. This concept has emerged since the work of Daily (1997) and Costanza *et al.* (1997). Daily (1997) used the definition that “ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life”. According to Daily, ecosystem services sustain biodiversity and the production of ecosystem goods consumed by humans. They also include functions that support human lives, such as cleansing, recycling, and renewal. Ecosystem services also provide many intangible aesthetic and cultural benefits. Meanwhile, Costanza *et al.* (1997) pointed out that ecosystem services consist of ecosystem goods and services that bring benefits that humans extract, directly or indirectly, from ecosystem functions (such as habitats, and biological or ecosystem components or processes). By defining it this way, ecosystem services include flows of materials, energy, and information provided by natural resources in combination with other forms of capital to support human well-being. De Groot *et al.* (2002) explained that: “ecosystem goods or services are reconceptualized from observed ecosystem functions when human values are implied”. They stressed that the concept of ecosystem services is constructed based on anthropocentric perspectives. For them, complex ecological structures and processes are translated into ecosystem functions that provide ecosystem services valued by humans.

The work of the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) serves as a benchmark in the development process of the concept of ecosystem services. The definition provided by the Millennium Ecosystem Assessment (2005) has been globally acknowledged by the scientific community (De Groot *et al.*, 2010; TEEB Synthesis, 2010; Bateman *et al.*, 2011; UK NEA, 2011; De Groot *et al.*, 2012; Bateman *et al.*, 2013; Costanza *et al.*, 2014; UK NEA, 2014). In this report, ecosystem services are broadly defined as the benefits provided by ecosystems. They classify ecosystem services into four categories: provisioning services, regulating services, cultural services, and supporting services. The significant contribution of this literature is the revised conceptual framework that links human societies and their well-being with ecosystems. In this framework, ecosystem services provide benefits to human well-being either indirectly through interactions with other forms of capital or directly.

The above definitions share a common idea that is rooted in anthropocentric perspectives by referring to ecosystem services as human benefits derived from ecosystems. However, the definitions proposed by different authors vary. De Groot *et al.* (2002) and Daily (1997) agreed that ecosystem services are considered to be ecosystem conditions/structures, processes, and life-support functions. Costanza *et al.* (1997) described ecosystem services as flows of goods and services derived from ecosystem functions. On the other hand, the Millennium Ecosystem Assessment (2005) synthesized the broad and neutral definition acknowledged by the global scientific community in which ecosystem services are defined as benefits that humans obtain from ecosystems.

Although widely accepted by the academic community, these above definitions are often criticized for being ambiguous and challenging when applied to decision making in natural resource management (Boyd & Banzhaf, 2007; Wallace, 2007). In order to make it easier to take values of ecosystems into account during decision-making processes, a number of scientists have offered alternative definitions of ecosystem services. The following paragraphs highlight their significant contributions.

While accepting the broad definition provided by the Millennium Ecosystem Assessment (2005) that "ecosystem services are the benefits provided by ecosystems", Wallace (2007) argued for an explicitly separate definition of the key terms: ecosystem functions/processes and services. According to his judging, the terms ecosystem functions and ecosystem processes are synonyms. He defines ecosystem processes as the complex physical and biological cycles and interactions among biotic elements of ecosystems. In broader terms, the processes engaged in the transfer of energy and materials. Compared with the definition proposed by De Groot *et al.* (2002) who defined ecosystem functions as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly", Wallace's definition is significantly different. For him, ecosystem functions are a subset of ecological processes and ecosystem structures, and are not ecosystem services. Thus, he proposed a new term: "ecosystem benefits" for ecosystem services. In other words, according to Wallace, ecosystem services are benefits (derived from ecosystems) that are valued by humans.

Boyd & Banzhaf (2007), on the other hand, aiming to integrate the values of ecosystem services into accounting systems, argue that the definition of ecosystem services should be consistent and compatible with the conventionally defined terms of goods and services currently used in the national account system. For this purpose, the authors represent ecosystem services as ecological components (things or qualities) that are directly utilized (either consumed directly or combined with other inputs) by humans. Based on their definition, ecosystem services are end-products, objective rather than qualitative, provided by ecosystems. Therefore, ecosystem services do not include indirect ecosystem processes and functions. In addition, ecosystem services are physically measurable since they refer to the components of ecosystems.

The work of Fisher *et al.* (2008) and also Fisher *et al.* (2009) conceptualize the term of ecosystem services by integrating the definitions discussed earlier. In line with the definitions of Millennium Ecosystem Assessment (2005), Daily (1997), and Costanza *et al.* (1997), ecosystem services are defined as "the aspects of ecosystems utilized (actively or passively) to produce human well-being". Based on this definition, ecosystem services are either ecological elements (structures and components) or processes and functions. These ecological phenomena become ecosystem services only if human societies receive benefits from them. Also, to become services, they do not have to be directly utilized, as argued by Wallace (2007) and Boyd & Banzhaf (2007). In their view, ecosystem services are those that have a direct effect on social welfare and are usually in combination with other capital inputs (e.g.,

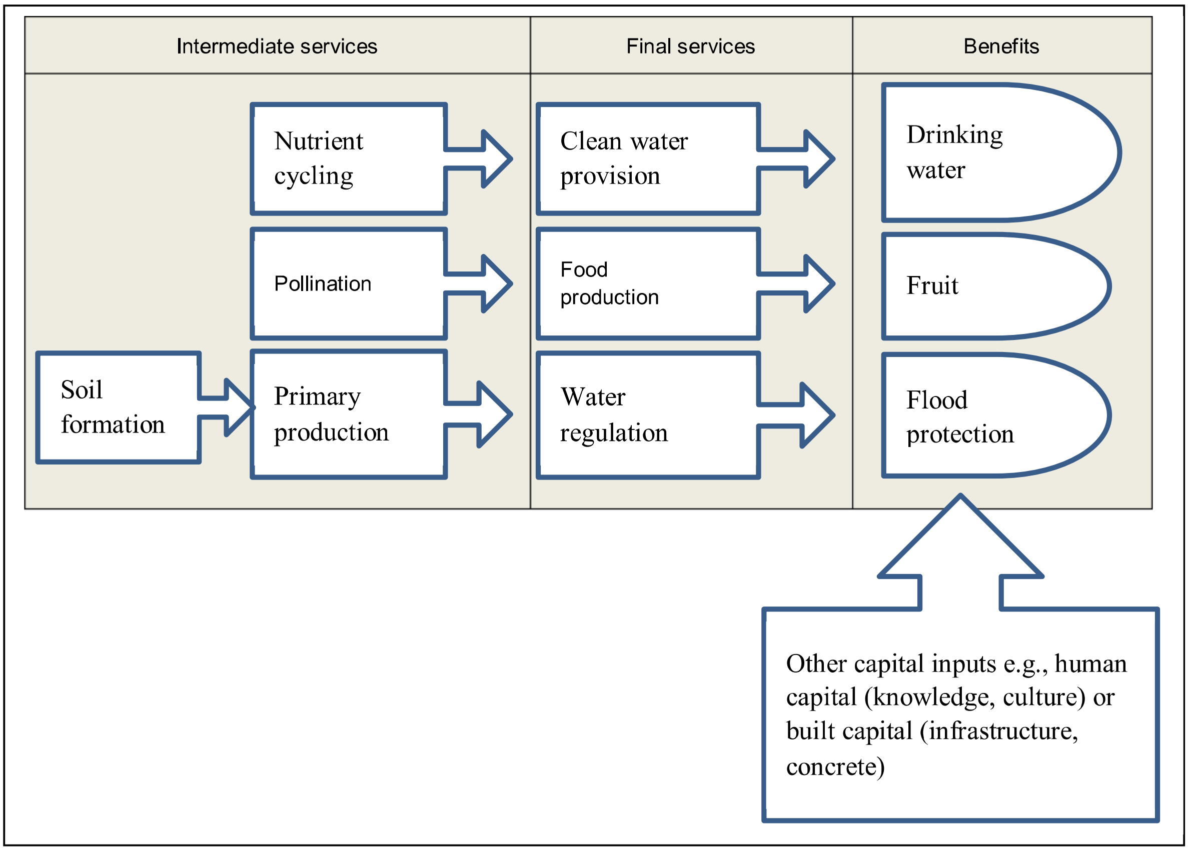

Figure 1. Stylized relationships among representative intermediate services, final services, and benefits introduced in Fisher *et al.* (2008)

human capital and manufactured capital). The notion that ecosystem services provide benefits to human well-being through interactions with other forms of capital is also proposed by an updated study of Costanza and his colleagues on valuing global ecosystem services (Costanza *et al.*, 2014). Fisher *et al.* (2008) also note that the definition of ecosystem services should be based on the specific characteristics of the ecosystem of interest. For the purposes of economic valuation and accounting practices, they suggest that only benefits derived from final services can be aggregated to avoid the problem of double-counting (e.g. stylized relationships among representative intermediate services, final services, and benefits as shown in **Figure 1**).

Haines-Young & Potschin (2010) joined the debate by analyzing the links among biodiversity, ecosystem services, and human well-being. They argue that the mere definition of the Millennium Ecosystem Assessment (2005): "ecosystem services are the benefits that ecosystems provide" makes it difficult to precisely interpret what an ecosystem service is in practice. Although they did not propose their own definition, they provide a diagram that presents the relationship among "biodiversity, ecosystem function, ecosystem services, and human well-being" (**Figure 2**). As presented in **Figure 2**, there is a stylized distinction between ecological structures and processes and the benefits that people enjoy. It is quite clear that Haines-Young and Potschin (2010) did not consider ecosystem structures or functions as ecosystem services, but rather "ecosystem flows" derived from the ecosystems that benefit humans. The diagram also integrates the ideas of Wallace (2007) and Boyd & Banzhaf (2007) regarding intermediate and final ecosystem services. It shows that an ecosystem service can be either an intermediate or a final one depending on how human societies utilize it, indirectly or directly. This is also similar to the view of Costanza (2008).

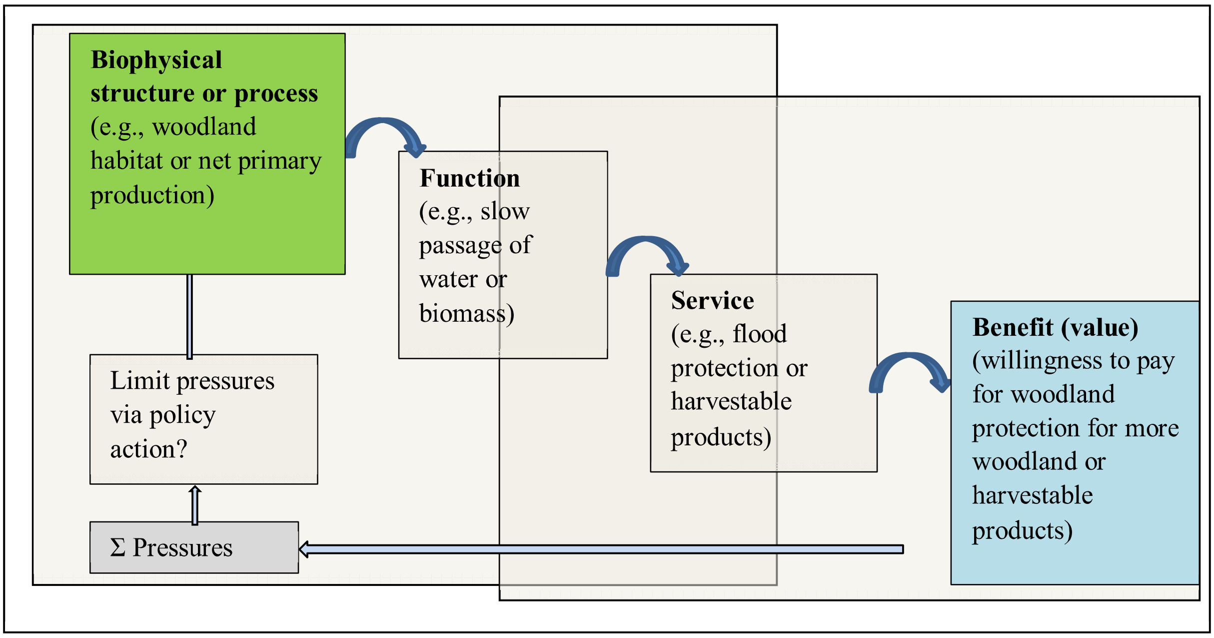

Figure 1. The relationship between biodiversity, ecosystem function, and human well-being in Haines-Young and Potschin (2010)

The work of De Groot *et al.* (2010) on determining the "challenges in integrating the concepts of ecosystem services and values in landscape planning, management, and decision making" took the issue of the distinction between ecosystem functions and services proposed by Wallace (2007) and Fisher *et al.* (2009) into account. They then introduced a figure adapted from Haines-Young and Potschin that portrays the link between ecosystems and human well-being (**Figure 3**). The figure illustrates that ecosystem services are generated by ecosystem functions. At the same time, ecosystem functions are established by ecosystem structures and

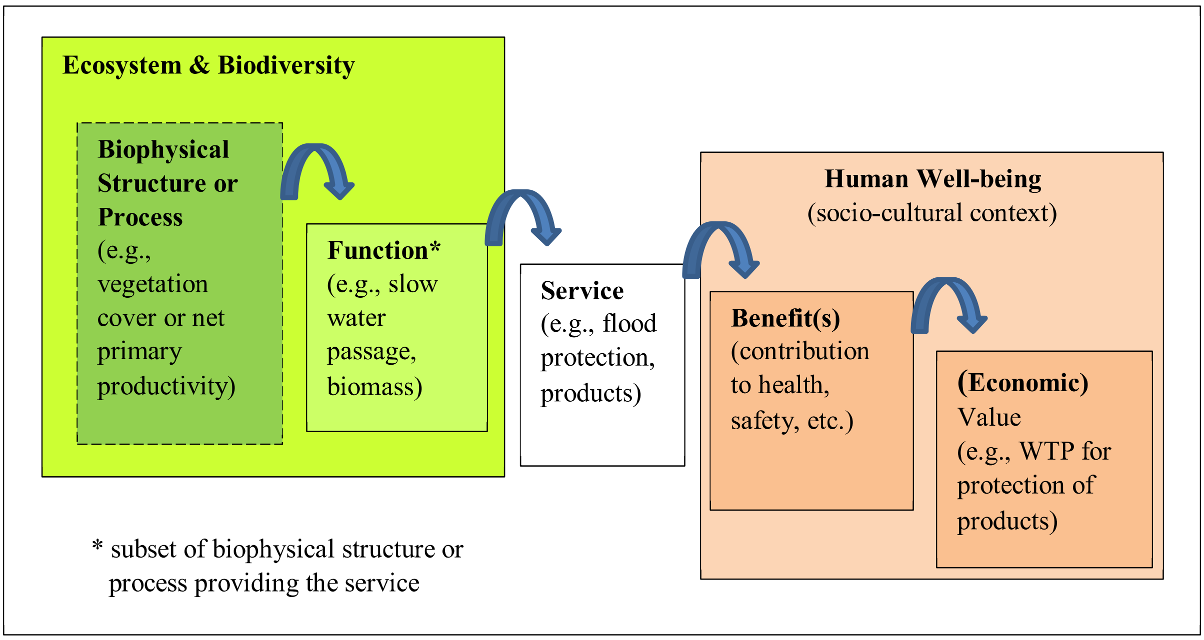

Figure 2. Framework for linking ecosystems to human well-being proposed in De Groot *et al.* (2010)

processes. It can be interpreted that ecosystem services are provided by ecosystem structures and processes that are intermediated by ecosystem functions. The actual usage of ecosystem services brings benefits to human well-being.

In papers by Potschin & Haines-Young (2011; 2016), an 'ecosystem service cascade model' was introduced to define ecosystem services (**Figure 4**). This model clarified a 'product line' of ecosystem services from ecological structures and processes to human well-being. It identifies the 'production boundary' and stresses ecosystem services as end products of ecological structures and processes and how they most directly affect human well-being.

TEEB (2010) contributes to the concept of ecosystem services by refining the Millennium Ecosystem Assessment's definition. In TEEB, ecosystem services are defined as "the direct and

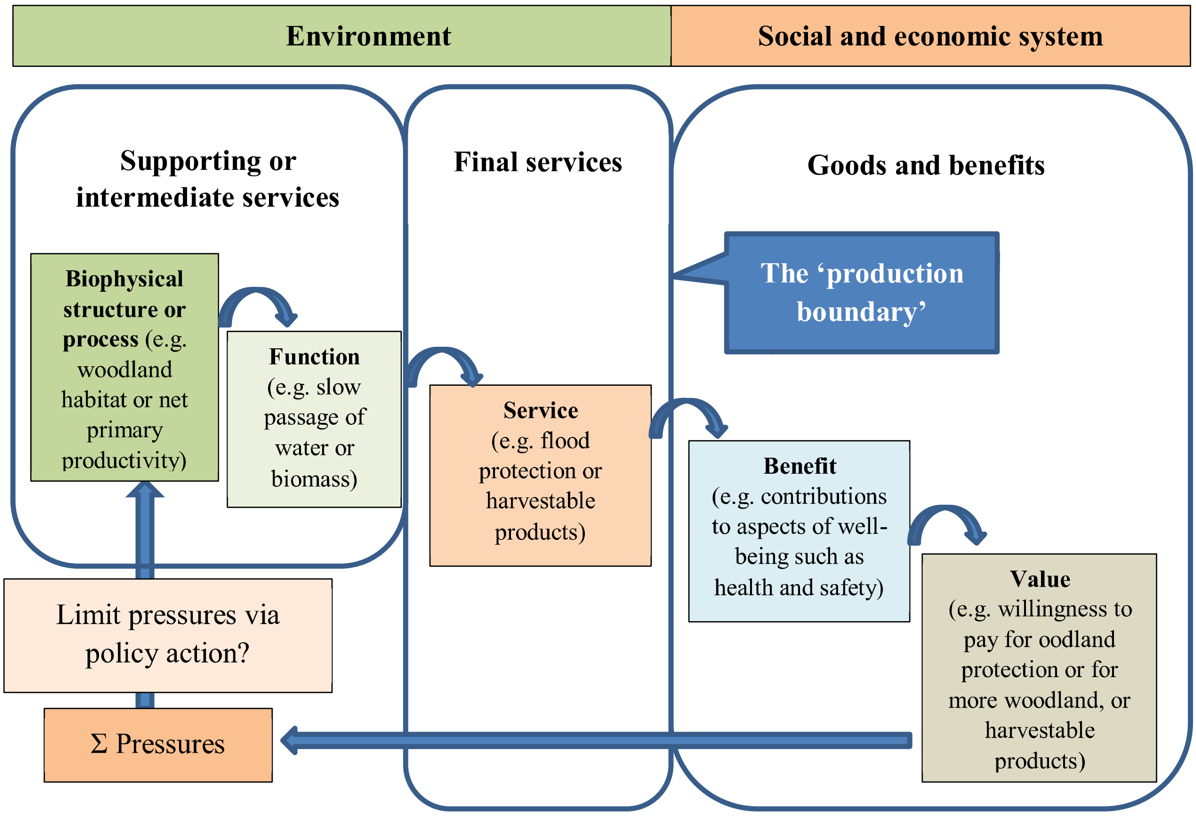

Figure 3. The ecosystem service cascade model proposed in Potschin & Haines-Young (2016)

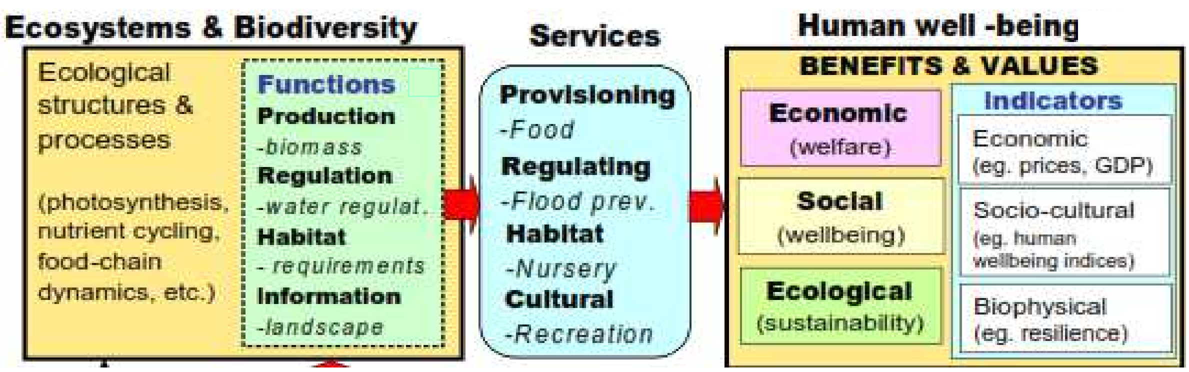

Figure 4. Adopted from the conceptual framework for linking ecosystems and human well-being (TEEB, 2010)

indirect contributions of ecosystems to human well-being." Within the TEEB framework (**Figure 5**), ecosystem services and benefits are differentiated, and the framework also acknowledges that services can benefit humans in multiple ways. Ecosystem services can directly or indirectly benefit humans in terms of economic welfare, social well-being, and ecological sustainability.

Another significant contribution was made by the scientific team of the Natural Capital Project (Sharp *et al.*, 2018). They followed the broad concept of the Millennium Ecosystem Assessment (2005) and proposed a simple ecosystem services framework delineating "supply, service, and value" to link ecosystem production functions to the benefits provided to people (**Figure 6**). In this framework, "Supply" includes what is likely to be provided by ecosystems (i.e., what the structure and function of the ecosystem can provide). "Service" adds in demands and therefore uses information about the beneficiaries of that service (e.g., location and activities of the beneficiaries). "Value" incorporates social preferences of the service and allows for economic valuation.

Recently, in the work of valuing forest ecosystem services, following the concepts of the TEEB and Natural Capital Project, Nguyen *et al.* (2018) defined ecosystem services as 'outputs of ecosystem functions' that indirectly or directly benefit humans. These outputs, as mentioned by Costanza and his colleagues (Costanza *et al.*, 1997; Costanza *et al.*, 2014), consist of "materials, energy, and information" derived from ecosystems that combine with other types of capital, such as manufactured and human capital, to create human well-being. They are physically measurable and directly or indirectly contribute to human welfare. This concept of ecosystem services is depicted in **Figure 7**.

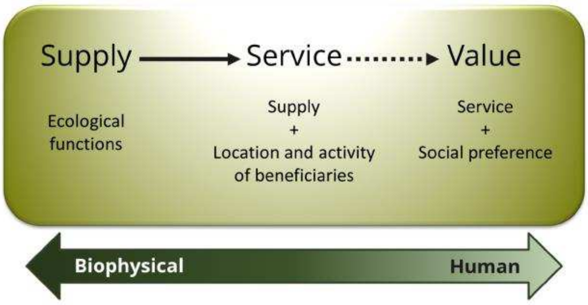

Figure 5. The ecosystem service supply chain, linking ecological functions to ecosystem services and the benefits provided to people (Sharp *et al.*, 2018)

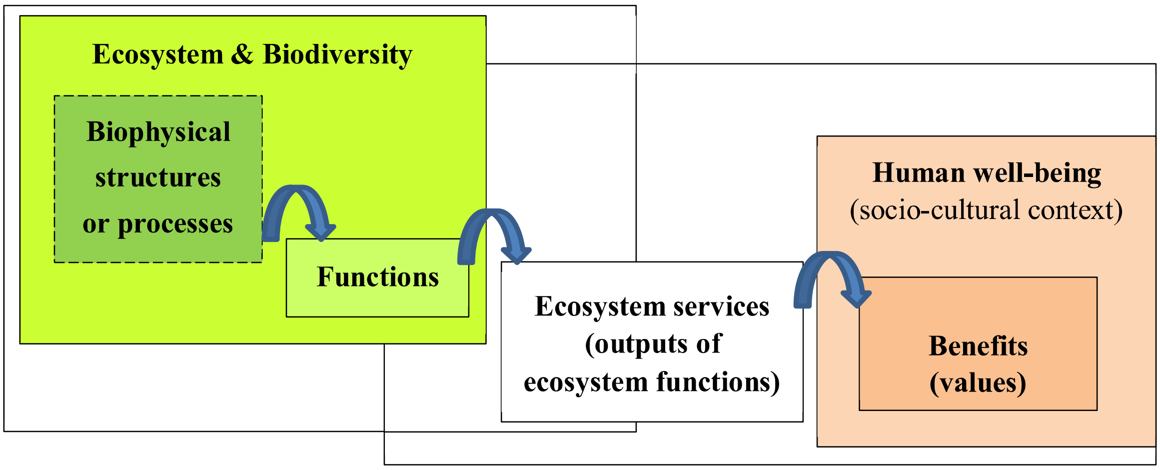

Figure 6. Ecosystem services: Linking ecosystems to human well-being proposed in Nguyen *et al.* (2018)

Classification of Ecosystem Services for Valuation Purposes

In order to integrate the ecosystem service approach to the valuation framework, it is essential to classify ecosystem services properly. There have been several efforts to classify ecosystem services that coincide with the definitions of ecosystem services as discussed previously. Daily (1997) provides a list that is considered to be a set of ecosystem functions/processes. By defining ecosystem services as ecosystem conditions and processes, Daily tries to illustrate the link between ecosystems and human well-being. Obviously, this classification comes from the perspective of an ecologist immersed in ecologically underpinned processes. The list is criticized by Boyd & Banzhaf (2007) as being an unsuitable classification scheme for valuation purposes. This is because the list is not practical enough to measure ecosystem services. Firstly, measuring outcomes of ecosystem processes is much easier than measuring the processes. Secondly, a process that provides final services is valuable, but this process is not a final service in an economic sense, meaning that if a process is considered as an ecosystem service, the problem of double-counting might occur (Boyd & Banzhaf, 2007).

Costanza *et al.* (1997) offer a comprehensive list of ecosystem services when they try to measure the economic value of the world's ecosystem services. In this list, they only take renewable ecosystem services into consideration (non-renewable fuels, minerals, and the atmosphere are excluded from their list) which are then grouped into 17 main categories. In each major category of ecosystem services, they show corresponding ecosystem functions that engage in the provision of the services as well as some key examples of ecosystem services. They also make a cautious note that ecosystem services and functions do not necessarily exhibit a one-to-one correspondence, meaning that, in some cases, an ecosystem service can be an output of more than one ecosystem function while, in other cases, one ecosystem function can contribute to more than one ecosystem service. They also recognize the problem of "double-counting" caused by the interdependence between ecosystem functions and ecosystem services. Attempting to solve the double-counting problem, they suggest distinguishing 'joint and addable products' from products that would represent 'double-counting'. This task is not easy because, in some cases, when ecosystem functions and services are interdependent, they can jointly produce benefits to humans. In these cases, their benefits can be added. In other cases, double-counting would result from one service representing different aspects if they were aggregated.

De Groot *et al.* (2002) aim to standardize a conceptual framework to help describe, classify, and value ecosystem functions and services. For this purpose, they organize ecosystem services based on ecosystem functions. In conceptualizing ecosystem functions as a subset of ecosystem structures and ecosystem processes, they propose four fundamental categories of ecosystem functions, namely regulation, habitat, production, and information functions, that include 23 specific functions. Firstly, they define regulation functions as the capacity of ecosystems to regulate essential ecological processes and life-support systems. These regulation functions provide many services that provide benefits to humans either directly or indirectly (e.g., clean air, water, soil, and biological control services). Secondly, habitat functions are the functions of a natural ecosystem that provide habitat or refuge and support reproduction for wild plants and animals. These functions play essential roles in the conservation of biodiversity, genetic resources, and evolutionary processes. Thirdly, production functions are those that relate to photosynthesis and nutrient uptake, which typically use the energy from sunlight to convert carbon dioxide, water, and nutrients into a wide variety of carbohydrate structures. Fourthly, information functions are defined as 'reference functions' that are vital sources of inspiration for science, art, and culture. These functions also relate to the provision of opportunities for spiritual enrichment, mental development, and leisure. In addition, in order to generate an entire ecosystem service typology, they present specific functions based on the four categories. For every function, they provide examples of associated ecosystem services and ecosystem components and processes that underpin each function. Similar to Costanza *et al.* (1997), they realize that ecosystem processes and services do not always show a one-to-one correspondence. For example, the function of "gas regulation" maintains air quality based on biogeochemical cycles (e.g., CO_2/O_2 balance), but also contributes to the greenhouse effect and thereby engages in "climate regulation". They also note that ecosystem functions and services can overlap, which results in the possibility of economic "double-counting". For example, gas regulation functions (and related services) have an impact on the climate and can, therefore, be double-counted in valuing the climate regulation service.

The Millennium Ecosystem Assessment (2005) attempts to create an ecosystem service framework that links ecosystem services to human welfare. Similar to the classification of De Groot *et al.* (2002), the Millennium Ecosystem Assessment (2005) proposes a genetic typology of ecosystem services' classification based on ecosystem functions. It classifies ecosystem services into four main groups, namely provisioning, regulating, cultural, and support services (**Table 1**). This way of classifying ecosystem services advocates for ecosystem service measurements and valuation

Table 1. Categories of ecosystem services

Type of service	Service
Provisioning services	Food
	Fiber
	Genetic resources
	Biochemicals, natural medicines, etc.
	Ornamental resources
	Fresh water
Regulating services	Air quality regulation
	Climate regulation
	Water regulation
	Erosion regulation
	Water purification and waste treatment
	Disease regulation
	Pest regulation
	Pollination
	Natural hazard regulation
Cultural services	Cultural diversity
	Spiritual and religious values
	Aesthetic values
	Knowledge systems
	Educational values
	Inspiration
	Social relations
	Sense of place
	Cultural heritage values
	Recreation and ecotourism
Supporting services	Soil formation
	Photosynthesis
	Primary production
	Nutrient cycling
	Water cycling

Source: Adapted from Box 2.1 (pp. 43) in the Millennium Ecosystem Assessment (2005).

for decision making (Boyd & Banzhaf, 2007; Fisher *et al.*, 2009). However, the classification of the Millennium Ecosystem Assessment (2005) is criticized by Wallace (2007) and Boyd & Banzhaf (2007) for the vague classifications and risk of double-counting in valuing ecosystem services. Although acknowledging the effort of the Millennium Ecosystem Assessment classification scheme, in terms of motivating quantifying ecosystem services, critics claim that the Millennium Ecosystem Assessment's system is overly generic and confounding. For example, the regulating services relate to ecosystem functions and processes that cause difficulties in practical measurements. Besides this, supporting services are not services in their own right, in the sense that they are not final services, as defined by Wallace (2007) and Boyd & Banzhaf (2007), which leads to the problem of double-counting (Boyd & Banzhaf, 2007; Wallace, 2007; Fisher *et al.*, 2009). Wallace (2007) presents an alternative classification scheme. By criticizing the mainstream literature of ecosystem service classifications because they are represented by the typology of the ecosystem service offered by Millennium Ecosystem Assessment (2005), which has a risk of double-counting and makes it difficult to apply in natural resource management, he argues that for effective decisions, the classification must be constructed as a coherent set of services that can be evaluated and traded off in a decision system. Examining the classification system of the Millennium Ecosystem Assessment (2005), Wallace points out that in the classification of the Millennium Ecosystem Assessment the processes (means) and services (ends) are mixed up, which leads to the categories not being able to be used for decision making. For example, according to Wallace, water regulation is not a service in its own right; instead, it is a process to achieve drinking water or to control flooding. Therefore, the regulation services are not ends, but they are means to attain ends. Similarly, the supporting services are not ends in their own right. For example, nutrient and water cycling are not ends; instead, they are means to provide human welfare. Wallace also demonstrates the possibility of double-counting when using the Millennium Ecosystem Assessment (2005) classification system for valuing ecosystem services. For instance, many regulating services underpin several services, and if the services are valued separately, double-counting occurs. To solve these problems, he first redefined ecosystem services as the structure and composition of particular ecosystem elements. Then he classifies the services based on the specific human values they support that include: (1) adequate resources (basic needs), (2) protection from predators, diseases, and parasites, (3) benign physical and chemical environments, and (4) socio-cultural fulfilment. He argues that this classification system links values with ecosystem services and can be useful for analyzing alternative uses of natural resources so that decisions can be made to sustain human well-being. This is because the classification removes the confusion between processes (means) and services (ends), which solves the problem of double-counting and is consistent with a human decision-making framework because the values describe important aspects of human well-being.

The classification of Wallace, however, is strongly criticized by Costanza (2008) for its oversimplification of the complex nature of ecosystem services. According to Costanza, Wallace's idea that ecosystem processes are means while ecosystem services are ends is flawed, because human well-being is 'the end'. Therefore, by definition, all ecosystem services are means to achieve human well-being. In this sense, ecosystem processes can be services.

Boyd & Banzhaf (2007) argue for standardized units of ecosystem services that can be used in welfare accounting, so they offer a definition of final ecosystem service units (which is rooted in economic principles) that is comparable to the conventional national accounting system. In this manner, they attempt to classify ecosystem services in a way that the values of ecosystem services can be incorporated into the existing national accounts. They illustrate the classification of ecosystem services associated with sources of human well-being. According to Boyd & Banzhaf (2007), the sources of well-being consist of harvested elements that satisfy the needs of human consumption of food, fiber, and other materials, or the human demand for good health, safety, and recreation. When classifying in this way, only end-products derived from ecosystems are taken into account. It is also worth noting that their classification is rooted in the notion that ecosystem services are economic benefit-specific. By benefit-specific, they mean that ecosystem services are benefit-contingent and depend on particular human activities or wants. This means that a particular ecological component is accounted as an ecosystem service if it directly contributes to human welfare and is not accounted as an ecosystem service if it is used as an intermediate input in processes producing final products consumed by humans (see Boyd & Banzhaf (2007) for an example of this).

Fisher *et al.* (2009) provide a comprehensive assessment of ecosystem service classification schemes. They contend that the main theme of ecosystem service classification, such as the one proposed by the Millennium Ecosystem Assessment (2005), is not suitable for valuation purposes because it could lead to double-counting. Therefore, for valuation purposes, they argue for a classification scheme that differentiates ecosystem services into intermediate services, final services, and benefits, like the one proposed by Boyd & Banzhaf (2007). Recognizing that the link between ecosystems and human welfare is complex, the same service can be both intermediate and final depending on its links to human welfare. They suggest that the classification must be clear about whether the service is the final one or not. This classification avoids the risk of double-counting because only the final benefits are valued and aggregated.

TEEB (2010) proposes an updated typology of ecosystem services that is mainly based on the classification system initiated by the Millennium Ecosystem Assessment. TEEB provides 22 specific ecosystem services and then categorizes them into 4 main groups: provisioning, regulating, habitat, and cultural and amenity services (**Table 2**). The important revision of TEEB in comparison with the Millennium Ecosystem Assessment is the omission of supporting services and the initiation of habitat services. Habitat services include those that relate to the maintenance of life cycles and genetic diversity. The classification of TEEB complies with the notion that ecosystem services and benefits gained by human societies are necessarily differentiated and ecosystem services can benefit humans in multiple ways. In the recent work of De Groot *et al.* (De Groot *et al.*, 2010; De Groot *et al.*, 2012), they revise the ecosystem service classification after the popular publications of the Millennium Ecosystem Assessment (2005) and TEEB (2010). The major revisions include changes in the four categories of ecosystem services. They rename the “ecosystem functions” to “ecosystem services”, replace the “information functions” with “cultural services”, and also rename the specific names of particular services. In addition, they reorder the four categories as: provisioning, regulating, habitat, and cultural services, and focus more on describing the indicators used to measure the stock and flows of ecosystem services.

The Millennium Ecosystem Assessment’s classification system of ecosystem services is also adopted in the UK National Ecosystem Assessment (UK NEA, 2011). This was the first attempt to assess the UK natural ecosystem resources that involved about 500 experts from various government, academic, NGO, and private sector institutions working in the fields of natural sciences, economics, and the social sciences. The UK NEA follow-up study reported in 2014 (UK NEA, 2014) continued using the Millennium Ecosystem Assessment’s classification. The important contribution of the UK NEA (2011, 2014) is the incorporation of the post-Millennium Ecosystem Assessment advances focus on ‘final ecosystem services’ to avoid the double counting of services into the ecosystem service classification.

In order to provide a standard classification of ecosystem services, based on their previous

Table 2. TEEB's classification of ecosystem services and examples

	Main service types
	PROVISIONING SERVICES
1	Food (e.g. fish and fruit)
2	Water (e.g. for drinking, irrigation, cooling, and hydropower production)
3	Raw materials (e.g. fiber, timber, fuelwood, fodder, and fertilizer)
4	Genetic resources (e.g. for crop-improvement and medicinal purposes)
5	Medicinal resources (e.g. biochemical products, models, and test-organisms)
6	Ornamental resources (e.g. artisan work, decorative plants, pet animals, and fashion)
	REGULATING SERVICES
7	Air quality regulation (e.g. capturing fine dust and chemicals, etc.)
8	Climate regulation (e.g. carbon sequestration and influence of vegetation on rainfall)
9	Moderation of extreme events (e.g. storm protection and flood prevention)
10	Regulation of water flows (e.g. natural drainage, irrigation, and drought prevention)
11	Waste treatment (especially water purification)
12	Erosion prevention
13	Maintenance of soil fertility (including soil formation)
14	Pollination
15	Biological control (e.g. seed dispersal, pest, and disease control)
	HABITAT SERVICES
16	Maintenance of life cycles of migratory species (including nursery services)
17	Maintenance of genetic diversity (especially in gene pool protection)
	CULTURAL & AMENITY SERVICES
18	Aesthetic information
19	Opportunities for recreation and tourism
20	Inspiration for culture, art, and design
21	Spiritual experiences
22	Information for cognitive development

Source: Adapted from Table 3 (TEEB, 2010)

work on the concept of ecosystem services (Haines-Young & Potschin, 2010; Potschin & Haines-Young, 2011; 2016), Potschin and Haines-Young (2018) created the Common International Classification of Ecosystem Services (CICES) platform. The CICES classification aims to build an environmental accounting system that is compatible with the current economic accounting system. Therefore, it focuses on identifying and classifying final services. As a result, there are only 3 ecosystem service groups in the CICES, namely provisioning services, regulating and maintenance services, and cultural services, making this system different from the classification systems of the Millennium Ecosystem Assessment (2005) and TEEB (2010). Habitat services (TEEB, 2010) or supporting services (Millennium Ecosystem Assessment, 2005) are removed from the CICES. The reason given is that the habitat/supporting services are not final services since they do not directly affect human well-being. The advantages of the CICES classification are in solving the double-counting problem and enabling the integration of the environmental-accounting system into the current economic accounting system. However, in practice, the final service determination depends very much on the specific ecosystem and the interactions between humans and the ecosystem. In some circumstances, a service may be an intermediary service, but in other cases, it may be the final service. For example, spring water, if used as a source of drinking water, can be considered a final service. But if people use spring water to raise fish for fishing, spring water is not the final service. This means that an ecosystem can provide many ecosystem services and each service benefits people in many different ways. Therefore, while the CICES aims to provide a classification of final services, it should be used as a classification of potential final services. The user has to determine whether in a particular application context, a service is a final or an intermediate service. Additionally, the CICES platform also provides a way of translating between different commonly used ecosystem service classification systems that are proposed by the Millennium Ecosystem Assessment (2005) and TEEB (2010).

The total economic value of ecosystem services

Valuation of ecosystem services is based on the concept of the Total Economic Value (TEV), which has become a widely used framework for looking at the value of ecosystems (Pearce, 2001; Hein *et al.*, 2006; Smith *et al.*, 2006; Pascual *et al.*, 2010; Nguyen & Do, 2011). The TEV, which is based on the notion of neoclassical economics, is typically divided into two categories: use values and non-use values (**Figure 8**).

Projecting the values of ecosystem services onto the TEV framework, Smith *et al.* (2006) suggest that:

- Use values consists of three elements:

  - Direct-use value stems from both consumptive and non-consumptive uses from ecosystems. It is mainly derived from goods that can be consumed or enjoyed directly by humans. For example, provisioning services (e.g., food, drinking water, and timber, etc.) and cultural services (e.g., recreation and tourism) provide direct-use value.
  - Indirect-use value is derived from the goods and services provided by an ecosystem that are used indirectly by humans. It is mainly derived from the regulating services that the environment provides such as climate regulation, water regulation, water purification, and erosion prevention.
  - Option value relates to keeping the possibility of the use of ecosystem services (all services) available in the future.

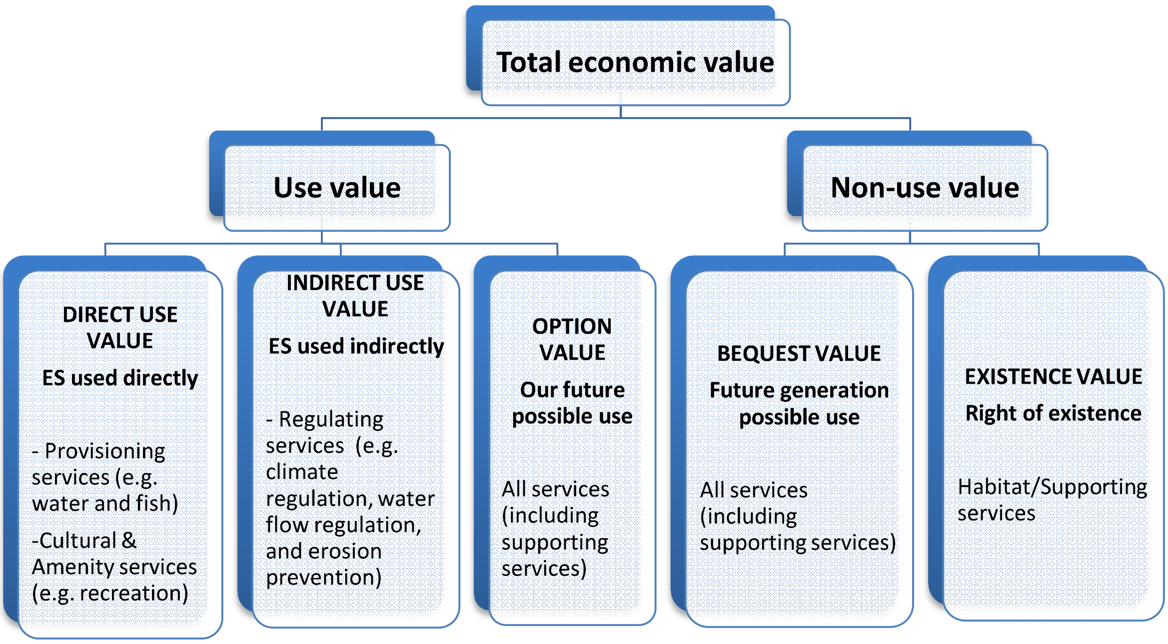

Figure 7. Total economic value of ecosystem services (Smith *et al.*, 2006)

- In contrast, non-use values are those values that do not relate to direct or indirect uses of ecosystem services. They are comprised of:

  - Bequest value reflects the desire to pass on the use of ecosystems to future generations. Bequest value can be generated from all ecosystem services (including supported services).

Existence value is the value people derive from the existence of ecosystem services, even if they never plan to use them. Existence value is mainly related to habitat/supporting services.

It can be seen from **Figure 8** that the common Millennium Ecosystem Assessment and TEEB's concepts, as well as their associated classification systems of ecosystem services, seem to capture the total economy of ecosystems well. However, when these ecosystem services classifications and the total economic value framework are projected together as presented in **Figure 9**, it shows that there are possibilities of double-counting issues that might occur due to the complexity of interactions among ecosystem services. For example, the values of habitat/supporting services may be already included in the other types of services such as provisioning, regulation, and cultural services. This is because habitat/supporting services are not final services and their values are intermediate in other types of services. In order to reduce the possibility of double-counting, value habitat/supporting services should not be aggregated into the total value (Potschin & Haines-Young, 2018).

Therefore, in order to bring the economic value of ecosystem services into the current economic accounting system, the issue of double-counting must be addressed (Fisher *et al.*, 2009; Potschin & Haines-Young, 2016). It is suggested that in each valuation study it is essential

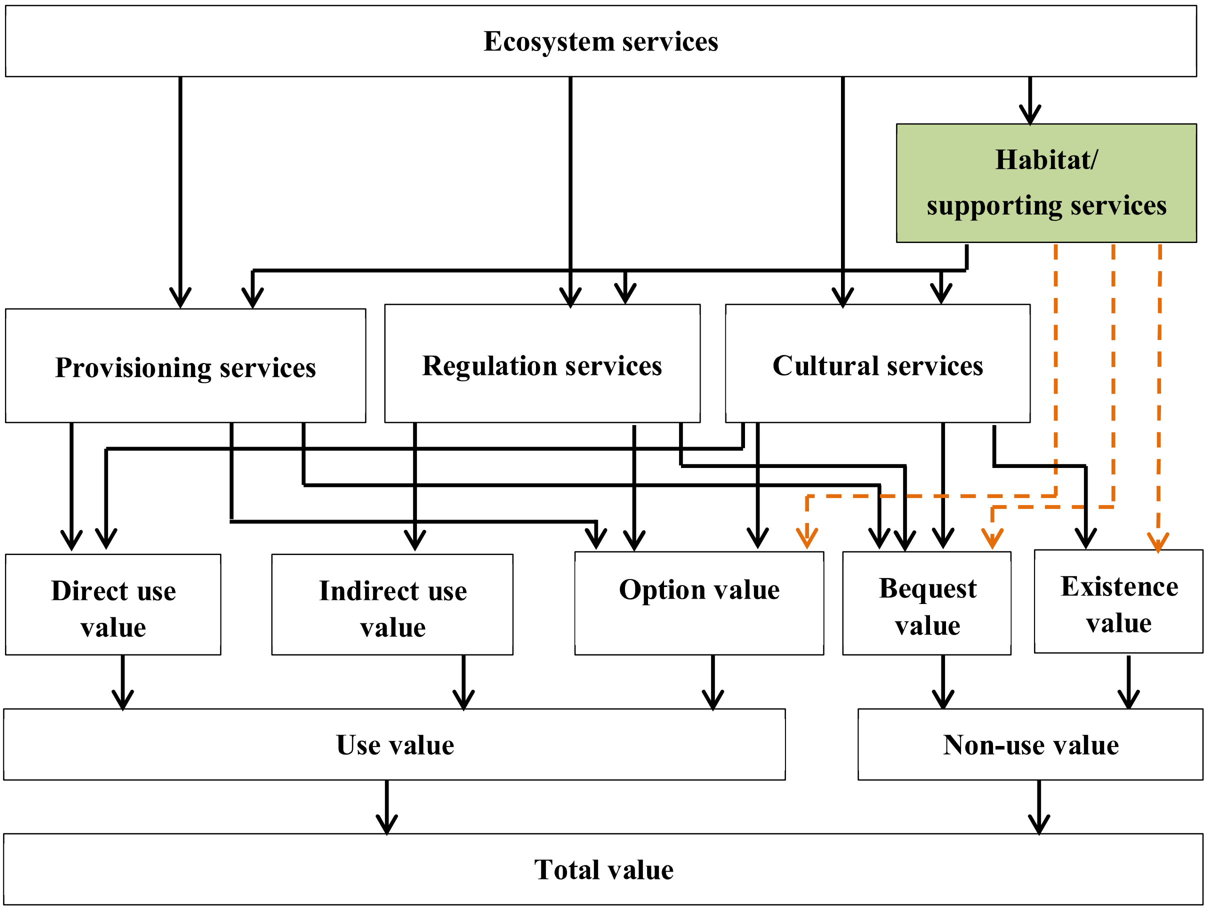

Figure 8. The ecosystem classification and total economic value framework. The orange dashed lines indicate the values of habitat/supporting services that are possibly double-counted.

to disentangle the interactions and overlaps between ecosystem services and clearly identify and remove intermediary services (Turner *et al.*, 2010; Fu *et al.*, 2011). In this regard, the CICES is acknowledged for its efforts in identifying final services and removing habitat/supporting services from its ecosystem services classification system.

Conclusions

In summary, there are different definitions and their associated schemes that can be used to classify ecosystem services that fit the different purposes of various studies (Costanza, 2008). For the purpose of valuing ecosystem services that aid decision making in natural resource management, we need to clearly define and classify ecosystem services in consistent ways such as those provided by the Millennium Ecosystem Assessment (2005) and TEEB (2010). Moreover, it is necessary to identify ecosystem services as intermediate services or final services in a particular valuation study, in which only final services are accounted for. Therefore, when applying the mainstream definitions and classification schemes proposed by the Millennium Ecosystem Assessment (2005) and TEEB (2010), it is essential to carefully examine the degree of the connection between ecosystem services and their interest to human welfare. The 'ecosystem service cascade model' provided by Potschin and Haines-Young (2011, 2016) as well as their work on the CICES platform are useful in identifying the final services that are valued and aggregated into the total value of ecosystem services.

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