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REVIEW ARTICLE

Ecosystem services valuation: a review of concepts, systems, new issues, and considerations about pollution in ecosystem services

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Abstract

Managers can determine the function of ecosystem services in decision-making processes through valuation. Ecological functions and processes that benefit people lead to ecosystem services. Valuing ecosystem services mean finding values for the benefits of ecosystem services. For the concepts related to ecosystem services and their valuation, categories in different articles have been presented. One of the most important issues is providing a suitable grouping for different methods and concepts of valuing ecosystem services. In this study, the most recent topics related to ecosystem service valuation methods were compiled and categorized by using the system theory. The aim of this study was to introduce some of the most important classical and modern methods and concepts of valuing ecosystem services. For this aim, a review of articles related to ecosystem service valuation methods, content analysis, and categorization of their contents was used to provide definitions, concepts, and categorization of different methods. To summarize, valuation methods are classified into two types: classical and modern methods. Classical approaches include the avoided cost method, the replacement cost method, the factor income method, the travel cost method, hedonic pricing, and contingent value. Modern methods include the basic value transfer method, deliberative ecosystem service valuation, valuation of climate change risks, and other cases that evolve every day in the world of science. Findings of the paper have the potential to be beneficial in comprehending the definitions and ideas of ecosystem services in ecosystem management, particularly in protected areas, participatory management, and pollutant research. This research can add to the worldwide literature on the valuing of ecosystem services while also determining the most pressing issues and difficulties of today, such as climate change, pollution, ecosystem management, and participatory management.

Keywords Classical valuation methods · Basic value transfer method · Deliberative ecosystem service valuation · Climate change

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Introduction

Ecosystem services and cascade model

The services that ecosystems have for people and are defined according to people's interests are known as ecosystem services (Costanza et al. 2017). Ecosystem services are related to other concepts in ecosystems such as ecosystem functions and ecosystem benefits. Potschin and Haines-Young (2014) have used a cascade model to explain the concepts of functions, services, benefits, and values. Figure 1 shows the cascade model to explain these concepts.

Figure 1 indicated that the components of the cascade are the source of other factors from top to bottom. For example, net primary productivity can be a biophysical process or

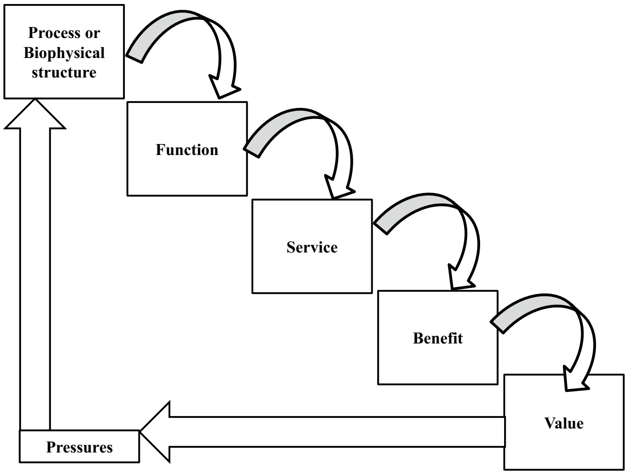


Fig. 1 Cascade model to explain the concepts of function, services, benefits, and values. *Summarized from Potschin and Haines-Young* (2016)

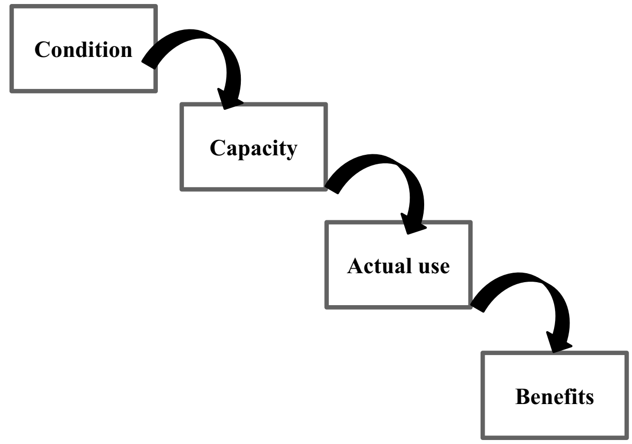


Fig. 2 A 4-step framework from condition to benefits. *Summarized from* Czúcza et al. (2020)

structure, reducing water flow can be a function, flood protection can be a service of this function, public safety can be a benefit, and willingness to pay for protection can be a value of this service (Potschin & Haines-Young 2011; Haines-Young and Potschin 2014). The functions of an ecosystem are generated in this model based on internal processes such as growth, light absorption, photosynthesis, and primary production. The functions of an ecosystem are the capacities that an ecosystem can have as a result of its internal processes to provide services and goods and meet human needs. Ecosystem benefits include the safety, welfare, and health extracted from ecosystem services (Haines-Young & Potschin 2014).

In another definition, ecosystem function depends on the ecosystem's capacity to provide ecosystem services. Natural processes give rise to ecosystem capacity, and ecosystem elements eventually provide commodities and services that satisfy needs of human (de Groot et al. 2002). Ecosystem services are obtained from ecosystem function based on the model presented in Fig. 1. Ultimately, ecosystem benefits provide ecosystem benefits for people and communities. To achieve an ecosystem benefit, a 4-step framework from condition to benefits was designed, as shown in Fig. 2.

In Fig. 2, condition introduces the overall quality of the ecosystem, and capacity presents the potential to achieve specific ecosystem services. Benefits includes improvements to human well-being, and practical use introduces the public to the real flow of certain ecological services (Czúcza et al. 2020). According to Fig. 2, benefits include changes in human well-being that are the achievement of the third phase in this figure (the stage actual use). Actual use originates from capacity, and these capacities depend on the condition/state of the ecosystem.

Ecosystem services valuation

The value notion has an extensive background (Farber et al. 2002). In general, something that is valuable has relevance, utility, or a proportionate stake in it. This idea also refers to an object or action's relevance, worth, usefulness, or proportionate contributions to accomplishing goals, objectives, or intended results (Costanza 2020). Expression of the relative importance of a certain action or thing is called valuation. Some ecosystem services have tangible benefits, such as timber production from forest ecosystems, and some other services have intangible benefits, such as watersheds, soil protection, nutrient cycling, and other services in forest and rangeland ecosystems (Smith et al. 2011). If the ecosystem managers can include intangible benefits in decision-making processes in addition to tangible benefits, they will be able to have appropriate protection for the ecosystem (Ninan & Kontolen 2016). Ecosystem services, especially services that have intangible benefits (e.g., food cycles), are often not properly considered in ecosystem managers' decisions. Evaluating ecosystem services can be a way to highlight these services to help ecosystem managers.

The following steps may be helpful in incorporating these services into decision-making processes (Longle-Flores & Quijas 2020). (1) Combining knowledge about ecosystem services: it means that the knowledge of ecosystem management conducts surveys to synthesizes services that provide tangible and intangible benefits. The means of tangible benefits are the benefits of ecosystem services related to physical processes that are easily visible by human perception, such as wildlife habitats and buffer effects. The means of intangible benefits are the benefits (e.g., aesthetics and cultural heritage) that human perception hardly understands (Vejre et al. 2010). (2) Ecosystem service economic valuation: valuing ecosystem services is one of the best methods to incorporate them into decision-making. As the name implies, valuation is the process of finding ecosystem values. Ecosystem values are the criteria that human beings set to value ecosystem interests. Willingness to pay to protect an ecosystem is an example of ecosystem value. (3) Quantification and specialization of ecosystem services: this process is focused on pursuing ecosystem services at different levels in order to make optimal use of them. (4) Providing information: it means providing information in the field of ecosystem services for those involved. (5) Joint implementation: it means joint implementation of protection and exploitation of ecosystem services owned by stakeholders. (6) Achieving large-scale collaborations: it means international collaborations for ecosystem services (Langle-Flores and Quijas 2020). The process of assessing how ecosystem services can be included to the human well-being sustainability is known as ecosystem service valuation (ESV). ESV displays the value of nature inside a unit of accounting. It also aids in balancing the costs and advantages of preserving or enlarging protected areas (Chen 2021; Chen et al. 2022). According to research done on the ESV problem, China's annual benefit from sustaining terrestrial protected areas is USD 2.64 trillion, which is more than 14 times larger than their expenses (Chen et al. 2022).

Many ecosystem services in protected areas are non-marketable and intangible. Hence, in decision-making, managers ignore or compromise some ecosystem services if these services could not be evaluated. Valuation is one of the strong tools for the relationship between conservation and economy. Valuation is able to present a pluralistic view of the ecosystems and change the status quo from black or white (Chen 2021). This means that any ecosystem service with a certain amount of value could be included in decision-making processes instead of the black and white view in which either an ecosystem service is considered or not.

Research problem and aims

Regarding the field of ecosystem services and their valuation, there are numerous articles, global studies, and review articles in the study literature. Some articles are on specific topics, and they are like valuing in urban forests in social and economic value of ecosystem services and cultural issues by Nesbitt et al. (2017). Other studies include Himes-Cornell et al.'s (2018) valuation of salt marshes and mangrove forests, Richter et al.'s (2021) valuation of grasslands, Costanza et al.'s (2021) valuation of coastal wetlands for storm protection, and Shen et al.'s (2023) valuation of forest carbon mechanisms. In addition, some review studies focused on developing countries (e.g., Villegas-Palacio et al. (2016)) or specific continent (e.g., Azadi et al. (2021) in Africa). In addition, this study does not intend to compare previous studies in terms of statistics, topics, authorship, and networks because experts have prepared comprehensive and complete articles in this field (e.g., the study of Comte et al. (2022) in ecosystem accounting and Kubiszewski et al. (2023) in research networks). All these studies have produced important new understandings and insights for science, but this study aims to provide a general set of information that can be useful for all ecosystems. This information can provide an overview of all concepts of ecosystem services and new concepts in the valuation of services for all ecosystems in a fluent language.

Moreover, issues related to the system theory and especially different sub-systems for natural systems needing more analysis have been presented in this article. To the best of our knowledge, sub-systems in valuation theories have not yet been comprehensively explored. Examining sub-systems could fill the study gap to know the finer components in these subjects so that the readers of this article can receive a package of all the concepts and contents and a categorization of them in system view, especially with the sub-system theory.

The main focus of this study is to examine the ideas of ecosystem services as well as various techniques of measuring ecosystem services. This article will look at some topics presented in the subject of ecosystem services, such as ecosystem functions, system theory, socio-ecological systems, and ecosystem benefits, and how to value these services. In addition, the methodology of valuing ecosystem services will be investigated based on new concepts and valuation applications for today's issues such as pollution, protected areas, participatory management, and climate change.

This study has three main aims: first, formulating general frameworks for ecosystem services based on the sub-system theory; second, identifying the general concepts and categories of ecosystem services and their valuation within a short period of time through the divisions related to valuation in ecosystem services; and third, identifying and conclusion on new topics in the concepts of ecosystem service valuation to generate new ideas in managing ecosystems. Since the concepts of ecosystems and their valuation can be used in a wide range of areas such as forests, rangeland ecosystems, and protected ecosystems, this article can be used for a wide range of international readers.

Theoretical topics

System theory

The system theory was first developed by Bertalanffy in the 1930s in the framework of the general system theory.

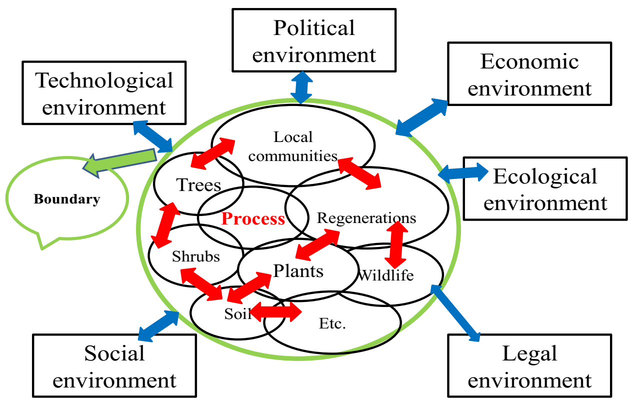


Fig. 3 An overview of the system theory in a hypothetical ecosystem. *Modified from* Danehkar & Zandebasiri (2020)

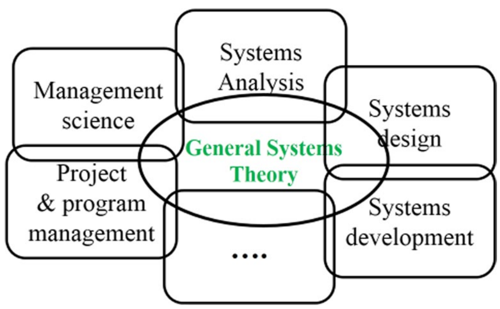


Fig. 4 The system theory as the heart of system and management issues. Novikov (2015)

In this theory, holism and consideration of generality for phenomena are examined along with the study of internal and external connections of components of a phenomenon (Novikov 2015). Figure 3 shows the applying system theory for ecosystem management.

In Fig. 3, trees, plants, shrubs, soil, wildlife, and regeneration of trees and shrubs are the main elements of the system. Also, local communities live in this system. Outside the boundary of the system, the internal elements have two-way communication with the parameters of the external environment of the system. The external environments of the system are technical, environmental, political, managerial, ecological, and social, and everything outside the system affects the system. In Fig. 4, the two-way red arrows are the system's internal communications, the green circle is the boundary of the system, and the two-way blue arrows are communications inside and outside the system.

Figure 4 shows that an understanding of the system theory is essential for all these topics, and none of these topics can be discussed without the system theory. This means each system and organization could be faced with several issues. Development of the system, projects, and programs, managerial issues, and design and analysis are among of these issues, and all of them are related to the system theory.

Ecosystem accounting and ecological–economic systems

The statistical framework for organizing data, measuring ecosystem services, and tracking ecosystem change status and the relationship between this information and economic activities constitute ecosystem accounting (Haines-Young, and Potschin 2014). Ecosystem accounting encompasses a broad range of concepts and subjects. Ecosystem accounting focuses on ecosystem services and related data. Ecosystem services are the outcomes of natural processes that benefit humans and are defined by people's interests. Ecosystem services cannot be defined independently of people's interests. Given the importance of the notions of human interests and ecosystem services, it is vital to present multiple views in this topic analytically (Costanza et al. 2017). The contributions that ecosystems offer to human welfare are known as ecosystem services. The maintenance of an infrastructure connection between ecosystem functions and natural structures and processes defines ecosystem services (Potschin & Haines-Young 2016). Furthermore, ecosystem services can be a framework for ecosystem stewardship (Smith et al. 2011). Understanding the ideas of ecosystem services and associated concerns can be useful for managing ecosystem services as well as in relation to economic operations, given the connection between well-being of human and ecosystem services.

The value of ecosystem services, which ensures that ecosystem services with lower exchange in the economic markets are not regarded less valuable in choices and policies, is a crucial problem that arises following the definition and acknowledgment of ecosystem services. The idea of valuing ecosystem services will be examined in this study based on the functioning of ecosystem services in maintaining sustainable human well-being. Ecosystem services provide a bridge between resources and long-term human well-being (Costanza et al. 2014). Many theories have been proposed in the field of ecosystem services (e.g., ecological economic systems by Costanza et al. (2017) and social–ecological–technological systems by McPhearson et al. (2022)). The system theory can be a foundation for such theories (Danehkar & Zandebasiri 2020; Small et al. 2021). In this context, it is necessary for researchers to pay much attention to the role of the system theory in ecosystem services and ecosystem sustainability because it is one of the theories that can be used for the concept of ecosystem services (Danehkar & Zandebasiri 2020; Small et al. 2021).

The system theory is one of the most important theories in management science that focuses on the concept of comprehensiveness and component communication (Small et al. 2021). This theory defines a set of sub-systems for each system that make up a macro-system. Presenting a system by its sub-systems increases the knowledge of managers and decision-makers about the system and better identifies the connections of system components. This increased identification and information will improve the quality of managers' and planners' decision-making processes (Danehkar & Zandebasiri 2020). Economic–ecological systems are one of the applied theories of systems in natural resources management that increase the interdependence of the human economy and natural ecosystems in terms of space and time (Costanza et al. 2017). In economic–ecological systems, economics discusses natural phenomena, ecological cycles, human health, human welfare, and justice in ecological systems (Melgar-Melgar & Hall 2020; Langle-Flores & Quijas, et al. 2020). Some issues are important in ecological–economic systems, including the laws of thermodynamics equilibrium as well as the internal/external energy of entering/exiting biological systems. Furthermore, sustainable development of ecosystems, study of all human activities, prominent role of the environment, and uncertainty of long-term results can be studied and analyzed in these systems (Zandebasiri & Pourhashemi 2018). Ecological–economic systems are complex systems, and their decomposition into sub-systems (including natural sub-systems, economic sub-systems, social sub-systems, and other internal components) leads to more knowledge of these complex systems. This decomposition helps managers and planners to identify the components of ecological–economics in a variety of social, cultural, and economic environments with more relevant and practical connections (Danehkar & Zandebasiri 2020).

Socio-ecological systems

One of the main topics in ecological–economic systems is the concept of sustainable development that requires justice in the use of nature over time (Zandebasiri & Pourhashemi 2018). Hence, in the theory of ecological–economic systems, ecosystems are referred to as natural capital; however, it must be stated that natural capital cannot be a direct and the sole factor in achieving sustainable human well-being (Fig. 5).

According to Fig. 5, natural capital does not directly affect sustainable human well-being and can lead to sustainable human well-being by the provision of ecosystem services and interaction of these services with human, artificial, and social capital (Costanza et al. 2014). To explain the relevant concepts, it is necessary to describe the types of capital in this section. Natural capital, actual or produced capital, human capital, and social or cultural capital are all examples of capital. Natural capital refers to capital that does not require human intervention. The natural ecosystems that supply services are mentioned to natural capital. The term

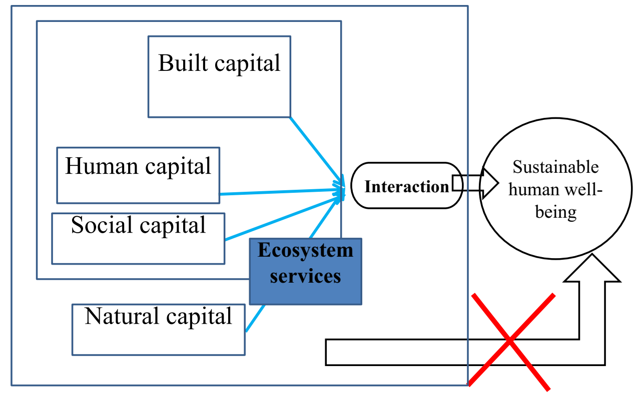


Fig. 5 The relationship between types of capital and human well-being. Costanza et al. (2014)

capital refers to the flow of services through time as well as

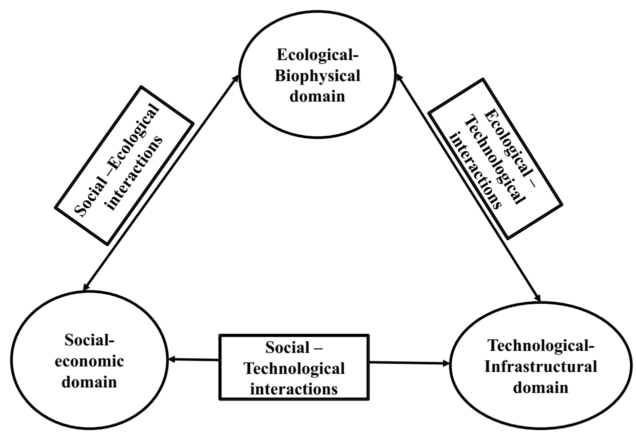


Fig. 6 Social–ecological–technological systems and their interactions. *Summarized from* McPhearson et al. (2022)

the combination of human economic and ecological components. In this regard (i.e., combining human economy with ecological dimensions), a great understanding of sustainable human well-being is found (Fig. 5). Natural capital is related to three other forms of capital including (1) capital made, (2) human, and (3) social capital consists of construct capital (Costanza et al. 2014, 2017). McPhearson et al. (2022) also use socio-ecological systems to represent capital systems. Social–ecological–technological systems are one of the key models for displaying communications and interactions in ecosystems. Based on this model, three main categories of communication are ecological, socio-economic, and technological dimensions (Fig. 6).

Figure 6 depicts the conceptual framework for social–ecological–technological systems. The social–ecological–technological systems overview structure focuses on the connections between a complex system's social, ecological, and technical elements (McPhearson et al. 2022). Interactions between these aspects underpin this complicated system.

Methodology

This study aims to categorize various ideas and makes generalizations about both classical and contemporary concepts for academics who plan to do research in many sectors of ecosystem services, particularly the economic value of ecosystem services. This study was an extension of the resource review section of a research project in a protected area in Iran, which reviewed the resources of various classical and modern valuation models in valuing ecosystem services. The review system in this paper is to expand and supplement information in different branches of definitions and concepts of ecosystem services and to review new concepts in the valuation of these ecosystem services. For the purposes of classifications related to ecosystem service valuations, the study has encountered two categories of divisions: (1) ecosystem services and (2) the valuation of ecosystem services. This study seeks to outline the concepts and ideas of the ecosystem services sector in a general way. Therefore, in the ecosystem services sector, more basic sources were discussed. However, in the valuation section, more focus was directed toward new topics that can provide an information package of new contents for the readers.

Figure 7 introduces the general situation in the investigations to provide the necessary divisions in this study. In order to have a systemic thinking in each subject, the concepts of open systems were presented for use in both ecosystem services sector and their valuation sector in such a way that the inputs and outputs of each of the theories proposed by the previous experts were examined. Summarizing these

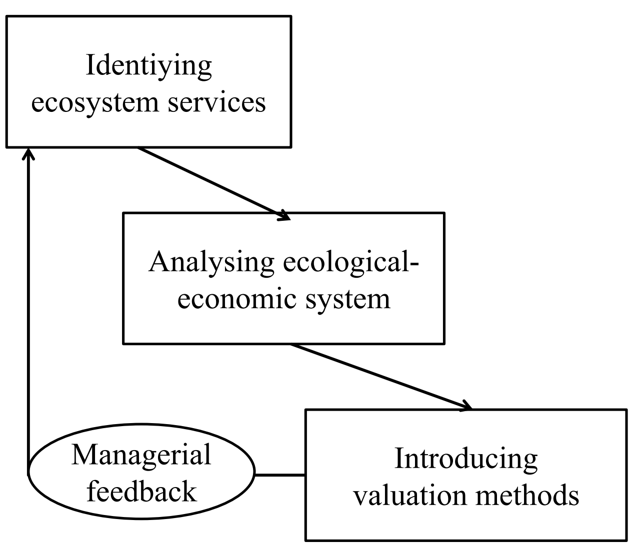


Fig. 7 Systematic way in showing different categorization from different sources. *Research findings*

processes in order to have managerial feedback is the last step, as presented in Fig. 7.

In this study, a kind of snowball sampling, similar to what is done in social studies (Iranmanesh et al. 2022), was used. While information saturation is important in the snowball sampling, here, it does not mean that it is not possible to add new topics by reading the next articles. Rather, it means that after reading the articles related to the sources of this study, it is possible to summarize and infer the contents to compile valuing method topics. In the field of valuing ecosystem services, it was provided, and the readers of the text will be able to examine and draw conclusions from new concepts, methods, and topics.

The design of this paper was based on compiling articles relating to the ideas and categories linked to ecosystem services and their valuation techniques in order to provide material about ecosystem services and their valuation methods. The aim was to utilize more resources from the previous five years. The information in this page was compiled from papers that discussed valuation principles and techniques, particularly fresh approaches to ecosystem service value, although some basic sources from more distant years were also explored, such as Potschin and Haines-Young (2011) and Costanza et al. (2014).

In order to gather information for this review paper, sources pertaining to the value of ecosystem services were subjected to content analysis, topic division, and content categorization. This led to the description of the traditional techniques of ecosystem service valuation in the method section ("System theory"). In the second step, new issues and methods in the valuation of ecosystem services were determined and explained in the section for new findings ("Methodology"). Accordingly, in this study, classical methods were identified first.

General frameworks in valuing ecosystem services

The avoided cost approach, the replacement cost method, the factor income method, trip cost, hedonic pricing, and contingent valuation are examples of traditional valuation techniques. The fundamental value transfer approach, deliberate ecosystem service valuation, pricing of climate change risks, and subsequent effect on ecosystem services are examples of new valuation methodologies. Other classifications separate stated preferences techniques and revealed preference methods for valuation approaches (for non-market services). Contrary to revealed preferences techniques, which rely on the market demand curve, stated preference methods rely on the compensated demand curve. In order to investigate the appropriate methods to value ecosystem services, various sources of valuing ecosystem services, including those proposed by Farber et al. (2006) (Table 1) and Ling et al. (2018) (Table 2), were studied (Tables 2, 3, and 4). In this

Table 1 Conventional economic valuation methods

Stated-preferences	Assessment methods
Contingent valuation	Individual index-based methods
Conjoint analysis	Rating or ranking
Cost-based approaches	Choice models
Replacement cost	Expert opinion
Avoidance cost	Group-based methods
Revealed-preference approaches	Voting mechanisms
Travel cost	Focus groups
Market methods	Citizen juries
Hedonic methods	Stakeholder analysis
Production approaches	

Farber et al. (2006)

regard, some researchers have identified appropriate valuation methods for each ecosystem service separately. In this regard, Farber et al. (2006) presented the most appropriate method for valuation (Table 3).

Classical valuation of ecosystem services

According to economic and ecological concepts, six main methods for valuation have been developed (Farber et al., 2022).

Avoided cost method

This method estimates economic values in a situation that ecosystem services prevent damages caused by loss of

Table 2 Classifying valuation methods of ecosystem services

Market-based	Cost-based	Production-based	Revealed preference
Market prices	Avoided cost	Bio-economic modeling	Hedonic pricing
Substitute goods	Conversion cost	Factor income or production function	Averting behavior
Net price method	Damage cost	Stated preference	Public investments
Existing knowledge	Mitigation cost	Choice modeling	Travel cost method
Delphi approach	Opportunity cost	Contingent ranking	Other non-monetary
Benefits transfer	Replacement cost	Contingent valuation method	Deliberative
	Restoration cost	Participatory or deliberative valuation	Qualitative
			Quantitative

Modified from Ling et al. (2018)

Table 3 The most appropriate method for the valuation of ecosystem services*

Ecosystem services	Method	Ecosystem services	Method	Ecosystem services	Method
Gas regulation	Contingent valuation, avoided cost, replacement cost	Waste regulation	Replacement cost, avoided cost, contingent valuation	Medicinal resources	Avoided cost, replacement cost, production approach
Climate regulation	Contingent valuation	Nutrient regulation	Avoided cost, contingent valuation	Ornamental resources	Avoided cost, replacement cost, hedonic pricing
Disturbance regulation	Avoided cost	Water supply	Avoided cost, replacement cost, Market pricing, travel cost	Recreation	Ttravel cost, contingent valuation, ranking
Biological regulation	Avoided cost, production approach	Food	Market pricing, production approach	Aesthetics	hedonic pricing, contingent valuation, Travel cost, Ranking
Water regulation	Market pricing, avoided cost, replacement cost, hedonic pricing, production approach, contingent valuation	Raw materials	Market pricing, production approach	Science and education	Ranking
Soil retention	Avoided cost, replacement cost, hedonic pricing	Genetic resources	Market pricing, avoided cost	Spiritual and historic	Contingent valuation, ranking

Farber et al. (2006)

Table 4 Norms for valuing ecosystem services in the state of New Mexico in the United States of America (Table 4a), in the Nagarhole national park, Rajiv Gandi in India (Table 4b), and in the Oku Aizu region (a forest reserve in Japan) (Table 4c)

(a) The state of New Mexico in the United States of America	
Ecosystem	Norms
Rangeland health	(1) Stated preferences methods, (2) contingent valuation method, and (3) hedonic pricing and integration with geographic information systems
Livestock production	(1) Production of domestic livestock and (2) evaluation before treatment and after treatment
Wildlife benefits	(1) Travel cost and (2) value of habitat improvement
Watershed benefits	Predicting and estimating social values
Carbon sequestration	Market-based approach in increasing soil water retention
Reducing fire hazard	(1) Cost of fire suppression, (2) cost of post-fire restoration, and (3) effect of management actions and saleable production
Source for Table 4 (a): Torrel et al. (2014)	
(b) The Nagarhole National Park, Rajiv Gandi in India	
Water conservation	(1) Alternate cost and (2) replacing the economic cost of water storage after estimating protected water
Soil conservation	(1) Hedonic pricing, (2) opportunity cost method, (3) depreciation of land due to depletion of nutrient value and soil quality, and (4) preventing reduced fertility of forest lands due to erosion
Carbon sequestration	Estimation of carbon fixed in the ecosystem multiplication in marginal social damage cost
Source for Table 4 (b): Ninan & Kontoloen (2016)	
(c) The Oku Aizu region (a forest reserve in Japan)	
Water conservation	Alternate cost
Soil protection	Hedonic pricing
Carbon fixation	(1) Market price and (2) damage cost
Nutrient cycling	(1) Alternate cost and (2) market price
Water purification	Alternate cost
Air pollution absorption	Alternate cost
Recreation	Willingness to pay
Source for Table 4 (c): Ninan and Kontoloen (2013)	

service (ELD Initiative 2019). In the avoided cost method, it is emphasized that in the absenteeism of some services, damage will be incurred. The value of avoiding these damages is in fact the value of ecosystem services. For sample, flood control by forest ecosystems prevents health costs and waste treatment. In the cost avoidance theory, the value of these costs is actually the value of flood control (Farber et al. 2002).

Replacement cost method

The cost of supplying replacements for an ecosystem or its services is used as an examination of the worth of the ecosystem services in this technique (Farber et al. 2002). The expenses involved with erecting industrial carbon dioxide absorption centers around polluting facilities, for example, are used to determine the utility of carbon dioxide uptake in rangeland ecosystems. In other words, if we want to estimate the value of oxygen production in a forest or rangeland ecosystem, we can calculate how expensive a certain amount of oxygen is in industrial oxygen production devices. Then, we can introduce this cost as an alternative cost for oxygen production and, in fact, as the service value of oxygen production (Amirnejad & Ataei Solout 2017).

Factor income method

This method means that ecosystem services can increase income in different segments of society. This increase in revenue is due to ecosystem services and some of the values of these services. For example, when the quality of water from ecosystems increases, fisheries and fishing thrive, leading to an increase in fishermen's income. This increase in revenue is the ecosystem value of water quality (Farber et al. 2002).

Travel cost

The travel cost method (TCM) is based on the theory of demand and assumes that the demand for a recreational place is inversely related to travel expenses that a particular visitor has to face to enjoy it. To apply the TCM to users, data about tourists is needed (Torres-Ortega et al. 2018). Furthermore, this method needs data on demand for some ecosystem services such as landscaping, tourism, and leisure services. The costs of this demand (trip) reflect the implicit value of ecosystem services. The value of willingness to pay to travel to an area is the value of the services of an ecosystem, which attracts visitors from afar (Farber et al. 2002).

Hedonic pricing

According to the theory of this method, the value of each ecosystem/land affects the value of assets that are adjacent to it (Martinez-Jimenez et al. 2017). Demand for associated goods can reflect the prices that people are willing to pay for services. For example, the price of a house on the coast is higher than the price of a house in a city, which indicates the difference between the price of the value of ecosystem services and the pleasures of ecosystem services (Farber et al. 2002).

Contingent valuation

Contingent valuation is a set of methods that are done through scenario-making and examining different conditions (Mashayekhi et al. 2018). In other words, service demand may consider hypothetical scenarios which include some option values. For example, people are willing to increase their willingness to pay by fishing or picking deer bags in the forests of Europe. In this situation, the scenarios of the value of tourism with or without fishing can be examined separately (Farber et al. 2002).

Division of valuation methods into stated preferences and revealed preferences

Due to the wide range of topics in valuation methods, there are many classifications in this field, such as the division of non-market service valuation to stated preferences methods and revealed preference methods. Stated preferences methods apply people's preferences for goods and services using the behavior of individuals in a hypothetical situation; however, in revealed preference methods, market demand is used to determine values. Thus, the possibility of using revealed preference methods in valuing ecosystem services seems more limited. Stated preferences methods, unlike revealed preference methods which depend on the market demand curve, depend on the compensated demand curve. Thus, the stated preferences methods are more used in valuing ecosystem services. The contingent valuation method and the choice experiment method are two examples of stated preference methods. These methods rely on the random utility model. The contingent valuation method is based on the values that communities place on changing the environment, while the choice experiment method takes into account the value that people place on each feature of the environment (Mashayekhi et al. 2018). When prices are not available, stated preference methods on answering surveyed questions can be a good tool for economic valuation. In this method, questions about monetary amounts, choices, ratings, and preferences were presented (Torrel et al. 2014).

In the choice experiment method, after specifying the problem under study and describing the features, the design of the selection test is performed, in which the final option is presented to the respondents. In the choice experiment method, the basic assumption in economics was applied that people make choices most desirable to them. In selection theories in economics, desirability is a function of fluctuations and changes because of the tastes and perceptions of individuals. For example, the choice experiment method can be used to calculate willingness to pay (Sharzei & Majed 2015). The choice experiment method is a survey-based method in which individuals are asked to choose between policy scenarios in a series of choices. Each decision set is characterized by qualities with distinct ecosystem services offered by the ecosystem, and levels are determined for each attribute in each political scenario. Characteristics and ecosystem services are the same, and levels are the number of predicted levels for characteristics. The Ngene program is used to select the experiment technique. In the choice experiment method, the willingness to pay is used for economic valuation. The willingness to pay is the maximum price at which or below which people definitely buy a unit of that product (Bernue ́s et al. 2014). The choice experiment method, due to the simplicity of polling and surveying opinions, can also be used to examine the importance and preferences of local communities (Alphayo et al. 2020).

Norms to estimate valuing ecosystem services

Valuation norms refer to methods that can provide the closest estimate of the value of a particular ecosystem service. Norms reflect working methods that in some cases are based on previous protocols and in some studies are based on ecosystem conditions. In this section, some of the norms presented in previous articles are briefly presented in Table 4a, b, and c.

New methods for valuing ecosystem services

Since valuing classical methods of ecosystem services usually requires a lot of time and money, today, researchers are less inclined to use classical methods (and more for case studies) by developing some methods. These methods provide usability for larger areas at a lower cost and shorter time, known as modern valuation methods, which are more common for macro-level ecosystems. Examples for these macro-level ecosystems are forest ecosystems or rangeland ecosystems which are introduced in a country, continent and etc. In new valuation methods, the transfer of benefits/values takes place. A description of this issue is provided in the following sections (Sangha et al. 2017; Sanches et al. 2021). In the new theories of valuation of ecosystem services, many other topics such as ecological–economic systems, risks related to climate change, and the issues related to participatory management are also discussed, which are presented in detail in "Methodology."

Results

Categorization of ecosystem services

Identifying each of the dimensions of social–ecological–technological systems (Fig. 4) requires identifying different parts of the ecosystem and their interactions with each other. Different researchers have proposed different classifications for ecosystem services. Potschin and Haines-Young (2011) have divided ecosystem services into three categories. Table 1 introduces these three categories including (1) provisioning, (2) cultural, and (3) regulation and maintenance services (Table 5).

As mentioned in Table 5, the division of services into three categories (i.e., provisioning, cultural, and regulation and maintenance) is one of the divisions related to ecosystem services. In this category, provisioning services include food supply materials and energy, cultural services include symbolic, intellectual, and experiential services, and regulation and maintenance services include different mediations such as mediation of waste, flows (mass, liquid, and gaseous), toxics, and other nuisances (Potschin & Haines-Young 2011). For a better understanding of the terms in this section, the means of the terms are described in the following. Mediation means adjusting or reducing the pressures. This regulation is done either by living organisms (mediation by biota), that is by microorganisms, plants, and animals, or by ecosystems (mediation by ecosystems), which is diluted by atmosphere as well as accumulation is used by ecosystems (e.g., carbon

Table 5 A classification for ecosystem services

Theme	Class	Group
Provisioning		
	Nutrition	Terrestrial plants and foodstuffs
		Freshwater and animal foodstuffs
		Marine plant and animal foodstuffs
		Potable water
	Materials	Biotic materials
		Abiotic materials
	Energy	Renewable biofuels
Renewable abiotic energy sources		
Cultural		
	Symbolic	Aesthetics, heritage
		Religious and spiritual
	Intellectual and experiential	Recreation, community activities
		Information and knowledge
Regulation and maintenance		
	Regulation of waste	Bioremediation
		Dilution and sequestration
	Flow regulation	Air flow regulation
		Water flow regulation
		Mass flow regulation
	Regulation of physical environment	Atmospheric regulation
		Water quality regulation
		Pedogenesis and soil quality regulation
	Regulation of biotic environment	Life cycle maintenance, habitat protection
		Pests and disease control
		Gen pool protection

Potschin & Haines-Young (2011)

sequestration, dilution of fresh water and aquatic ecosystems and modulating the effects of inhalation). Maintenance refers to the maintenance of habitat conditions such as maintaining the balance of living organisms and maintaining the balance of oxygen. Maintenance can take 5 different forms: (1) maintenance of the life cycle and habitat and support of genetic storage, (2) pest and disease control, (3) soil formation and recording of soil composition and structure, (4) maintenance of water conditions, and (5) maintaining the composition and structure of the atmosphere and regulating the climate (Haines-Young and Potschin 2014).

In another division, some researchers (e.g., Strenger et al. 2009; Costanza et al. 2017) categorized ecosystem services into four sections: (1) provisioning, (2) regulating, (3) cultural services, and (4) supporting and habitat services. Figure 5 shows these four categories of services. Production of food and wood from forest ecosystems are examples of provisioning services, flood control, and water regulation are examples of regulating and habitat services, recreation, landscaping, and education are benefits of cultural services, and support services include support for food cycles and habitat provision (Strenger et al. 2009).

Figure 8 depicts the categorization of ecosystem services as provisioning, regulatory, cultural, and support services. It goes without saying that depending on the biological and socio-economic conditions, each ecosystem may provide some or all of these functions. Also, it may not provide some services at all, which depends on the ecosystem and habitat conditions. Richter et al. (2021) have used the ES indicator conversion framework in order to specify ecosystem services. In this research, each indicator could be the source of one or more ES. For example, high plant diversity can be the source of some ecosystem services including nursery population and habitats, as well as educational and existence services according to CICES

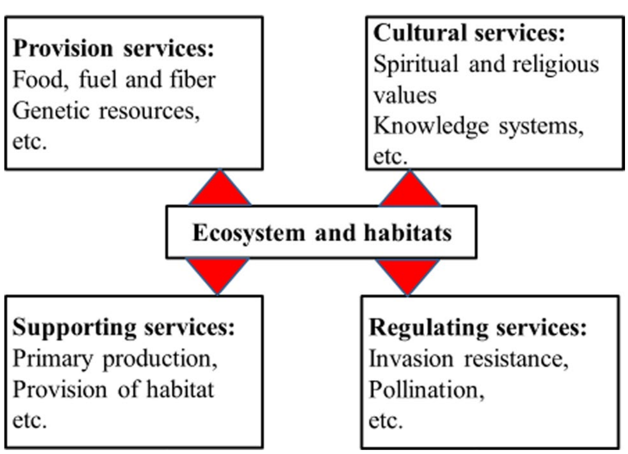


Fig. 8 Classifying ecosystem services into four categories. *Summarized from* DEWHA (2009)

5.1. framework. Given that each service can have separate values, the total economic value (TEV) index is defined to calculate their total value. All the values collected by a particular ecosystem constitute the TEV for the whole ecosystem (Bernue´s et al. 2014). Melvani et al. (2022) classified TEV based on use and non-use values (Fig. 9).

In Fig. 9, indirect use includes environmental services, option values include biological assets, bequest is related to land, and intrinsic values includes tranquility, contentment, and pride. Furthermore, consumptive values include food, timber, fuelwood, and other consumptive cases for people. In addition, the aesthetic value of land is an example of the non-consumptive category (Melvani et al. 2022).

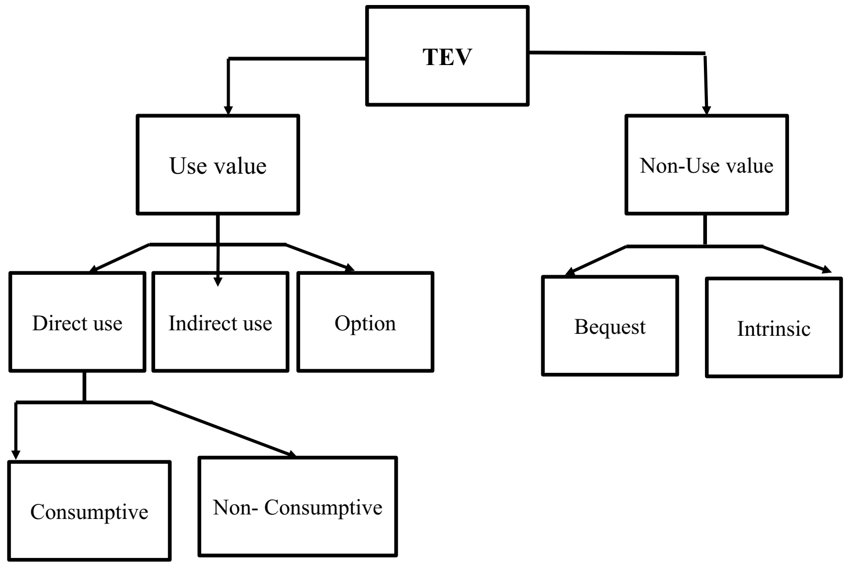
Sub-systems for ecosystem services and issue of valuing ecosystem services

In this section, five theories related to the latest issues of new methods for valuing ecosystem services are proposed, including the ecological economic system theory, the basic value transfer method, the deliberative ecosystem service valuation, valuation in climate change risks, subsequent influence on ecosystem services, and valuing ecosystem disservices. The cascade model presented in Fig. 5 has come under several criticisms (Costanza et al. 2017): 1) the cascade model is an oversimplification of a complex reality in the communication between ecosystem services and different capitals; 2) the distinction between benefit and values is very difficult to discern and limited, and some concepts and unnecessary side effects have been reported for these concepts; 3) the relationship between the factors and concepts of ecosystem services is considered linear and simple. In fact, the relationship between these factors is nonlinear and dynamic; and 4) In this model, interests are things that human beings are willing to value. This model discusses more conventional economics.

In the conventional economic model, the values that are perceived by people and people are willing to pay for them are discussed (Costanza et al. 2017; Turner et al. 2021). Hence,the benefits that communities are not willing to pay for them are less discussed. To solve this problem, Costanza et al. (2017) presented a model based on different types of capitals including built, human, and social capital (Fig. 10). According to Fig. 10, ecological–economic systems were used instead of cascade model and presented a macro-model in an ecological–economic system for ecosystem services by using the three types of social, built, and human capital.

As shown in Fig. 10, the effectiveness of ecological factors such as water, nutrients, and biomass in the economy has been shown on the left side, and the three capitals (i.e., social, built, and human capital) of ecosystem issues have been shown on the right side. Sub-systems are different parts of a macro-system (original system), which can be

Fig. 9 Classification of TEV according to use value and non-use value. *Summarized from Melvani* et al. *(2022) and originally published by Pascual* et al. *(2010)*



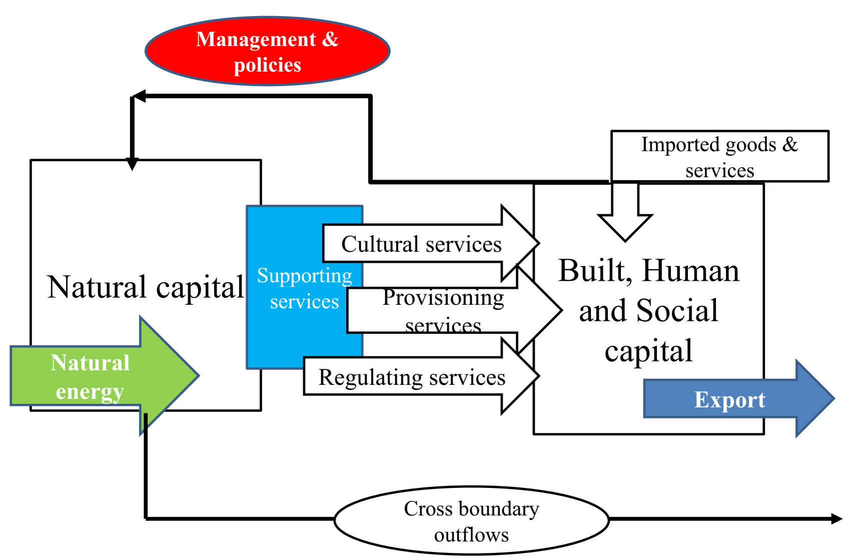
considered as a system, and their internal connections flow to achieve a specific goal (Danehkar & Zandebasiri 2020).

Ecological–economic sub-systems

Ecological–economic systems are complex systems, and their decomposition into sub-systems (including natural sub-systems, economic sub-systems, social sub-systems, and other inside sub-systems), leads to more knowledge of these complex systems. This decomposition helps managers and planners to identify the components of ecological-economics in a variety of social, cultural, and economic environments with more relevant and practical connections (Danehkar & Zandebasiri 2020). The model in Fig. 10 can be presented for different ecosystems. If for a protected area is presumed the problem of cattle grazing and cold climate, three sub-systems are defined including natural capital sub-system, ecosystem services' sub-system, and valuing ecosystem services' sub-system. The first system in this framework is the ecosystem, and it is defined as an open system for its various inputs and outputs (e.g., climate inputs and services' outputs). The next sub-system is ecosystem services, and finally, the third sub-system is ecosystem service valuation sub-system which is defined for completing the ecological economic system that complements the previous two sub-systems. With regard to these sub-systems, Fig. 11a shows an open system for the natural capital sub-system.

The model of natural capital is an open system, and it should be noted that in ecological environment inputs, a very important attribute is the data related to the region's climate, cold, snow, and rain at the input of the system, which makes the climatic conditions of the ecosystem unique. Based on

Fig. 10 Ecosystem services in an ecological economic system. *Summarized from* Costanza et al. (2017)



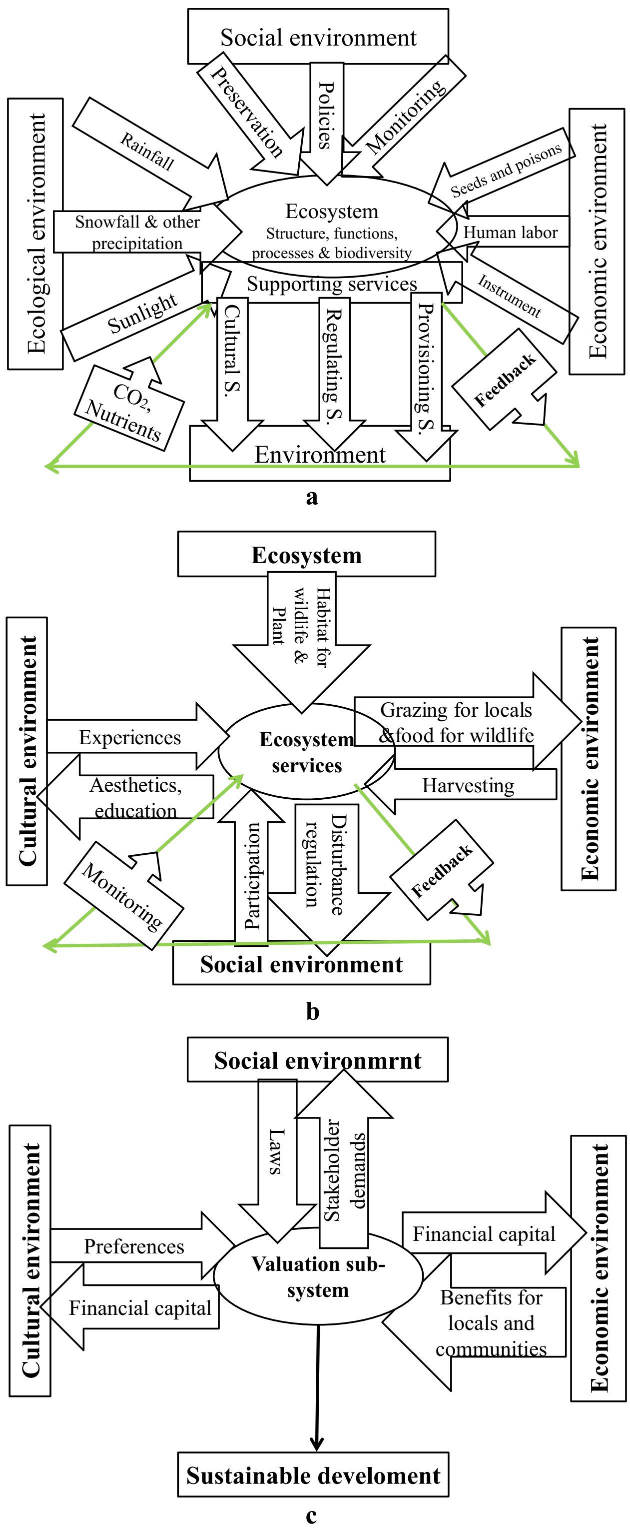


Fig. 11 **A** System model for the natural capital sub-system. **b** System model for ecosystem services' sub-system. **c** Sub-system model for valuing ecosystem services. *Findings of the research for presenting a sub-system based on* Costanza et al. (2017) *model for capitals in ecological economic systems*

Fig. 11b, in social environment inputs, this system definitely needs to be monitored in order to be able to maintain plant and animal diversity in addition to providing services. Figure 11c shows a sub-system model for valuing ecosystem services as another sub-system for ecological–economic sub-systems. The issues of socio-ecological systems are very important; however, social and environmental drivers and interactions at different times are also very important. In this context, there is a need to separate issues, especially in cultural ecosystem services, for individuals, groups, communities, and society (Small et al. 2017).

Combining classical methods with modern topics and current research

Tyllianakis et al. (2019) employed the avoided cost technique to value information in the British Virgin Islands. In order to value these ecosystems as sensitive and significant, they applied the cost–benefit analysis approach. The averted costs to society and government expenditures arising from the effects of carbon in the atmosphere were used by the researchers for the benefits section. Furthermore, Jackson et al. (2014) employed the replacement cost technique to analyze and manage the implications of water resource development on indigenous customary economies in three significant river systems in northern Australia. To quantify such distinction with cash income, they present the replacement values as a "per household, per fortnight" number.

Byrne et al. (2020) in Inner Mongolia, China, investigated income methods in a novel approach, combining them with the notion of payments for ecosystem services. They estimated grassland preservation subsidy payments regarding livestock herders, using factor income. Juutinen et al., (2022) investigated the trip cost approach for four countries of Norway, Denmark, Finland, and Sweden. The study presented close-to-home visits and trips connected to nature-based tourism based on data collected on one-day or fewer visits and longer-than-one-day visits. Czembrowski and Kronenberg (2016) used hedonic pricing and variables such as price, living area, and number of rooms for using space types and sizes in Lodz, a city in central Poland. Ndebele and Forgie (2017) used contingent valuation by estimating the economic benefits of a wetland restoration plan in New Zealand based on the output of a pilot research and using focus group.

According to Azadi et al. (2021), preference methods include contingent valuation method, conjoint analysis, and factor income methods. Also, revealed preference methods include market price method, productivity method, hedonic pricing method, and travel cost method. Accordingly, Van Houtven et al. (2014) used the combination of expert extraction and stated a preference for new models in valuing ecosystem services for lake water quality in the southeastern US. In the same direction, the study of Liebelt et al. (2018) can be a source for another hedonic pricing as well as revealed preference method.

Basic value transfer method

This method tries to use previous studies such as global studies or extensive databases to value ecosystem services. Global inflation rates for certain study years are added to this method. In addition to using databases, some topics native to an area may be added to the data stream for these studies. In fire management costs, weed management, road construction costs, canopies, and other factors affecting fire, this method is used for valuation in many situations where researchers intend to conduct a meta-analysis on a wide range of topics in large global ecosystems. In some other studies, this equivalent method or benefit transfer method is used. In these methods, due to various time constraints, costs, and available resources, pre-existing studies in one or more habitats should be used for valuation (Sangha et al. 2017; Sanchez et al. 2021).

Deliberative ecosystem service valuation

Evaluating ecosystem services individually cannot accurately determine willingness for paying ecosystem services. Concerning this issue, an agreed framework for valuing ecosystem services could assess ecosystem services continuously. For this agreed framework, the people who value, the stakeholders, and the beneficiaries of the valuation issue are very important (Maynard et al. 2015). Deliberative valuation can cover a variety of values for communities. Furthermore, interactive processes that require values to be discussed, talked about, and shared with others are better considered in deliberative valuation. Two issues are very important in deliberative valuation including (1) learning and (2) participants (Saarikoski et al., 2021). Deliberative valuation can be a combination of choice experiment and participatory multi-criteria decision-making. One of the main criticisms of deliberative valuation is involving only a limited number of participants in the problem. Therefore, the results are more related to the same group dynamics and randomness. Hence, it is essential to pay special notice to the issue of valuing ecosystem service using this method. Deliberative valuation has been founded on theories of democracy, which maintains collective decisions to discuss personal interests instead (Saarikoski et al., 2021). In the field of deliberative valuation, one of the important issues is collecting the opinions of local communities. Local people have a very good understanding of ecosystem services. In some situations, ecosystem managers try to reduce community interference and local community use of ecosystems due to conservation issues (Zandebasiri et al. 2017, 2020). Traditional conservation, the relationships between the customary rules, and indigenous beliefs with local people's perception of ecosystem service are among the important issues in ecosystem services related to local communities and participatory ecosystem management (Hassen et al. 2023).

Since local communities' uses of ecosystems can include livestock grazing, using non-timber crops, and planting undergrowth in the ecosystem (Zandebasiri et al. 2021), it may be thought that people can no longer have an understanding of ecosystem services in ecosystem protection programs. However, recent research results in conservation programs have shown that about 73% of locals have a good understanding of ecosystem services. In particular, 68% of local communities have a good understanding of cultural services, and 66% have a good understanding of tourist-related services in conservation programs (Liu et al. 2022). Recent studies in logged tropical forests have also shown that clean water and air, as well as temperature regulating, flood, and erosion are the most important factors in the field of ecosystem services from the viewpoint of local communities (Lefeuvreet al., 2022). Therefore, with this high understanding of the local communities, which has been reported in the study of ecosystem services, it is necessary to seek their opinions on the valuation of ecosystem services, especially in deliberative valuation methods.

Valuation of climate change risks

Recently, some researchers have proposed the economic valuation of climate change risks due to the importance of climate change issues. This model is shown in Fig. 12. Based on the model proposed in Fig. 12, the climate change model with two factors (i.e., damage function and abatement function) is associated with the economic growth model (Rising et al. 2022).

This model has two separate sections including abatement function and damage function. Abatement function presents output into emission reduction, and damage function presents temperature into economic impacts. In the end of the model, the economic growth model could be affected by fundamental economic assumptions about key variables such as welfare metrics, general equilibrium, utility functions, and discounting. Reducing the damage costs, non-marginal costs, and the impact on growth rate of economic output are such future studies (Rising et al. 2022).

Subsequent influence on ecosystem services

This method uses the effects of one ecosystem function or service on another ecosystem service. Finally, the economic value of all services that are affected by an ecosystem service is expressed as its economic value. For example,

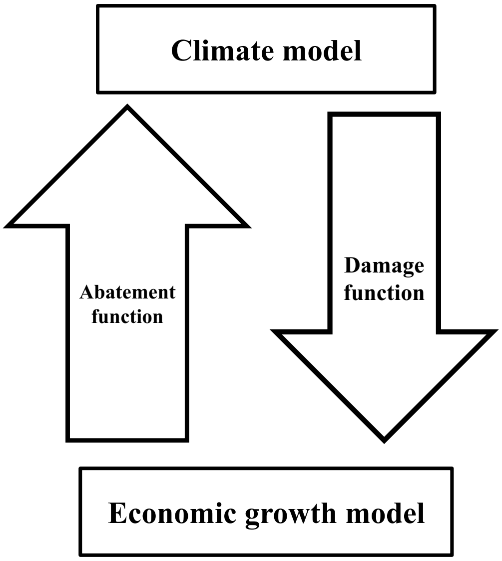


Fig. 12 Economic valuation of climate change risks. *Summarized from Rising* et al. (2022)

this method can be used to calculate the economic value of earthworms. Earthworms can affect different aspects of the ecosystem and, in turn, create several ecosystem services. Provision of food quantity, provision of support for animals, flood mitigation, recycling animal excreta (waste), and carbon storage and greenhouse gas regulation are examples of these services that are created by earthworms. Such a method is more useful for ecological valuation, where each ecological service can be the source of several other services, and in this method, the contributions of an ecosystem service to economic evaluation are considered. In such situations, there is usually a set of ecological constraints on valuation because not all services affected by a service can be provided to the economic figure, and in some cases, there are restrictions on the valuation of some of them (Schon & Dominati 2020). Also, some ecological functions may have diverse values (McPhearson et al. 2022), and all aspects of their subjects are not identified correctly.

Valuing ecosystem disservices

The disservice valuation method is the approach of valuing damages for disservices. In this approach, losses (from ecosystem disservices) are estimated and added to the negative number in the ESV calculations. In the calculations related to the ESV, it is necessary to introduce the concept of ecosystem disservices and estimate negative value ecosystem disservices. Cases such as the presence of Asian elephants on agricultural land or wildlife damage to coffee growers reported in India are examples of ecosystem disservices (Ninan & Kontoloen, 2016). Items that are ecosystem disservices, if left unmanaged, can reduce production, efficiency, or quality of ecosystem performance. Herd-Hoare and Shackleton (2020) studied ecosystem disservices. They categorized crop pests as invertebrate pests, birds, monkeys, moles, and weeds and defined pre-emptive and reactive activities for each of them. Different methods can be introduced to value ecosystem disservices. The average payment of ecosystem managers (per year) for damage caused by wildlife, as well as damage for their products, as the compensation for local communities is one of the methods of valuing ecosystem disservices (Ninan & Kontoloen, 2016). In the case of forest fires, one of the issues that needs to be estimated is the cost of carbon emissions which can cause health hazards to human health and ecosystems. Previous studies show that 75% of the local community did not fill out the compensation form because the cost of their damage was much higher than what the ecosystem managers intended to pay them. Those who received the compensation also stated that they were paid less than 10% of the actual damages (Ninan & Kontoloen, 2016).

Valuing ecosystem services and issues related to pollution

Valuing ecosystem damage caused by environmental pollution is basically a social and economic issue (Zhai et al. 2022). However, a large proportion of studies (e.g., Rolón et al. 2022) in this field have been devoted to ecological issues. In this part, the issue of willingness to pay becomes more meaningful for the people of the society. People are willing to pay for health improvement, and this money can be used to improve their health in line with reduction in air pollution. As shown in Fig. 13, the chain from the ecosystem to valuation is considered linearly (mostly due to the simplification of the model), and in the lower part, parallel to that, the topic of pollution reduction and its place in this chain is presented. Based on this, pollution reduction can be designed as a kind of service in parallel with the "goods and services" part. Also, the willingness to pay will be designed in parallel with the valuing section.

Pollutants can enter an environment and cause it to become unstable, unbalanced, damaged, or uncomfortable for living things. Emissions from human activities (direct or indirect) are discharged into natural waters and lead to the pollution of river basins for agriculture, natural resources, and industry. This issue challenges the functions and services of the ecosystems. With regard to these issues, causes, effects, and control of pollutants are described by Goel (2006). Chemical pollution impacts the quality of water systems as well as the ecosystem services of the ecosystems. Valuing ecosystem services has become a suitable tool for investigating sustainable development. However, the impact of pollution on ecosystem services is rarely measured. Wang et al. (2021) discussed the effects of chemical exposures

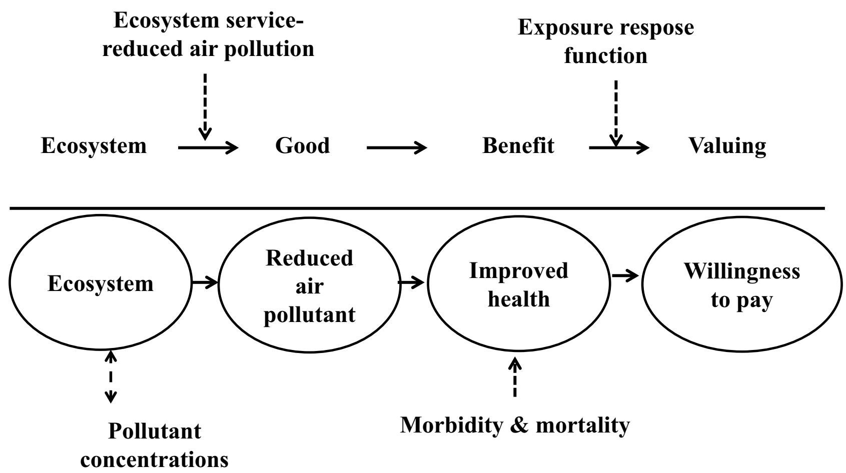


Fig. 13 Linking the chain from ecosystem to valuation with pollution reduction. *Summarized from Jones* et al. (2017)

on ecosystem values. They explored how to estimate the economic benefits of mussels' filtration service in relation to chemical exposure. Their study investigated chemical pollution, which can contribute to the production of mussels' filtration functions. They conclude the economic value of mussel filtration functions under chemical exposure. They applied the bootstrapping method to calculate the filtration volume of dreissenid mussels that were exposed to metal mixtures in the Netherlands. The study presents a novel approach to quantify the economic valuing of mussel filtration associated with chemical pollution.

The subject of the need for a systemic approach in ecosystem services was presented earlier (see "Introduction"). This attitude becomes more noticeable in different ecosystems and its connection with ecosystem services. Aquatic ecosystem programs are related to forest ecosystems because both the aquatic and forest ecosystems of an area can be sub-systems of a larger ecosystem such as a larger watershed. The increase in runoff in the deforested lands can lead to an increase in the concentration of hazardous elements for fishes in aquatic ecosystems, and this issue also endangers the health of humans when consuming fish. The results of Rolón et al. (2022) founded the necessity of reducing the entry of pollutants into streams with special attention to reducing runoff in deforested areas. In this context, Van Opstal et al. (2022) reported the increase in pollution due to improper land use changes. The findings of this study demonstrated how changes in land use have impacted the health of aquatic ecosystems and destroyed key ecosystem services. The increase in the area of agricultural land and the decrease in forest land cause the increase the use of herbicides, insecticides, and fungicides in surface water. In this way, instead of discussing agriculture ecosystems, it is necessary to simultaneously investigate the relationship between agriculture, forest, and aquatic ecosystems in a shared macro-ecosystem. However, these studies can only describe the impact of pollutants on the ecosystems or evaluate the number of heavy metals released in the ecosystems. In addition to this, the important issue is the economic valuation of pollutants on the ecosystems. In other words, it becomes clearer that the entry of these waters into ecosystems (e.g., the rivers, forests, and other ecosystems) in terms of economic values in ecosystem services. This issue can be checked out by valuing ecosystem disservices (such as those in Sect. 3.6 in this article) or the value transfer method for valuing the effect of pollution on ecosystem services. Defining the affected pollution, identifying and selecting economic valuation evidence, and transferring evidence and estimating the value of the policy good are considered parts of this method (Jones et al. 2012). Very recently, Zhai et al. (2022) have shown that in the economic valuation related to damage and pollution affecting ecosystems, the largest share of total loss was related to the cost of ecological restoration (85.6%), emergency disposal (11.2%), and finally loss of ecosystem services (3.2%). Despite this high importance, it seems necessary to conduct more research on the topic of ecological restoration in different ecosystems and different sources of pollution in ecosystems.

Conclusion

Determining the values of ecosystem services has several basic advantages including providing numbers and quantities instead of merely quality issues, specifying importance, assisting managers in decision-making processes, and prioritizing, and even budgeting for ecosystem services can be in terms of values and related numbers. In this study, a review of both classic and modern research literature was done on the valuation of ecosystem services. This study has several results; the most important of which are as follows: (1) valuation is a topic that is necessary in the cycle of studies related to ecosystem services at the end of the cycle. If studies on this loop are not done, some services, especially non-market services, may be compromised in decision-making processes, and their place in the decisions may not be properly exercised. (2) The correct classification of ecosystem services and the identification of appropriate valuation methods and models for each ecosystem help to determine the correct values and their place in decision-making processes. (3) Ecological-related services and their issues have several challenges for valuation, and the correct identification of each of the ecological relationships and processes and their effects on the ecosystem is the beginning of the valuation discussion on this category of ecosystem services. (4) The issue of ecosystem disservices also needs to be included in the valuations, and preventive measures, as well as appropriate responses, should be provided for each of them. (5) The use of participatory concepts and the study of values from a wide range of communities can lead to the dissemination of different views and perspectives. Finally, combining opinions (instead of personal interests) can provide an acceptable value for different communities. This value can be accepted by the whole wider community for the ecosystem services in question. (6) Using system management to apply ecosystem service valuation concepts has a special place, especially in the concept of sub-systems. (7) The main challenges in the management of ecosystems, including climate change, can be discussed in the concepts of valuation of ecosystem services. Therefore, the valuation of ecosystem services, in addition to its application in ecosystem services and managers' decisions, has the ability to complete models related to ecosystem management challenges. (8) In the calculations related to ecosystem services, it is necessary to reduce the value of disservices from the total calculations in order to present the real value of the ecosystem to people and managers. Moreover, this issue can provide a suitable model for the necessary assistance to the affected sections of society. (9) The issue of valuing pollution is very important, and it is necessary to determine the willingness to pay of people for the welfare of public health. Regarding this issue, it is essential to firstly estimate the costs of pollution and then take into account these costs in the field of valuing the harmful effects of pollution and making a decision for ecosystem services.

Each of the six methods discussed in the classic valuation methods section has its strengths and weaknesses. The use of each of them depends on the valuation conditions, the studied ecosystem, different conditions, and data that are available or collectible from the ecosystem. In some situations, several methods may be used together. In general, the use of these methods requires time and money for data collection and economic analysis or data analysis in related software. However, for studies at national, continental, and global levels, it is more useful to study the ecosystem services and value them using the method of value transfer as well as previous studies. In addition, the same general results from such meta-analyses can be used as raw data for case studies in situations where there is no time and cost to evaluate the value of ecosystem services. Moreover, the use of valuation methods using software has been a way to reduce costs in valuing ecosystem services in recent years (Pourtoosi et al. 2018). The method of running software applications such as "itree" is based on the information extracted from the biomass of an area, and the adaptation of the results for a specific place is based on the information recorded for that place. It was expected that each of the methods would have its own effectiveness; however, the noteworthy point is the increasing use of valuation concepts in ecosystem services in the management of ecosystems in the last decade to solve the problems of ecosystems and the challenges they face. The classification of these concepts and presenting new models based on the system theory could be the novelty of this study. This study has a policy recommendation: considering the importance of valuing ecosystem services, it is necessary to use the modeling of global issues with the help of the concept of valuing ecosystem services in addition to quantitative measures for ecosystem services for better ecosystem management. Moreover, this study has international policy implications. In this study, a theoretical implication and one practical implication are presented. It is necessary to formulate the theories and methods, update the issues and challenges of different ecosystems, and integrate them with the issues of ecosystem services and their valuation. It is necessary to consider this issue by using the theory of systems. The system theory can have an overview as well as holism and describe each sub-system and small components (theoretical implication). In addition, their practical modeling is inevitable for decision-making and positioning of each ecosystem service and its value connection with the decision-making process (practical implication). Considering the continuous communication of ecosystems all over the world, it is necessary to consider the issue of valuing ecosystem services for all ecosystems worldwide and update their information. The ecosystems of each country can affect other countries. Therefore, it is essential that global policies determine the values of different ecosystems so that managers of all ecosystems can decide to present economic values of ecosystem services and consider them in decisions and priorities.

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Data availability For further information, please contact with the corresponding author: mehdi.zandebasiri@yahoo.com.

Declarations

Ethics approval This is not applicable.

Consent for publication This is not applicable.

Conflict of interest The authors declare no competing interests.

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This article is a review article based on a review of resources related to the valuation of ecosystem services.