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Methods for monetary valuation of ecosystem services: A scoping review

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Abstract: Adequate assessment of ecosystem services is important for the development of policies and management plans related to forestry activities and the environment. Carefully identified ecosystem values can determine which options policy makers should prioritize to provide the greatest benefit. There are numerous methods used by researchers to evaluate ecosystem services. The most widely applied methods are monetary valuation methods, they are often deemed to be the most pragmatic language when it comes to communication with political and business institutions. The main goal of this review is to analyse available literature using the methodology particular to the scoping review approach in order to identify and describe valuation methods that can be applied for monetary assessment of ecosystem services. As a result of the scoping review, over 20 monetary valuation techniques (including several less common methods such as willingness to sell and Delphi method) were derived from 16 literature sources. In the process of compiling the range of different methods, a few flaws and gaps in the communication of methods were observed such as lack of consistency in the names of different methods and mixing up concepts. In addition, a few areas for future research are suggested.

Keywords: ecosystem services; monetary valuation; stated preferences; revealed preferences; market-based approach

The concept that people benefit from the environment has been accepted for a very long time. During the development of the field of environmental science, this concept has become known as ecosystem services (ES). The term was used for the first time in an article published by Ehrlich and Ehrlich (1981). In 1997, two major works were published (Costanza et al. 1997; Daily 1997) that served as catalysts to new research and policies related to this topic. In 2005, the Millennium Ecosystem Assessment (MEA) proposed a classification of ES and brought more attention from policy makers. Even though the classification of ES was adjusted and developed in later publications (TEEB 2010; Haines-Young, Potschin 2018), the original classification is widely used by researchers even today. According to MA, ES can be divided into four categories. The first category is provisioning services, which includes food, timber, fresh water, and other products obtained from ecosystems. Next, regulating services are benefits obtained from the regulation of ecosystem processes such as climate regulation and water filtration. The third category is cultural services, or nonmaterial benefits derived from ecosystems including recreation, tourism, aesthetics, and spirituality. The last category is supporting services that represent services necessary for the production of all other ecosystems – soil formation, nutrient cycling, etc. In addition to the categorized definition, it is im-

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portant to understand the difference between ES and ecosystem functions. Ecosystem functions can be defined as the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly (De-Groot et al. 2002). However, ecosystem functions exist independently of human needs. In contrast, ES require humans to appreciate the goods and services provided by ecosystems. Despite the fact that there is no single accepted definition, ES can be defined as direct and indirect contributions of ecosystems to human well-being (TEEB 2010). Contributions of ecosystems can also be referred to as benefits or values. According to the Total Economic Value (TEV) framework (Figure 1), benefits that humans obtain from ecosystems can be divided into use values and non-use values. Even further, use values consist of direct use values, indirect use values, and option value. Direct use values are goods and services that can be consumed directly (timber, medicinal plants, etc.). Indirect use values are goods and services that are enjoyed indirectly but they can contribute to another activity (crop pollination, carbon sequestration, etc.). Option value is the benefit placed on the potential ability to use a resource in the future even though it is not currently being used, while the likelihood of future use is very low (Conner 2014). Non-use values include bequest value and existence value. Bequest value can be defined as the value attributed to maintaining something for the benefit of future generations. Existence value is the satisfaction from knowing that something exists.

Adequate assessment of ES is important for the development of policies and management plans related to forestry activities and the environment. Carefully identified ecosystem values can determine which options policy makers should prioritize to provide the greatest benefit. It is particularly relevant when planning forest management activities because forests, when sustainably managed, simultaneously fulfil ecological, economic,

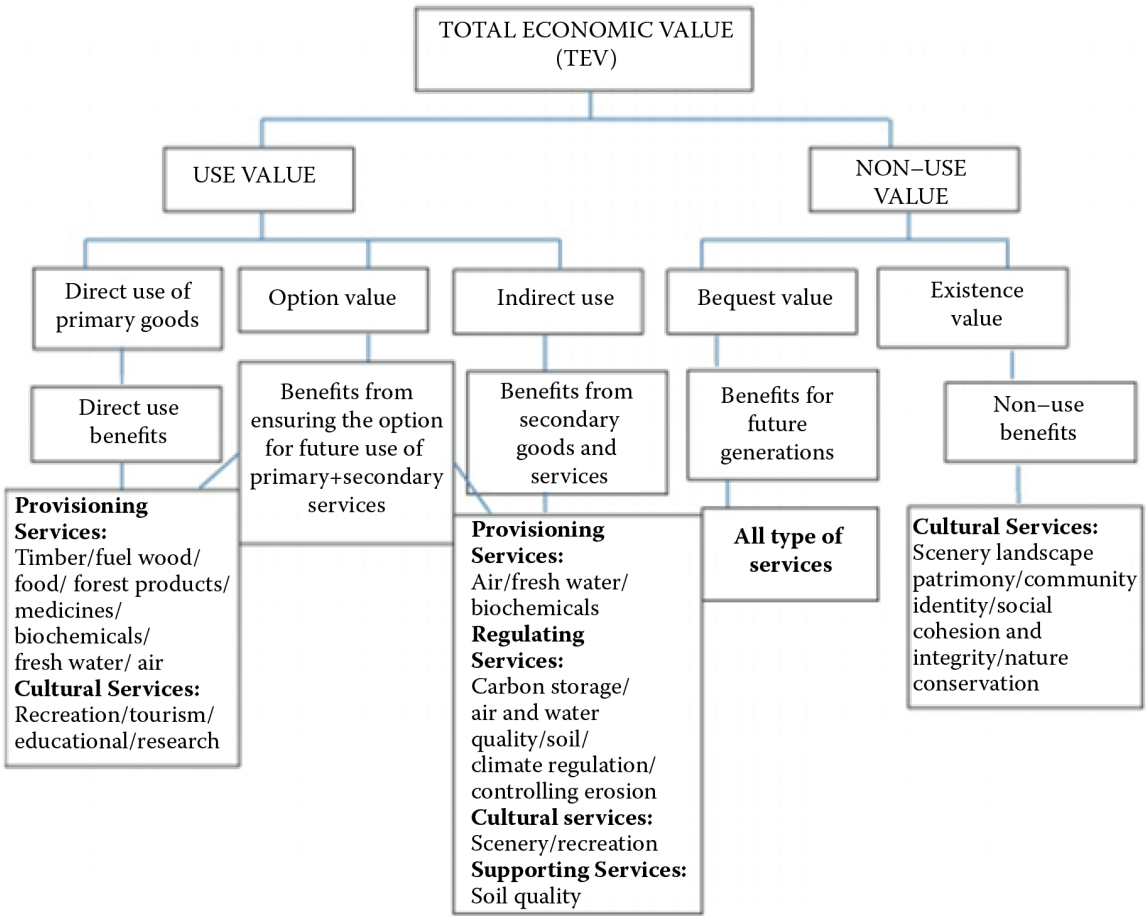

Figure 1. Total economic value framework (Mendes 2012)

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and social functions, and provide a great number of supporting, regulating, cultural, and provisioning ES that significantly affect human well-being (Fürst et al. 2007). Over recent years, the influence of the ES framework on environmental and conservation policy has grown (Kull et al. 2015). Generally, there are three different ways to assess the value of ES: qualitative analysis, quantitative analysis, and monetary analysis (TEEB 2011). According to Kettunen et al. (2012), qualitative analysis focuses on non-numerical indicators of the value such as benefits to mental and physical health, social benefits from recreation. Quantitative analysis focuses on numerical data such as quantity of sequestered carbon, quality of water, etc. Monetary analysis focuses on translating the qualitative and quantitative aspects into a particular currency. Monetary valuation of ES is the most widely applied approach (Christie et al. 2012), as it is often deemed to be the most pragmatic language when it comes to communication with political and business institutions (Spash 2013).

Despite the fact that there is neither commonly accepted methodology nor statistical standards for ES assessment (Whitham et al. 2015; Kornatowska, Sienkiewicz 2018; Mengist, Soromessa 2019), the number of published articles dedicated to ecosystem services and, in particular, to the assessment of ES is increasing (McDonough et al. 2017; Acharya et al. 2019). Furthermore, the number of studies devoted to the assessment of forest ES has gradually increased in recent years (Mengist, Soromessa 2019; Di Franco et al. 2021). There are numerous methods used by researchers to evaluate ES. Especially, monetary valuation can be carried out by means of a wide variety of different approaches. The main goal of this review is to analyse available literature using the methodology particular to the scoping review approach. This approach facilitates the identification of all possible methods that can be used for monetary valuation of ES. It should be noted that in this paper, the terms 'method' and 'approach' will be used interchangeably. Similarly, the terms 'valuation' and 'assessment' will be treated as synonyms.

SCOPING REVIEW

The review presented here was conducted according to the scoping review methodology. This methodology is appropriate for identifying and analysing knowledge gaps, for clarifying general concepts and definitions in the literature, and for identifying key topics within a field of research (Munn et al. 2018). The approach facilitates the analysis of existing literature and a summary of findings from a range of different study designs and methods. This paper will use the five original stages of the scoping review methodology first introduced by Arksey and O'Malley (2005) but it will also follow recommendations derived from Guidance for the Conduct of JBI Scoping Reviews (Peters et al. 2017). The five stages are: (1) identifying the research questions, (2) identifying relevant studies, (3) selecting eligible studies, (4) charting the data, (5) and summarizing and reporting findings.

Identifying research questions. The main research question of this scoping review is: what are the methods that can be used for monetary valuation of ecosystem services?

Identifying relevant studies. The Web of Science and Scopus databases were used in order to identify studies relevant to the purpose of this scoping review. The publication time frame entered into the search criteria for each database ranged from 2010 to March of 2021, with the time frame ending at the time this review was performed. 2010 was chosen as a starting point for the literature review because the quantity of articles focusing on monetary assessment of forest ecosystem services rapidly increased starting that year compared to the consistently lower number in previous years (Acharya et al. 2019). The search strategy involved a data search by title in both databases using the following key phrases: "ecosystem services assessment method" and "ecosystem services valuation method". In addition, a forward-backward article search (also known as 'citation chaining') was used to collect references that are frequently cited in topical papers (Robinne et al. 2020). Furthermore, a list of inclusion criteria was developed for the study selection stage:

– Peer-reviewed articles, published book chapters, and reports were analysed.

– All analysed publications were written in English.

– No restrictions regarding the country of publication were enforced.

– Reviewed articles were not limited by the ecosystem type.

– All analysed articles needed to include a description of method(s) used for monetary valuation of ecosystem services.

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– Case studies that had a thorough description of the valuation method were also included in the scoping review.

Study selection. In the study selection process, a total of 109 articles were identified using the chosen key phrases. Out of these 109 articles, 59 were found via Web of Science (WoS) database and 45 articles were found via Scopus database. During the screening process, 49 papers were excluded as not relevant to the topic and 18 papers were excluded as duplicates. Therefore, 42 articles were obtained from WoS and Scopus; five additional articles were obtained through chaining. As a result of the screening, 42 articles were selected for subsequent full-text analysis. In the course of the full-text analysis, 26 articles were excluded. Therefore, the final number of articles included in this scoping review is 16. The study selection process is summarized in Figure 2.

Charting the data. Charting the data provides a logical and descriptive summary of the results that aligns with the objective and question of the scoping review (Peters et al. 2017). During this stage of the scoping review, the charting table was developed in order to record the key information that was relevant to the objectives of the study. This table included the following information about analysed articles: author, year of publication, type of publication, goal of the study, definition of the 'value', name of the method for ecosystem service valuation, description of the method, and other notes.

Summarizing and reporting findings. The last stage of the scoping review is summarizing the data in relation to the purpose of the review, making conclusions, and noting any implications of the findings.

RESULTS AND DISCUSSION

Study context. A total of 16 articles were included in this scoping review. Nine of them were published within the last five years. Most of these papers (75%) were published as peer-reviewed ar-

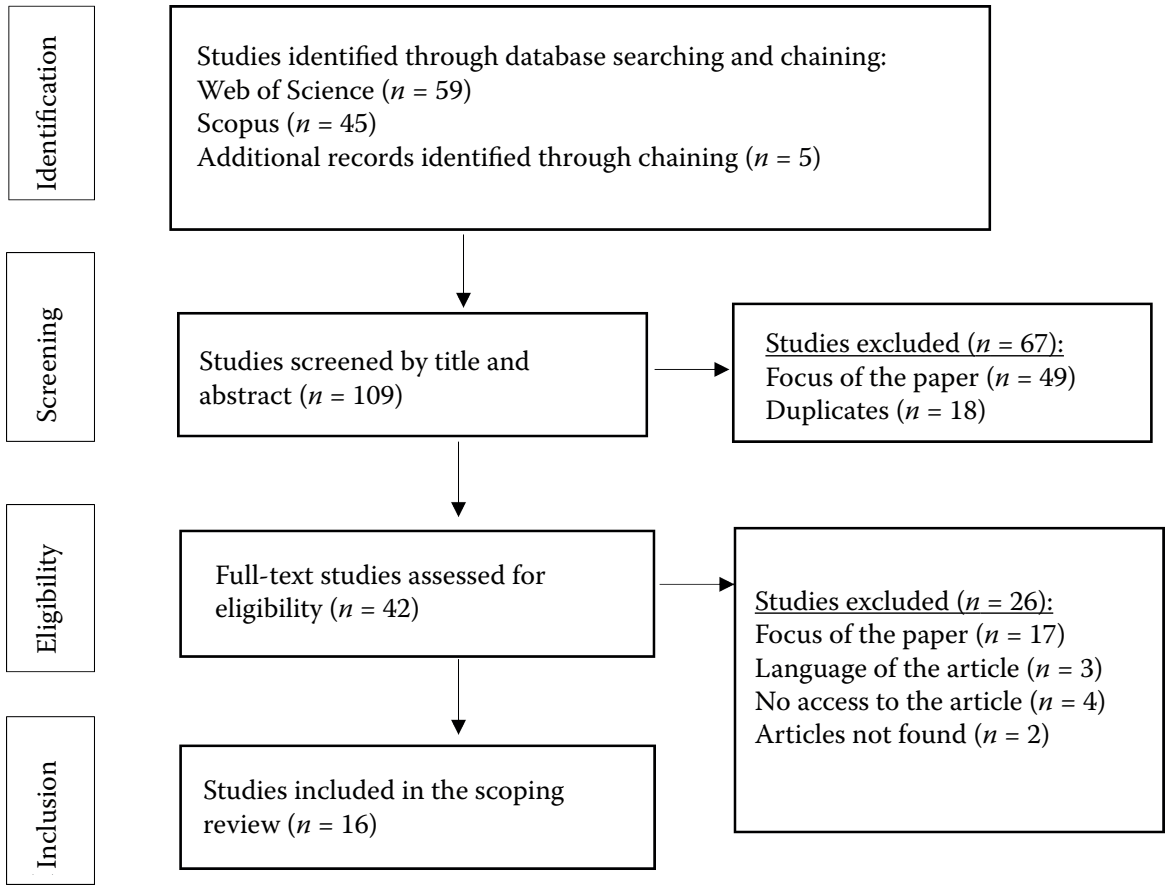

Figure 2. Flow chart of the study selection process

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ticles, whereas two papers were published as book chapters and one paper as a report. Regarding the goal of these studies, eight publications mentioned a review of the ES valuation methods among the objectives of the paper (e.g., Arias-Arévalo et al. 2018; Van Beukering et al. 2015). Two articles were focused on reviewing only one particular valuation method (Chang, Yoshino 2017; Navrud, Strand 2018). Other papers did not state reviewing valuation methods among their main goals. Nevertheless, these articles provided an overview of at least one ES valuation method.

Definition of the term 'value'. During the process of data charting, one of the investigated issues was the definition of the term 'value' as provided by the authors. Analysis of the literature showed that ten articles did not provide a definition of the term 'value'. Other articles defined the term 'value' similarly as ecosystem service contributions to human well-being (Costanza et al. 2017; Chen 2020). In addition, some articles discussed the concept of the value in more detail and provided multiple definitions of 'value' (Hattam et al. 2015; Costanza et al. 2017; Kornatowska, Sienkiewicz 2018).

Monetary valuation methods identified. During the full-text analysis of the articles included in this scoping review, many methods applicable to monetary valuation of ecosystem services were identified. Table 1 summarizes all valuation methods identified during the scoping review.

Description of ES assessment methods. The following part of this paper aims to describe the identified ES assessment methods. In this study, valuation methods are divided into three main groups according to Van Beukering et al. (2015): direct market valuation methods, indirect market valuation methods, and non-market valuation methods (Figure 3).

Direct market valuation methods. This group of methods uses data from existing markets as a basis for the ES valuation process. That means that this method operates with prices for goods and services that actually exist in real markets. Direct market valuation methods consist of the following approaches: market price-based (exchange-based) valuation approach, cost-based valuation approach, and production function valuation approach.

Market price-based approach (aka direct market prices valuation approach or exchange-based valuation). This approach uses the prices of ES that are traded on the markets as a proxy for their monetary value (Arias-Arévalo et al. 2018). For example, the value of the timber production ES can be defined as the price of this timber on the market. When market prices are adjusted to correct for market distortions such as taxes and subsidies, this approach could be called adjusted market price method (Bateman et al. 2011).

The cost-based valuation approach assumes that the value of ES can be defined at least as the costs that are avoided because ES exist. There are a few variations of the cost-based approach: replacement cost method, substitute cost method, damage cost avoided method, and mitigation cost method.

– Replacement cost method estimates the value of an ES as the costs associated with replacing it. For example, if the forest stand has to be harvested due to construction work, the value of the forest stand will be equal to at least the costs of establishing a new forest stand by planting new trees.

– Substitute cost method is recognized as an original method that differs from replacement cost approach (Van Beukering et al. 2015; Kornatowska, Sienkiewicz 2018). However, most of the articles included in the scoping review do not distinguish between these two methods and both replacement cost and substitute cost concepts are summarized under the umbrella of replacement cost method. Nevertheless, substitute cost approach can be defined as a method that uses the cost of the ES substitute as the value of this ecosystem. For example, the costs of building a water storage tank as a substitute to a lake.

– Damage cost avoided method (aka preventive expenditure method or averting cost method) defines the value of an ES as the costs associated with the hypothetical damage that was avoided due to the existence of this ES. A classic example is a mangrove forest that prevents the damage that could have been caused by storm waters.

– Mitigation cost method (aka restoration cost method) assumes that the cost of ES is equal to the expenses incurred from the mitigation of the negative effects caused by the degradation of the ecosystem. An example would be the purification of the water from a polluted reservoir that provides drinking water. The main difference between this method and damage cost avoided method is that the damage is hypothetical in the latter.

Production function approach (aka net factor income approach) assumes that the value of an

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Table 1. Methods for monetary valuation of ecosystem services identified in the analysed articles

Publication	Methods described
Arias-Arevalo et al. (2018)	Market price based: market prices Market cost based: replacement costs; damage cost avoided; production function Revealed preference methods: travel cost; hedonic price Stated preference: contingent valuation; choice modeling Benefit transfer Deliberative economic valuation
Chang and Yoshino (2017)	Contingent valuation: WTP; WTA; WTS
Chen (2020)	Revealed preference: travel cost; market method Stated preference: contingent valuation; choice experiment Cost based methods: replacement cost; avoided cost Group deliberation or system modeling The benefit transfer method
Chu et al. (2020)	Revealed preferences: travel cost; hedonic pricing Stated preferences: choice experiments; contingent valuation (WTP; WTA)
Harrison et al. (2018)	Cost-effectiveness analysis: benefit cost Market price/exchange-based method: shadow pricing; mitigation cost-based valuation (restoration cost; replacement cost; clean-up cost) Revealed preferences: travel cost; hedonic pricing Stated preferences: contingent valuation; choice experiment; contingent ranking Resource rent method Simulated exchange Production/cost function Value transfer/benefit transfer
Hattam et al. (2015)	WTP
Kornatowska and Sienkiewicz (2018)	Stated preferences: contingent valuation (WTP; WTA); choice experiment Revealed preferences: travel cost; hedonic pricing; benefit transfer; cost-based methods (damage cost avoided; replacement cost; substitute cost)
Van Beukering et al. (2015)	Market based valuation: direct market prices; production function; Replacement costs; substitute costs; avoided damage costs Revealed preferences (Indirect market valuation): hedonic pricing; travel cost Stated preferences: contingent valuation (WTP; WTA); choice experiments Meta-analysis Value transfer
Navrud and Strand (2018)	The Delphi method
Torres-Miralles et al. (2017)	Contingent valuation: WTP Inferred valuation method
Villalobos and Huenchuelo (2010)	Contingent valuation: WTP Choice experiments
Costanza et al. (2017)	Revealed preferences: replacement cost; hedonic pricing Stated preferences: contingent valuation; choice experiments (conjoint analysis)

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Table 1 to be continued

Publication	Methods described
Costanza et al. (2011)	Revealed preferences: production-oriented analysis (production function); travel cost; hedonic pricing Stated preferences: contingent valuation; choice experiments
Bateman et al. (2011)	Adjusted market prices Production function Damage cost avoided Averting behavior Revealed preferences: travel cost; hedonic property price Stated preference: WTP; choice experiments
Forest Europe (2014)	Preference based valuation: travel cost; contingent valuation; choice experiments; hedonic pricing; market observations Cost-based methods: preventive expenditure (averting costs); replacement costs; damage costs
Pascual et al. (2010)	Direct market valuation methods: market price-based approaches; cost-based approaches (avoided cost; replacement cost; mitigation/restoration cost); production function Revealed preference approaches: travel cost; hedonic pricing Stated preference approaches: contingent valuation (WTP; WTA); choice modeling; group valuation (deliberative monetary valuation) Benefit/value transfer (BT): unit BT; adjusted unit BT; value function transfer; meta-analytic function transfer

WTP – willingness to pay; WTA – willingness to accept; WTS – willingness to sell

ES can be estimated as the contribution of this ES to the enhancement of income or productivity (Pascual et al. 2010). For example, the value of an ES such as water purification can be estimated based on the increased revenues from selling better quality water on the market.

Indirect market valuation methods. Indirect market valuation methods or the revealed preference approach assumes that ES values can be "revealed" through observable consumer behaviours or activities in relevant markets (Chu et al. 2020). This approach, in contrast to the stated preference approach described below in the text in this paper, uses data obtained from real markets where actual transactions have been made. During the analysis of the literature included in this scoping review, two indirect market valuation methods were identified: travel cost method and hedonic pricing method.

The travel cost method is commonly used for assessment of recreational ES. The rationale behind this method is that the base value of a particular ES can be measured as the time spent and costs incurred to access a recreational service. For example, the value of hiking at the national park can be reflected as the costs and time spent to travel to the park.

The hedonic pricing method assumes that the value of ES can be at least partially captured in the price of a property. The main idea is that there is a direct relationship between the location of real estate and its price. The closer the house to an ES, the higher the price of the house. For example, the difference between the price of a house located near a lake and the house located in the same area but farther from the lake can be interpreted as the value of ES provided by the lake.

Non-market valuation methods. The non-market valuation approach is often referred to as the stated preference approach. This approach can be used when no market prices are available and it is not possible to apply methods particular to the revealed preference approach (Van Beukering et al. 2015). The stated preference approach uses the hypothetical choices individual respondents stated to estimate the change in utility associated with a proposed increase in quality or quantity of an ES or bundle of services (Bateman et al. 2002). Non-market valuation methods include contingent valuation methods, choice modelling, and group valuation.

Contingent valuation (CV) methods have four variations:

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– Willingness to pay (WTP) – this method assesses the value of an ES by directly asking people how much they would be willing to pay for ecosystem improvements and the ES they will generate (Costanza et al. 2011; Endalew et al. 2020).

– Willingness to accept (WTA) – the WTA method askes individuals how much money they are willing to accept as a compensation for the loss or degradation of the ecosystem and goods and services it provides.

– Willingness to sell (WTS) – this method was described in detail by Chang and Yoshino (2017). Just like WTP and WTA, this method directly questions respondents to define what the reasonable price of some ES may be. This method tries to evaluate ES by asking respondents how much the good or service provided by an ecosystem is worth if sold or how much a third party would be willing to pay for this good or service. Unlike WTP and WTA, WTS approach attempts to keep the respondent in a neutral position. If the respondent has a closer relationship with the side of the seller during the survey, the answer will likely lead to an overestimated value. If the respondent relates more closely to the purchaser, the answer would likely be more cost-conservative. Thus, this method tries to take into account the perspective of both the seller and the buyer equally. In the application of this method, the question asked of participants can be formulated as follows: What would be the reasonable price for ES for both the buyer and the seller? Chang and Yoshino (2017) provided examples of the questions for assessment of ES by using three different methods:

(1) WTP question: If the construction of a new park like Amoy Bay Park requires public donations, what is the maximum amount of money you are willing to donate for the new park?

(2) WTS question: If this Amoy Bay Park were to belong to one of your friends, and for some reason he wanted to sell the park to another one of your friends, how much money do you think the park was worth if you were the middleman? What price do you think may be reasonable for both the buyer and the seller?

(3) WTA question: If this Amoy Bay Park belongs to you, it is going to be demolished for other land use purposes, and you will not be able to use it in the future, what is the minimum financial compensation you would expect for the loss of the park?

– Inferred valuation method – this method was mentioned once by Torres-Miralles et al. (2017) during the literature analysis. The inferred valuation method is similar to WTS as it attempts to minimize people's biases when answering standard questions particular to WTP and WTA. Authors of this method (Lusk, Norwood 2009) believe that in order to avoid biases, it would be the most effective to ask people to predict or infer others' values for an ecosystem service or good it provides instead of asking people to state their own opinion of its value.

Choice modelling (CM) is a group of survey-based methodologies for modelling respondent's

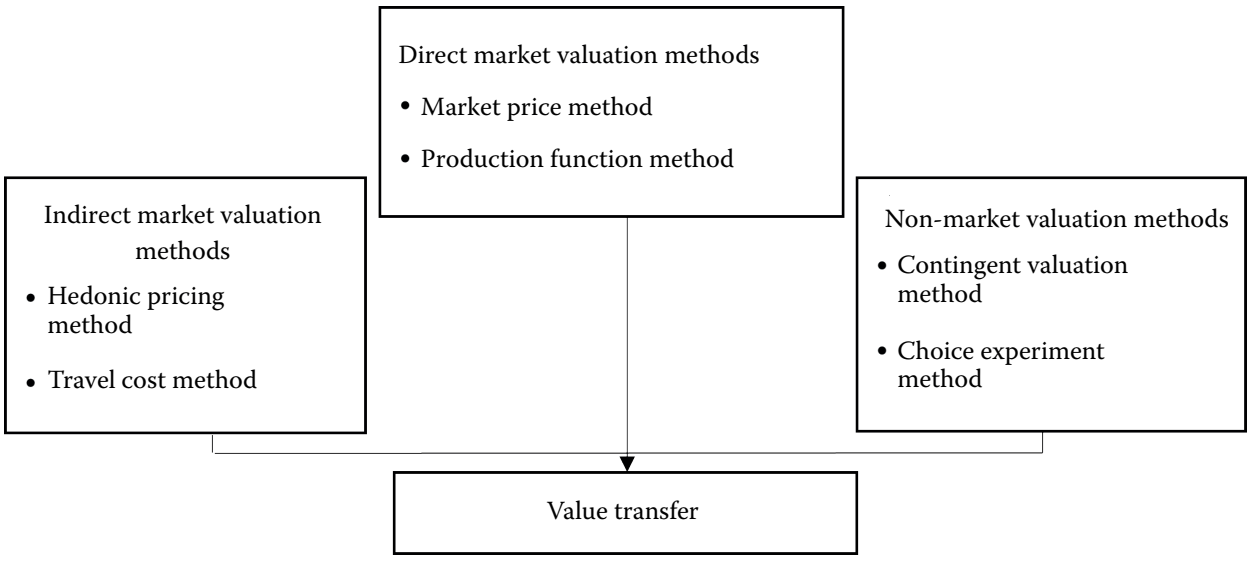

Figure 3. Methods used for valuation of ecosystem services (Van Beukeringet al. 2015)

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preferences for goods and services, which are described in terms of their level of certain attributes (Hanley et al. 2001). CM method, similar to CV method, operates with hypothetical scenarios. According to this approach, the value of ES can be assessed based on the respondent's WTP stated during the process of ES ranking, rating, or choice from a list of alternatives. Choice modelling methods identified during the scoping review in this paper include choice experiment and contingent ranking.

– Choice experiment method (conjoint analysis) estimates the value of ES through a questionnaire in which respondents have to choose one option from a list of alternatives.

– Contingent ranking method asks respondents to rank a set of alternatives given in the questionnaire.

Group valuation (deliberative valuation) methods assess ES based on the stated preferences obtained during the deliberation process of a group of individuals, as opposed to aggregated preferences of individuals gathered during CV and CM approaches. The main idea of the group valuation method is to bring small groups of stakeholders together to discuss and debate the relative importance of a particular set of public goods (Murphy et al. 2017). This method allows participants to evaluate ES based on their knowledge and understanding of the trade-offs identified during the discussion.

The Delphi method is a variation of the group valuation approach. This method was mentioned only in one paper (Navrud, Strand 2018) during the process of the literature analysis. The basis of this approach is similar to the traditional group valuation method, with the addition that the deliberation process for the value of ES occurs in the group of experts. Navrud and Strand describe the process of Delhi method as follows:

A common approach is to face experts with two or more rounds of questionnaires. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the stated reasons for their judgments. Thus, experts are encouraged to revise their earlier answers in light of the replies of other members of their panel.

Similar to the group valuation methods, the Delphi method is used to describe the preferences regarding ES stated by a group after the process of discussion amongst the individuals, rather than the preferences stated by individuals as a result of CV and CM.

Other methods. In addition to the methods described previously in this paper, there are methods that are difficult to assign to a particular group of methods. However, these uncategorized methods were also mentioned in the analyzed articles as options for evaluating ES. These methods include shadow pricing approach, value or benefit transfer methods, resource rent method, and simulated exchange method.

The shadow pricing method assesses the value of an ES based on the implicit form of market price, which is defined as the marginal price that society puts on the provision of non-marketed ecosystem services by setting environmental targets (Konrad et al. 2017). For example, when a country signs the Water Framework Directive, the costs that will be incurred in order to reach the agreed level of water quality can be used as data for the implicit value of water quality improvements (Kelemen et al. 2015).

The benefit transfer method (value transfer method) is not technically a valuation method (Van Beukering et al. 2015). However, it is an approach that can be used to estimate the value of ES. The main idea is that ecosystem values obtained at previously estimated sites (study sites) can be adjusted and extrapolated to a new site (policy site) that possesses similar socioeconomic and ecological contexts. Pascual et al. (2010) distinguished four variations of benefit transfer (BT): unit BT, adjusted unit BT, value function BT, and meta-analytic function transfer. They are characterized as follows:

– Unit BT method estimates the value of an ES at a policy site by multiplying a calculated mean unit value obtained from a study site by the quantity of that ecosystem service present at a policy site.

– Adjusted unit BT approach involves making corrections to the transferred unit values in order to reflect the individual differences between study site and policy site.

– Value function transfer uses functions estimated via valuation applications (travel cost, hedonic pricing, CV) for a study site together with information on parameter values for the policy site in order to transfer values. Parameter values of the policy site are plugged into the value function to calculate a transferred value that better reflects the unique characteristics of the policy site.

– Meta-analytic function transfer (meta-analysis) utilizes a value function estimated from multiple study sites pooled together with information

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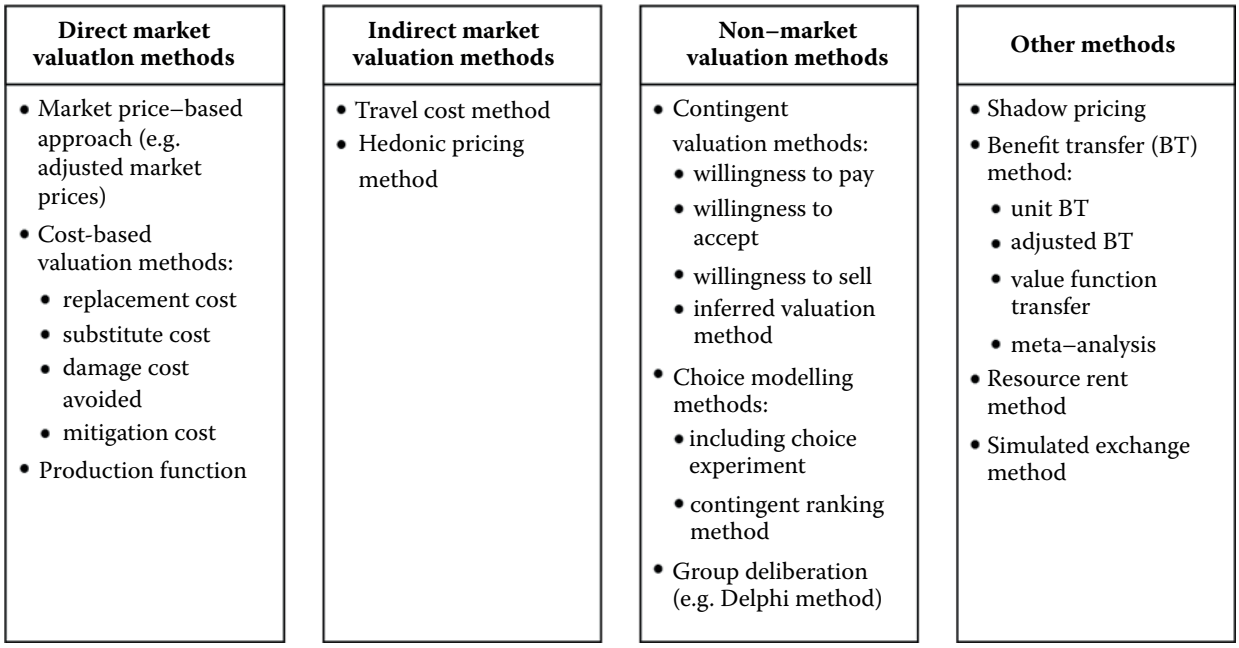

Figure 4. Methods for monetary valuation of ES identified during the scoping review

on parameter values for the policy site to estimate values. Therefore, the value function is not derived from a single study but from a collection of studies.

Resource rent method – this method was mentioned only once in the analyzed literature (Harrison et al. 2018). The rationale behind this method is that the value of ES can be derived as a residual amount after the contributions of other forms of capital have been deducted from the operating surplus. Since the residual reflects the return to the ecosystem asset that is used in production of marketed goods, it is consistent with exchange values (Obst et al. 2015).

Simulated exchange value method – this method was also described only once (Harrison et al. 2018) during this scoping review. The simulated exchange method consists of using WTP data that are estimated using the non-market valuation methods to simulate the entire market (demand, supply and competitive environment) to obtain the market value that one could obtain from a given ES if it were internalized into the market (Caparrós et al. 2017).

All ES valuation methods identified in this scoping review are presented in Figure 4.

CONCLUSION

This scoping review provides a number of methods that can be applied to the monetary valuation of ES. Over twenty valuation approaches were identified throughout the scoping review. Even though the majority of the methods are widely known (e.g., WTP, WTA, travel cost method, replacement cost method, etc.), several less common methods (e.g., WTS, Delphi method) were identified during the literature analysis. In the process of compiling the range of different methods, a few flaws and gaps in the communication of methods were observed during the process. There is a lack of consistency in the names of different methods (e.g., benefit transfer, aka value transfer; damage cost avoided method, aka averting cost method). In addition, rather than distinguishing between two methods, some articles pin one concept under the umbrella of another. For example, replacement cost could be used as a more general concept with substitute cost within its scope. In conclusion, there are a few areas of future study that could be potentially beneficial. Further research is needed to investigate literature by using a wider search strategy, namely search by title, abstract, and key words, rather than solely the abstract. In order to be useful to policy and decision makers, a study that investigates the disadvantages and advantages of all monetary valuation techniques is required. In addition, a list of assessment methods with commonly accepted names can be compiled to facilitate the work of policy makers and researchers.

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