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The economic valuation of ecosystem services: bibliometric analysis

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Keywords: *ecosystem services; natural resources management; sustainable development; market based valuation; revealed-stated preferences; transfer value methods*

Abstract

Research background: The services provided by ecosystems are the main support for human populations and for the development of any type of activity. Today, the provision of these services is under threat. The economic valuation of ecosystem services is vital to design appropriate policies, define strategies and manage ecosystems.
Purpose of the article: The objective of this study is to analyse the evolution of research on the economic valuation of ecosystem services over the last two decades. More specifically, it aims firstly to identify the main agents driving research and, secondly, it seeks to synthesize in a single

document the relevant information on the main economic valuation methods, relating them to the categories of services, ecosystems and regions where they have been employed.
Methods: A quantitative review was first carried out through a bibliometric analysis to identify the main drivers of this line of research and its development trends. Secondly, a qualitative review was conducted through a systematic review focusing on the most commonly used valuation techniques in relation to the characteristics of the service, the geographical scope and the ecosystem analysed.
Findings & value added: The main novelty of this work, compared to previous literature, is that the relationship between the study area, the type of ecosystem, the category of service and the economic valuation methodology are analysed for the first time. The results highlight the need to continue expanding knowledge in relation to the temporal and spatial scale in the economic value of ecosystem services, the subjective nature of the estimates and the heterogeneity between the different social sectors with respect to the benefit obtained.

Introduction

Ecosystem services (ES) can be understood as the transformation of natural resources into goods and services that have value for people and represent the series of benefits gained both directly and indirectly by society from ecosystems (Viti *et al.*, 2022). These services include the supply of a wide variety of resources that are fundamental for life, such as drinking water, clean air or food (Macaskill & Lloyd-Smith, 2022). However, there is a series of factors that drive the degradation of the ecosystems which provide these services. These include the growth of the population, changes in the use of the land, agricultural and urban expansion and over-exploitation as a result of economic development (Geijzendorffer *et al.*, 2017; Hossain *et al.*, 2018). Furthermore, among the different adverse consequences of global climate change we can expect prolonged drought periods and imbalances in water supply, a reduction in the carbon sequestration capacity of ecosystems, erosion and a loss of fertility of soil, desertification and a reduction in the capacity to produce food, among others (May *et al.*, 2017; Peñuelas *et al.*, 2017). This situation can generate a wide range of impacts on a large scale on ecosystems and biodiversity, which can be difficult and costly to repair or, even irreversible (Chitsaz & Azarnivand, 2017; Mitrică *et al.*, 2017). Consequently, losses will be incurred in terms of human well-being due to the decrease in the flow of ES, which will particularly affect the poorest and most vulnerable populations of the low-income regions (Damkjaer & Taylor, 2017).

The development of the ES field of study is generalised from the studies by Daily (1997) and Costanza *et al.* (1997). Initiatives such as the Millennium Ecosystem Assessment (MEA) Project (2005) and The Economics of Ecosystems and Biodiversity (TEEB) (Kumar, 2010) are milestones that have converted the concept of ES into a political instrument in order to achieve the sustainable use of natural resources (Macaskill & Lloyd-Smith, 2022; Ignatyeva *et al.*, 2022). Thus, the valuation of ecosystem services aims to provide stakeholders with knowledge useful for policy design, strategy definition and ecosystem management by identifying services as well as their flow and relative importance to society (Mirici, 2022). There is a high degree of consensus in the scientific literature with respect to the importance of valuing ES. The most recurrent arguments are: i) the absence of markets or the existence of market failures; ii) the underestimation of the ES and of the importance of promoting sustainable economic development; iii) the uncertainty existing with respect to the supply and demand of natural resources, particularly in the future; iv) the need to provide useful information to policy-makers for the design of environmental conservation programmes; v) the valuation of the damage caused to ecosystems and the determination of optimum taxes and sanctions which should be applied for the use of the ES (Velasco-Muñoz & Aznar-Sánchez, 2016).

Currently, there is a great demand for information from all the stakeholders involved. Furthermore, the different profiles of these users and the diversity of the decisions that they must take, require the availability of information expressed in commonly used terminology, easy to interpret and transmit in order to ensure consensus in the management processes (Hekrle, 2022). One alternative for resolving this issue is to estimate the value of the ES in monetary terms (Pascal *et al.*, 2018). Therefore, the ultimate objective of the majority of the studies on ES is to offer a monetary estimate through the economic valuation of the series of services supplied by the ecosystems, going beyond the simple valuation of the production of food and forestry assets or the quantification of another type of services (He *et al.*, 2015; Velasco-Muñoz & Aznar-Sánchez, 2016). This valuation is useful to the competent authorities for assessing conservation methods and assigning budgets in order to optimise the management of the scarce resources to achieve the economic, environmental and social objectives (Bateman & Kling, 2020).

The objective of this study is to analyse the evolution of research on the economic valuation of ecosystem services over the last two decades. More specifically, it aims firstly to identify the main agents driving research and, secondly, it seeks to synthesize in a single document the relevant information on the main economic valuation methods, relating them to the categories of services, ecosystems and regions where they have been employed. These objectives represent a novelty with respect to previous works. This knowledge is useful to know the main sources of information and result publication in this field of study, to establish relationships with other researchers and centres, and to identify gaps in research and new lines of work. This is useful for designing new studies and guiding future research.

To this end, a quantitative review was first carried out through a bibliometric analysis to identify the main drivers of this line of research and its development trends. Secondly, a qualitative review was conducted through a systematic review focusing on the most commonly used valuation techniques in relation to the characteristics of the service, the geographical scope and the ecosystem analysed.

After this introduction, the theoretical framework on the economic valuation of ecosystem services and available methodologies is presented. This is followed by a description of the methodological procedure used to carry out this study. Next, the results are presented, organised in such a way as to respond to the objectives set out. Finally, a discussion of the results is included together with conclusions.

The main novelty of this work, compared to previous literature, is that, in addition to the quantitative analysis in reference to the general variables that are usually evaluated in review works (number of articles published annually, main institutions and countries involved, and most relevant authors), the relationship between the study area, the type of ecosystem, the category of service and the economic valuation methodology used is analysed for the first time.

Theoretical framework

Economic valuation of ecosystem services (EVES)

According to MEA (2005) the services can be classified as i) provisioning services (the products obtained from the ecosystems); ii) regulating services (the benefits derived from the regulation produced by the ecosystem processes); and iii) cultural services (the intangible benefits obtained from the ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences).

The different categories of services encompass different types of values which should be considered in order to obtain a valuation of the service as a whole. In this way, the "Use Value", which is related to the contributions received from the ecosystems is distinguished from the "Non-use Value", which is related to moral or ethical considerations of the conservation of the ecosystems and the services that they provide (Bos & Ruijs, 2021). Within the use value, a distinction can be made between i) the direct use value (the result of the direct use and enjoyment of ecosystems, either through in situ experiences or through the extraction of what they produce): ii) the indirect use value (not reflected in conventional markets and referring to the ecological processes and regulating services of the ecosystems; and iii) option value (securing future benefits from resources that are not used today). On the other hand, among the non-use values, it is possible to find the existence value (related to the satisfaction of conserving ecosystems, independently of their enjoyment or use), the bequest value (satisfaction of conserving the ecosystems for future generations) and the altruist value (satisfaction of enabling other people to access the ecosystems and their services).

The most widespread approach to the economic valuation of ES is known as Total Economic Value (TEV) (Velasco-Muñoz & Aznar-Sánchez, 2016). It was introduced by Randall and Stoll (1983). TEV consists in aggregating the use value and the non-use value of all of the ES that make up an ecosystem. In order to calculate the TEV, if possible, the values of the information on the individual behaviour observed in the markets directly related to the ES are obtained. If these data are not available, the information on prices must be obtained from parallel markets indirectly related to the good or service being valued (Limaei *et al.*, 2017). If none of these information sources are available, hypothetical markets are created in order to estimate these values (Thompson *et al.*, 2017).

These situations correspond to a common classification of the techniques available for valuing the ES (Nie *et al.*, 2021): i) market- based valuation; ii) valuation based on revealed preferences; iii) valuation based on stated preferences; and iv) value transfer methods. Depending on each ecosystem and type of service that is to be valued within it, some valuation techniques are more appropriate than others. The choice of technique is usually related to the availability of resources, time and information. Figure 1 shows the link between the TEV and the different categories of services through the type of value.

Methodologies for economic valuation of ecosystem services

Market methods

The market-based techniques considered that have been compiled within the studies forming the sample are: the market price method; the production function method (changes in productivity); and cost methods (replacement cost, avoided cost, social cost, restoration cost, provision cost). The market prices are used to value services that have a market where they may be exchanged such as food, raw materials, drinking water, etc. (Kabil *et al.*, 2022). The service value is obtained by multiplying the number of physical units of the good obtained by its market price.

The production function method is used for those services related to products that have a market of reference in which they are sold. The production of one can be related to the availability of the other (Jiang *et al.*, 2016). Therefore, the monetary estimation is calculated as the marginal amount of a marketable product obtained from the ES studied multiplied by the market value of this product.

The avoided cost method calculates the economic value of the benefits that an ecosystem provides that would not exist without the ecosystem in place, and therefore, would represent an added cost to society if this environmental service no longer existed (Browne *et al.*, 2018).

Restoration costs are the actual and imputed expenditures for activities aiming at the restoration of depleted or degraded natural systems, partly or completely counteracting the (accumulated) environmental impacts of economic activities (Tu *et al.*, 2022).

Replacement costs include all those that are incurred in returning the negatively affected natural resources to their original state (Horváthová *et al.*, 2021). Their efficiency is limited to the proportionality between the value of the damage caused and the replacement costs (returning an affected natural or environmental resource to its original state).

Social cost can be defined as the set of private costs as a consequence of a transaction and the costs imposed on consumers as a consequence of that transaction for which they are neither compensated nor charged (Browne *et al.*, 2018).

Provision cost includes all those factors that are involved in the provision of services and must be remunerated on the basis of market-regulated values such as workers' salaries or owners' rents (Nie *et al.*, 2021).

Revealed preferences methods

The revealed preferences methods consist in observing the consumption choices made by individuals in the markets and drawing from these observations their preferences and the value of the ES analysed (Bateman & Kling, 2020). The two methods included in the studies of the sample are the travel cost method and the hedonic pricing method.

The travel cost method is used to estimate the indirect value of the use of those services that have no reference markets. This methodology is used to estimate the demand curve of the users of the service. Through the use of services, the users are asked about the total amount of costs that they incur when making visits to a particular place where they use the valued services, which is usually cultural (recreational, eco-tourism, landscape beauty, etc.). Furthermore, the participants in the survey are asked about their willingness to pay for the use of these services. In this way, the surplus of the visitor is established through the difference between what is obtained, through their willingness to pay and the costs incurred to receive the service (Kabil *et al.*, 2022).

The hedonic price method seeks to discover all of the attributes that explain the price of a good and the quantitative importance of each of them (Velasco-Muñoz & Aznar-Sánchez, 2016). This method consists in measuring in what way the value of certain market goods depends on the level reached by a particular variable or attribute (Dahal *et al.*, 2019). In other words, it consists in determining the value of an environmental aspect through the study of how it makes the value of market goods vary.

Stated preferences methods

Stated preferences methodologies use the preferences directly stated by the individuals in order to estimate the values of the ES that are not reflected in any markets. They are techniques based on surveys and experiments designed to obtain information about the preferences of the individuals regarding hypothetical changes in the quantity or quality of the ecosystem services (Cheng *et al.*, 2019). These methods can be used to value both use values and non-use values and constitute the only means of estimating the latter. The methods included in this group found in the sample of studies analysed are the contingent valuation and choice experiment.

The contingent valuation consists in asking people how willing they would be to pay for an increase or improvement in the provision of an ES or how willing they would be to accept their loss or deterioration. In other words, they are directly asked about their willingness to pay (WTP) or willingness to accept (WTA) for certain services (Ginsburgh, 2017).

In the choice experiment, the WTP/WTA is deduced using experiments in which people are faced with a series of choices on which they base their preferences and their decision-making process. The alternatives offered consist of a series of attributes and payments or subsidies that the stakeholders should consider and prioritise (Khan *et al.*, 2019).

Value transfer methods

Benefit transfer is not a methodology in itself, but a technique used to estimate the economic values of services of the ecosystem based on estimations using the information available in previous studies (Pinke *et al.*, 2022). It is considered appropriate to include this technique when making estimates based on market methodologies, through adapting the available information regarding the economic value of similar ES by using coefficients, obtained directly from other studies (Liu *et al.*, 2012) or calculated using econometric regressions and meta-data analysis (He *et al.*, 2015).

Similarly, meta-analysis is not an assessment methodology per se. Meta-analysis is a systematic method for synthesising results from different empirical studies on the effect of an independent variable on a final outcome (He *et al*., 2015). In this way, the results of economic valuations of services provided by specific ecosystems under specific conditions can be extrapolated to environments with similar conditions and adapted according to their particularities (Reynaud & Lanzanova, 2017). Meta-analysis and benefit transfer are often used in conjunction with each other.

Methods: bibliometric review

Bibliometrics is used in the study of the evolution of the trends of a research topic. It uses various analytical tools to assess the relative importance of publications in a specific field of study (Aznar-Sánchez *et al.*, 2018a). Furthermore, bibliometric analysis is used to represent the bibliographic information available in the different repositories, determining the principal authors, institutions, countries and research trends within a subject area (Zhong *et al.*, 2016).

The development of this work has followed a sequential process made up of the phases illustrated in Figure 2. The first phase (PHASE 1) is the selection of works to be analysed. This phase, in turn, consisted of the following sub-phases: i) selection of the database from which the documents are extracted, ii) establishment of the search parameters for the identification of documents and extraction of the initial sample, iii) establishment of the criteria for acceptance and inclusion of works and selection of the final sample. The literature review phase included two sub-samples. The first subsample (SUB-SAMPLE 1) includes all papers that study the economic valuation of ecosystem services. The second subsample (SUB-SAMPLE 2) focuses only on empirical papers. Once the samples have been delimited, we proceed to the second phase of the process (PHASE 2). In this phase, each of the sub-samples is analysed separately. SUB-SAMPLE 1 has been used to analyse the general evolution of research on EVES by means of bibliometric analysis. SUB-SAMPLE 2 includes the analysis of empirical work with the aim of focusing on aspects linked to the methodologies through a qualitative systematic review. Specific details of each stage of the process are described below."

The first step in developing the methodology is to select the sample of studies to analyse. Regarding the database selection for the extraction of the article sample, studies have been conducted to measure the overlap among databases and the impact of using different data sources for specific research fields on bibliometric indicators. A higher number of journals indexed by Scopus compared to those by WoS has been observed (Mongeon & Paul-Hus, 2015). In terms of overlap, 84% of WoS titles are also indexed in Scopus, while only 54% of Scopus titles are indexed in WoS (Cascajares *et al*., 2021). This was the main reason for selecting Scopus for this work. In addition, the database Scopus is considered to be the largest citation repository of abstracts and offers a high level of availability (Aznar-Sánchez *et al*., 2018b; Opejin *et al*., 2020). This database is equipped with tools for visualizing and analyzing publications and it enables more complete series of data search, processing and downloading options compared to Web of Science, which only enables the downloading of information contained in Core Collection (Albort-Morant *et al*., 2017; Velasco-Muñoz *et al*., 2019). Furthermore, many publications have used Scopus in bibliometric studies on parallel topics to this study (Zhong *et al*., 2016; Aznar-Sánchez *et al*., 2018c; Aznar-Sánchez *et al*., 2019).

The period of the sample of articles was established between the years 2000 and 2021. A search was carried out with the parameters: [TITLE-ABS-KEY ("ecosystem service*" or "environmental service*" or "ecological service*") AND TITLE-ABS-KEY ("market price" or "revealed preference" or "cost calculation" or "stated preference" or "productivity changes" or "production function" or "travel cost" or "hedonic pricing" or "avoided cost" or "replacement cost" or "contingent valuation" or "choice experiment" or "benefit transfer" or "total economic value" or "economic valuation" or "monetary valuation" or "restoration cost" or "mitigation cost" or "choice model")]. The search was carried out in March 2022. Given that it is a common practice for research results to be initially published as a conference contribution, working paper or book chapter before being published definitively as an article, this review only includes original articles in order to avoid duplications in the sample, (Gusmão-Caiado *et al*., 2017). The initial sample for the analysis of this study includes 1995 articles. The articles in the sample were reviewed one by one for their appropriateness to the topic of study. Thus, the final sample consisted of 1744 articles.

The information of the different variables analysed can include duplications due to the different registration options in terms of the name of the authors, the institutions, keywords or citations. Therefore, after downloading, these duplications were eliminated before proceeding with the analysis. Once the data had been cleaned, the different graphs and tables were elaborated in order to facilitate their correct visualisation and subsequent analysis. The variables analysed based on the information obtained are the year of publication of the articles, the journals, countries, institutions and authors. In order to assess the relative importance of the research on this topic, different quality indicators were analysed, such as the number of citations, the H index and the SCImago Journal Rank (SJR) impact factor. The H index shows the number h of a total of N documents that include at least h citations in each of them. This index is applied to a group of publications corresponding to an author, institution or country (Li & Zhao, 2015). The SJR measures the weighted citations received by the documents. The weighting of citations depends on the subject area and the prestige of the source of the citations (Falagas *et al.*, 2008).

Finally, a qualitative systematic review was carried out to analyse the scientific production based on the different groups into which the economic valuation methodologies of ES can be classified (Farber *et al.*, 2006): i) market-based valuation; ii) valuation based on revealed preferences; iii) valuation based on stated preferences; and iv) value transfer valuation methods. In addition, the variables analysed in this review are the area of study, the type of ecosystem, and the category of services used for the valuation. Figure 2 shows the methodology applied in this study.

Results

Quantitative analysis of the evolution of the research on EVES

Principal variables

Table 1 shows the evolution of the principal characteristics of the research studies on the economic valuation of ecosystem services (EVES) published in the period 2000–2021 (articles, authors, references, citations, journals and countries). The evolution of the number of articles on EVES has followed a growing trend from the beginning of the period. In 2000, six articles were published on this topic, while in 2021 a total of 210 were published. Only 35.2% of the total articles of the sample were published in the first 15 years of the period analysed, while 50.2% were published over the last five years (2017–2021). This trend indicates that the research in EVES has gained weight over the years until reaching a maximum number of articles published in 2021.

Table 1 shows the annual growth of the number of authors that increased from 11 in 2000 to 810 in 2021. However, 80.8% of the total authors only participated in the writing of one article, while just 2.3% participated in five articles or more. With respect to the evolution of the number of journals in which articles on EVES are published, it can be observed that the group of journals has grown, given that in 2000 just six journals published articles on the subject while in 2021 the number of journals was 114. With regard to the evolution of the number of countries that have published articles on EVES, the participation of an increasing number of countries in this field of study stands out, indicating that the EVES is receiving increasingly more attention on a global level. Specifically, in the year 2000 only two countries published articles on EVES while in 2021 there were a total of 64.

During the period of study, the articles of the sample in total were cited 45011 times, which is an average of 25.8 citations per article. This variable experienced exponential growth from the first citation in the year 2000 to the year 2021 with 8078 citations. Therefore, more than 65% of the total citations were concentrated in the last five years of the period analysed. With respect to the language in which the articles on EVES were published, 89.9% were published in English. This is followed by Chinese with 7.4% and Spanish with 1.9% of the total articles in the sample. The rest of the languages used, while accounting for less than 1%, were German, Portuguese, French, Persian, Japanese, Czech, Italian, Polish and Russian.

Distribution of articles published by journals

Table 2 shows the group of journals in which the highest number of articles on EVES was published between 2000 and 2021. In addition to the number of articles published (A), the table includes the impact (SJR), the country of the journal (C), the total number of citations of the articles of each journal (TC), the average number of citations per article (TC/A), the year of publication of the first article (1st A) and that of the last article on EVES of each journal (Last A).

The group made up of the first 11 journals in this ranking account for 35.3% of all of the articles published, which indicates a high concentration of the production in this subject area. In fact, almost 20% of the scientific production on EVES is concentrated in the first two journals of this ranking, which are the main benchmarks in this field of research. Of the top eleven journals, six are from the Netherlands, two from the United Kingdom, and one from Switzerland, China and the United States. They are all high quality journals, given that they are in the first quartile in terms of their SJR, except the Chinese journal.

The journal with the largest number of articles published on EVES is Ecological Economics, with a total of 171 articles, representing 9.8% of the total sample. Its first article on this subject was published in 2000, so it is also the most veteran in the group. This journal held the leadership in terms of the number of articles published from the beginning of the period analysed until 2015, when it was overtaken by Ecosystem Services. With respect to the number of accumulated citations, it also holds the first position with 12073 as it does in the average number of citations per article with 70.6. Furthermore, this journal has the highest H index (56) and the second highest SJR index (1.778). It is followed in terms of the number of articles published by Ecosystem Services with 145 (8.3% of the total) and, a long way behind, Land Use Policy with 48 (2.8% of the total), Journal of Environmental Management and Sustainability with 45 each one (2.6% of the total). Science of the Total Environment is the journal with the highest SJR index at 1.806. Sustainability is the journal that has most recently begun to publish on this topic, with its first article on EVES published in 2015. All the journals in the list maintain this line of publication in 2021.

Distribution of the articles published by country, institution and author

Table 3 shows the principal characteristics of the 10 countries with the highest number of articles on EVES between 2000 and 2021. In addition to the number of articles (A) it also includes the average number of articles per capita (APC), the total number of citations obtained with these articles (TC), the average number of citations per article (TC/A), the H index and the year of publication of the first article (1stA) and last article on EVES. The USA is the country with the highest number of articles on EVES in the period analysed with a total of 400 (22.9% of the total). This is followed by China with 301 (17.3% of the total), the UK with 215 (12.3% of the total), Australia with 122 (7.0% of the total) and Germany with 121 (6.9% of the total). However, when the publications are weighted in accordance with the population, the most prolific country is the Netherlands with 5.619 articles per million inhabitants. This is followed by Australia with 4.748, the UK with 3.199 and Spain with 2.491. The country with the highest total number of citations is also the USA with 13886 citations (30.9% of the total), followed by the Netherlands with 7747 (17.2% of the total), the UK with 7325 (16.3% of the total) and Germany with 5356 (11.9% of the total). However, the Netherlands is the country with the highest average number of citations per article, with 79.1. This is followed by France with 62.5, Germany with

44.3 and Australia with 38.2. Therefore, the articles published by these countries receive greater recognition based on the citations obtained. Figure 3 depicts the network of cross-country collaborations in EVES research.

Table 4 shows the percentage of articles elaborated by each country through international collaboration [IC(%)], the number of countries with which these collaborations were produced (NC), the five countries which have been collaborated with the most times (ordered in descending order per number of articles) and the average number of citations obtained by the articles produced through international collaboration (TC/A-IC) and those that were published without this international collaboration (TC/A-NIC). The countries with the highest percentage of studies carried out through international collaboration are the Netherlands (74.5%), the UK (70.7%), and France (70.2%). The USA is the country with the largest collaboration network with 65 different collaborators. These include the UK, China, Australia, Canada, and the Netherlands. The UK forms part of the group of the principal collaborators of the rest of the countries making up the top ten.

Table 5 shows the main characteristics of the institutions with the highest number of articles published on EVES. These are the country of the institution (C), the number of articles on EVES (A), the number of citations obtained with these studies (TC), the average number of citations per article (TC/A), the H index of the articles, the percentage of these articles carried out through international collaboration [IC(%)], the average number of citations obtained by the articles carried out through international collaboration (TC/A-IC) and those carried out without international collaboration (TC/A-NIC).

The Chinese Academy of Sciences holds the first position with 85 articles, representing 4.9% of the total sample. In terms of the number of articles, it is followed by Vrije Universiteit Amsterdam of the Netherlands with 42 (2.4% of the total), the Wageningen University of the Netherlands with 36 (2.1% of the total), the Natural Resources Institute Finland Luke with 28 (1.6% of the total), and the Helmholtz Zentrum für Umweltforschung of Germany and the Københavns Universitet of Denmark with 26 (1.5% of the total). In terms of the number of citations, Wageningen University stands out with a total of 5300 (11.8% of the total). This is followed by the Helmholtz Zentrum für Umweltforschung with 2587 (5.7% of the total), the Vrije Universiteit Amsterdam with 2134 (4.7% of the total), and the Chinese Academy of Sciences with 1129 (2.5% of the total). The Wageningen University also has a high average number of citations per article with 147.2, followed by the Helmholtz Zentrum für Umweltforschung with 99.5 and the Vrije Universiteit Amsterdam with 50.8.

On average, the international collaboration of the most prolific institutions is 62.1% of the total articles. However, certain institutions stand out, such as the University of Leeds, which conducted 90.5% of its articles in collaboration with institutions from other countries. Other centres that are prominent in this sense are Wageningen University (86.1%), the Københavns Universitet (80.8%), the University of East Anglia from the UK (72.0%), the Vrije Universiteit Amsterdam (64.3%), and the Sveriges lantbruksuniversitet from Sweden (63.6%). On the other end of the scale, those with a low level of international collaboration are the Chinese Academy of Sciences (20.0%), the Natural Resources Institute Finland Luke (42.9%), and the Helmholtz Zentrum für Umweltforschung (46.2%). This is because these institutions focus almost exclusively on topics of national interest.

Table 6 includes the principal characteristics of the twelve authors who have published the most articles on EVES. In addition to the name of the authors, it shows the number of articles on EVES of each of them (A), the total citations accumulated in these articles (TC), the average number of citations per article (TC/A), the H index of these articles, the country of affiliation (C) and the institution (AF), and the year of publication of the first article (1st A), and the last article on EVES (Last A).

Among the group of authors who have published the most articles on EVES, it is possible to distinguish authors who already have extensive experience in this field of research, given that they published their first article at the beginning of the period (Robert Costanza), together with other authors who have begun their research in the field more recently (Jérôme Dupras). In first place, in terms of number of articles, we find a group of 5 authors, with 12 articles each. These are Robert Costanza, from University College London, Jérôme Dupras, from Université du Québec en Outaouais, Andrea Ghermandi, from University of Haifa, R. Kerry Turner, from University of East Anglia, and Minjuan Zhao, from Northwest A&F University. Costanza is the author with the highest total number of citations in studies on EVES, with a total of 1117. In second place is Berta Martín-López, from the Leuphana Universität Lüneburg in Germany, with 1113. Peter H. Verburg, from the Vrije Universiteit Amsterdam, holds the third position in terms of the number of citations with 940. However, in terms of the average number of citations per article, Martín-López ranks first with 99.6, followed by Verburg with 94.0 and Costanza with 93.1.

Qualitative analysis of the evolution of the research on EVES

The articles that make up the sample were systematically reviewed to identify those that include an empirical application. From the total sample, 1371 articles were selected. These papers were classified according to the economic valuation methodologies implemented in each of them, the region in which the study was conducted, the type of service analysed and the type of ecosystem studied. The results are presented in different tables and will be analysed in the following sections.

General analysis

The methodologies for the economic valuation of ES have been grouped into four categories (market value, value of revealed preferences, value of stated preferences, and value transfer methods). The majority of the studies in the sample have used one or more methodologies of a single category (86.0%), while 14.0% have used a mixed combination of different types of methodologies. This explains why, in the individual analysis, the percentage sum is greater than 100%. In terms of the different types of methodology, techniques based on stated preferences dominate with 49.7% of the articles reviewed. These are followed by the series of market methodologies that were used in 36.3%, those based on value transfer methods with 21.4% and techniques of revealed preferences with 10.7%. With respect to the geographical scope, Asia is the region that is the object of study for the most number of articles on EVES (30.6%). The rest of the studies are divided between Europe (29.8%), North America (16.7%), Africa (8.4%), South America (6.0%), Oceania (4.2%), Middle East (3.4%) and Central America and the Caribbean (2.3%). There are a number of studies that do not focus on any particular region, but rather assess ecosystem services at a supra-regional or global level. Some examples are Siikamäki *et al.* (2012), Hynes *et al.* (2013), or Song (2018).

With respect to the different ecosystems analysed, 39.3% of the articles study forests; 35.4% analyse inland water ecosystems; 28.5% focus on agricultural ecosystems; 18.2% on coastal and grassland ecosystems; 15.6% study urban areas; 6.4% explore the ocean and marine ecosystems; 1.8% mountains; 1.6% deserts; 0.6% polar environments and 0.2% study islands. Furthermore, 25.6% of the studies evaluate the provision of services of a group of different kinds of ecosystems. These include those by De Valck *et al.* (2016), Liu *et al.* (2010), and Frélichová *et al.* (2014). The ES have been classified as provisioning, regulating and cultural. The results reveal that 49.6% analyse the provision of a single type of service as opposed to 50.4% that evaluate services corresponding to more than one category. From these categories, it is observed that 75.1% of the studies analyse regulatory services, 57.7% analyse cultural services and 49.0% analyse provisioning services.

Table 7 shows the percentage of studies carried out in the different geographical areas and are distinguished according to the type of ES analysed. A significant difference between the regions can be observed. In general, it can be observed that as the level of development of a region increases, evaluations of provisioning services lose weight in favour of regulating and cultural services. Africa is the region where the three categories of services have been assessed most homogeneously. Regulating services are the most valued in all regions of the world, although they are particularly prominent in Central America and the Caribbean, Oceania and Asia. Asia, Central America and the Caribbean and Africa have a much higher percentage of studies on provisioning services than the other regions. The regions where most attention is paid to cultural services are Asia and Europe, with a lesser role in North and South America and Africa. Finally, Asia and Central America and the Caribbean are the regions with the highest percentage of valuation studies including more than one category of services, while North and South America have the highest percentage of studies focusing on a single category.

Table 7 also shows the distribution of the studies in accordance with the type of ecosystem, also distinguishing them according to the type of ES category analysed. The results show a predominance of studies assessing regulating services for all ecosystem types, except for marine, mountain and polar environments, where more cultural services have been assessed. Provisioning services are not the most studied services in any type of ecosystem. However, polar, desert and grassland environments have the highest percentage of provisioning service assessments compared to other ecosystems. Cultural services is the second most studied category in all ecosystems. Furthermore, the percentage of these works by type of ecosystem is very similar, with polar, mountain and marine ecosystems standing out. Desert ecosystems are the only ecosystem type where cultural services occupy the last position. As for the work that assesses more than one service category simultaneously, there are notable differences depending on the type of ecosystem. Island, polar, desert and grassland ecosystems have the highest percentage of multiservice work. Marine, coastal, agricultural, urban and forest ecosystems are the ecosystems where a single category of service is most valued.

Analysis by type of methodology

As mentioned, the most commonly used methodologies have been those of the group based on stated preferences, followed by the series of market based methodologies, value transfer methods and revealed preferences. With regard to specific methodologies, in absolute terms, the most used were choice experiment with 26.3% of the total number of papers in the sample analysed, contingent valuation with 24.1%, market price with 23.3%, benefit transfer with 20.5%, and replacement cost with 10.5%. The remaining methods do not reach 10% of the papers in the sample. By category, of the studies reviewed that use stated preferences methodologies, 48.5% use the contingent valuation and 52.9% are based on choice experiment. The different methodologies included in the market category are distributed in the following way. The market price method was the most widely used of the market based tools, with 66.7% of the papers. This is followed by replacement cost with 31.3%, avoided cost with 24.4%, restoration cost with 15.0%, provision cost with 7.5%, production function with 7.3%, and social cost with 6.9%. From all the papers in which value transfer has been used, 95.6% use benefit transfer while 5.1% use meta-analysis. Of the studies that used revealed preferences, 84.4% used the travel cost method and 17.7% used the hedonic price method.

Table 8 shows the distribution of paper based on the method used by region. As mentioned above, the most commonly used methodologies have been those based on stated preferences. At regional level, on average 49.9% of the work has been carried out using these methods. The case of Europe stands out, where this percentage rises to almost 60%. However, in terms of specific methodologies, Oceania is the one that has made most use of choice experiments with 43.1% of its studies, while the Middle East stands out for contingent valuation with 37.0%. Asia is the only region where market-based methodologies have been used above all other categories with 43.9% of its valuation work. It is followed by Oceania with 41.4% and the Middle East with 39.1%. Within this group of methods, the market price method stands out, with Asia being the region that has used this method the most, with 33.4% of its valuations. The replacement cost method is the second most used method in its category, standing out in the Middle East (23.9%), Asia (16.7%), and Oceania (12.1%). Other methods that stand out in some regions are avoided cost in Oceania (12.1%) and restoration cost in Asia (10.5%). On average, value transfer methodologies have been used in 20.0% of the work at the regional level. However, the use of this methodology has been more intense in Oceania and Asia, with 27.6% and 27.4% of their valuation studies respectively. These data are mainly based on the use of the benefit transfer approach, since in comparative terms, the use of meta-analysis is residual. Finally, the group of methods based on revealed preferences accounts for approximately 10.0% of the papers in each region. This percentage is the highest in the Middle East where it reaches 17.4%, followed by Asia and Oceania where it is around 12.0%. In all regions, the use of the travel cost method predominates over the use of hedonic pricing.

Table 8 also shows the distribution of the studies according to the method used by ecosystem. In contrast to the analysis by region, when it comes to the classification by ecosystem, the use of the different methodological typologies is more balanced. On average, stated preference-based methods have been used in 39.1% of the studies, while value transfer-based methods have been used in 38.8% and market-based methods in 27.7%. Stated preference methods include the largest number of studies in all ecosystem types except desert, polar, grassland and urban environments where value transfer studies predominate. Regarding the most used methodologies within each category, in terms of stated preferences, choice experiments stand out, especially in island (66.7%), marine (28.4%), and mountain (24.0%) ecosystems. The use of contingent valuation is most significant in marine (29.5%), inland water (25.5%), and coastal (21.2%) ecosystems. In terms of value transfer, benefit transfer is the dominant methodology, especially in desert (63.6%), polar (62.5%), and grassland (45.0%) ecosystems. Within market-based methodologies, market price is dominant across all ecosystem types. Deserts and mountain ecosystems also show a high use of replacement cost (18.2% and 12.0% respectively). The avoided cost methodology is used to a greater extent in mountain (12.0%) and coastal (10.8%) ecosystems. The remaining market-based methodologies do not reach 10% of work in any ecosystem type. Finally, in terms of revealed preference methods, the use of travel cost predominates, especially in polar (12.5%), mountain (12.0%) and coastal (12.0%) ecosystems. The use of the hedonic price method is residual in comparative terms.

Discussion

First, it is important to take into account the time and spatial scale in the economic value of ecosystem services. Spatial heterogeneity can be observed in both the provision of the different types of ES (Paletto *et al.*, 2015) and in the preferences of people (Rai *et al.*, 2015; Khan *et al.*, 2019). With respect to the time aspect, the dynamic nature of the provision of ES makes it necessary to consider the variation in these services over time and their impact on the projected value of the services (Singh *et al.*, 2019). In their studies, Barbier (2012), Tardieu and Tuffery (2019), Groshans *et al.*, (2018), and Mikhailova *et al.*, (2019), among others, indicate the importance of incorporating these dimensions in the analysis of EVES.

In terms of methodology, these issues are particularly relevant when extrapolating values from previous studies through the benefit transfer method. The differences existing between the contexts for which the values were originally calculated and the context where they are to be transferred call into question the reliability of the estimates carried out (Ruiz-Agudelo & Bello, 2014; Zhang *et al.*, 2014; Ghermandi *et al.*, 2018). Also noteworthy in terms of the use of the different methodologies is that the techniques based on prices and costs have been used for valuing provisioning and regulating services (Anderson *et al.*, 2017). The techniques based on preferences have been used more homogeneously, encompassing all of the categories and services as well as regions and ecosystems.

With respect to preference-based methodologies, two relevant questions arise when undertaking valuation projects; the subjective nature of the estimates and the heterogeneity between the different social sectors with respect to the benefit obtained from the ES. Variables such as income, age, level of education, religious beliefs, etc. affect the value that each person attributes to the ES. This is particularly important in the economic valuation of cultural services, which have an even greater subjective element (Zandi *et al.*, 2018; Liu *et al.*, 2019a). The poorer groups experience a higher degree of dependence with respect to the flow of ES, particularly the provisioning services (Badola *et al.*, 2010; De Rezende *et al.*, 2015; Khan *et al.*, 2017). These stakeholders have a lower purchasing power which translates into a lower willingness to pay (Liu *et al.*, 2019b). Therefore, the preferences of the agents with a greater purchasing power have greater weight in the estimates (Bell *et al.*, 2017; Yu *et al.*, 2018). The identification of the different stakeholders and the level of dependence with respect to the flow of ES enables the potential conflict in environmental management to be valued (Raheem *et al.*, 2012) and, in turn, enables the correct valuation of the projects in which the interests of all of the agents involved are represented equally (Koschke *et al.*, 2012; Newton *et al.*, 2012).

With respect to the geographical scope, the results obtained in the bibliometric analysis reveal that the institutions involved in the study of EVES are concentrated in Europe, the United States, Australia and China. This conditions the distribution of the studies in terms of areas of study, with an under-representation in the available databases of the less-developed regions, such as South America and Africa (Reynaud & Lanzanova, 2017). It may be concluded that there is a need to complement existing databases with valuations of ecosystem services at different scales and socio-economic contexts in order to correct the under-representation of developing countries.

One of the main challenges for this field of research is related to the dynamic nature of the biological systems and the provision of ES. This is the high degree of uncertainty and the high sensitivity that the economic analyses have in relation to it (Gren, 2019; Solomon *et al.*, 2019). The problem of uncertainty hinders the incorporation of the ES in decision making, in view of the risk of providing information to the policy makers that underestimates the true socio-economic impact of the environmental degradation (Farr & Stoeckl, 2019).

The results also show that in order to enhance the value of the ecosystems and adopt effective management measures it is necessary to value the services supplied comprehensively, as a whole (Gan *et al.*, 2011; Rodríguez-Osuna *et al.*, 2014; Widney *et al.*, 2018). In order to incorporate the value of multiple ES, it is necessary to overcome certain methodological difficulties particularly linked to the aggregation of different valuations. In this sense, it is highly important to study the relations emerging between the different services (Roebeling *et al.*, 2013; Moondoko *et al.*, 2016). These synergies and trade-offs, as indicated by Hill *et al.* (2014), should be taken into account when designing a management plan for ES that seeks an optimum balance between them, given that different studies reveal the over or under-valuation of the services due to a failure to consider these relationships (Smith *et al.*, 2017; Kecinski *et al.*, 2018; Toledo *et al.*, 2018).

The development of new technologies, the greater availability of information and the capacity to process large databases are some of the fundamental elements that have enabled the development of this field and form the base on which to continue working in order to resolve the challenges. In order to optimise the resources for research, it is necessary to reinforce collaboration relationships to create multidisciplinary teams. In this respect, significant progress has been made. However, many studies reveal greater effort is still required to integrate both the different disciplines and the different groups of stakeholders involved in common projects in order to correctly identify and value the ES. It is also necessary to incorporate this information into decision making (Schmidt *et al.*, 2016; Vermaat *et al.*, 2016; Johnston *et al.*, 2017).

Conclusions

The main objective of this paper was to analyse the evolution of research on the economic valuation of ecosystem services. This main objective was divided into two specific objectives. The first one was to analyse the set of general variables on publications in this field of study by means of a bibliometric analysis. The results of this first part of the work show that research on EVES follows a growth trend, which is accentuated during the last five years of the period analysed. This growth is homogeneous for all variables, affecting both the number of documents published and the number of authors, institutions, countries and journals involved in the research. The countries that lead research in this field are among the most developed, especially concentrated in Europe and North America, where the most relevant institutions and authors are to be found.

The second specific objective focused on the qualitative analysis of the geographical scope, methodology, ecosystem type and service category within empirical studies. The results obtained show that there are significant differences in the analyzed variables. There is a bias in the application of methodology in favour of techniques based on stated preferences and market methodologies, to the detriment of those based on value transfer methods and techniques of revealed preferences. The same is true in terms of geographical scope, with most studies concentrated in Asia (especially China), Europe and North America. By ecosystem type, studies focus on forests, inland waters and agricultural systems, with little work on other ecosystem types. Within the ecosystem category, papers analysing regulating services are of particular relevance.

Despite the rigorous methodological procedure used, this work is not without limitations. Firstly, the main limitation derives from the enormous volume of literature available on the subject of study, which prevents a more specific treatment of each paper and forces generalization in some aspects. Secondly, the process of selecting a representative sample of papers requires a series of decisions to be made that condition the result, such as the repository, the search parameters and the papers acceptance criteria. Despite these limitations, the results and conclusions drawn are still robust and valid

Finally, results highlight the need to continue expanding knowledge on the following aspects: i) temporal and spatial scale in the economic value of ecosystem services; ii) the subjective nature of the estimates and the heterogeneity between the different social sectors regarding benefit, actors and the level of ES-flow dependence; and iii) complementing databases with valuations of ecosystem services at different scales and socio-economic contexts. Furthermore, the provided services should be valued in a comprehensive and holistic manner.

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Annex

Table 1. Major characteristics of the articles on EVES

Year	A	AU	J	C	TC	TC/CA
2000	6	11	6	2	1	0.2
2001	9	21	8	6	6	0.5
2002	5	14	4	3	16	1.2
2003	7	30	6	6	24	1.7
2004	7	18	4	4	42	2.6
2005	10	23	10	7	51	3.2
2006	26	69	13	13	125	3.8
2007	26	76	19	15	215	5.0
2008	34	97	25	20	263	5.7
2009	48	146	40	27	424	6.6
2010	66	230	44	26	751	7.9
2011	62	223	44	24	896	9.2
2012	86	363	53	37	1289	10.5
2013	94	338	59	40	1898	12.3
2014	127	571	77	50	2553	14.0
2015	128	498	74	49	3102	15.7
2016	128	551	80	53	3724	17.7
2017	137	492	80	49	4327	19.6
2018	164	698	75	59	5029	21.1
2019	167	649	98	58	5712	22.8
2020	197	795	112	57	6485	24.1
2021	210	810	114	64	8078	25.8

A: the annual number of total articles; AU: the annual number of authors; J: the annual number of journals; C: the annual number of countries; TC: the annual number of citations in cumulative articles; TC/CA: annual total citation per cumulative article.

Table 2. Top ten most productive journals in EVES

Journal	A	SJR	H index*	C	TC	TC/ A	1st A	Last A
Ecological Economics	171	1.778(Q1)	56	Netherlans	12073	70.6	2000	2021
Ecosystem Services	145	1.749(Q1)	36	Netherlans	4292	29.6	2012	2021
Land Use Policy	48	1.635(Q1)	18	UK	772	16.1	2013	2021
Journal of Environmental Management	45	1.481(Q1)	22	USA	1354	30.1	2001	2021
Sustainability	45	0.664(Q1)	10	Switzerland	241	5.4	2015	2021
Science of the Total Environment	35	1.806(Q1)	16	Netherlans	625	17.9	2004	2021
Environmental and Resource Economics	28	1.416(Q1)	14	Netherlans	1058	37.8	2003	2021
Ecological Indicators	26	1.284(Q1)	14	Netherlans	972	37.4	2007	2021
Forest Policy and Economics	25	1.057(Q1)	14	Netherlans	475	19.0	2005	2021
Ocean and Coastal Management	24	0.969 (Q1)	13	UK	399	16.6	2009	2021
Shengtai Xuebao	24	0.252(Q3)	6	China	85	3.5	2014	2021

*: Only sample items.
A: the annual number of total articles; SJR: Scopus Journal Ranking (2021); C: country; TC: the annual number of citations in total articles; TC/A: number of cites by article; 1stA: first article of EVES research by journal.

Table 3. Most productive countries in EVES

Country	A	APC	TC	TC/A	H index*	1st A	Last A
USA	400	1.207	13886	34.7	60	2000	2021
China	301	0.213	3078	10.2	28	2001	2021
UK	215	3.199	7325	34.1	50	2003	2021
Australia	122	4.748	4665	38.2	38	2001	2021
Germany	121	1.455	5356	44.3	36	2006	2021
Spain	118	2.491	3787	32.1	37	2001	2021
Netherlands	98	5.619	7747	79.1	37	2006	2021
Italy	96	1.615	2966	30.9	28	2008	2021
Canada	62	1.630	2321	37.4	22	2005	2021
France	57	0.846	3561	62.5	24	2003	2021

*: Only sample items.
A: the annual number of total articles; APC: the average per capita articles TC: the annual number of citations in total articles; TC/A: number of cites by article; 1stA: first article of EVES research by country.

Table 4. International collaboration between the most productive countries in EVES

Country	IC (%)	NC	Main collaborators	TC/A	
				IC	NIC
USA	44.25	65	UK, China, Australia, Canada, Netherlands	34.2	35.1
China	20.60	34	USA, Australia, Canada, Japan, UK	20.8	7.5
UK	70.70	58	USA, Netherlands, Australia, Spain, Germany	33.6	35.1
Australia	65.57	47	USA, UK, China, Netherlands, Canada	41.3	32.5
Germany	59.50	47	UK, Italy, Netherlands, France, Sweden	48.3	38.4
Spain	55.08	43	UK, Italy, USA, Portugal, Germany	32.8	31.2
Netherlands	74.49	53	UK, USA, Germany, Italy, Australia	46.6	173.7
Italy	57.29	45	UK, Germany, Netherlands, Spain, USA	39.2	19.7
Canada	58.06	16	USA, Australia, China, UK, Germany	51.6	17.8
France	70.18	43	Germany, UK, USA, Australia, Italy	79.7	21.9

IC: international collaborations; NC: total number of international collaborators; TC/A: total citation per article; NIC: no international collaborations.

Table 5. Most productive institutions in EVES

Institution	C	A	TC	TC/A	H index *	IC (%)	TC/A	
							IC	NIC
Chinese Academy of Sciences	China	85	1129	13.3	19	20.0	26.2	10.1
Vrije Universiteit Amsterdam	Netherlands	42	2134	50.8	24	64.3	49.4	53.4
Wageningen University & Research	Netherlands	36	5300	147.2	22	86.1	60.3	686.4
Natural Resources Institute Finland Luke	Finland	28	305	10.9	12	42.9	6.4	14.3
Helmholtz Zentrum für Umweltforschung	Germany	26	2587	99.5	17	46.2	169.3	39.7
Københavns Universitet	Denmark	26	790	30.4	16	80.8	32.5	21.4
University of East Anglia	UK	25	1002	40.1	15	72.0	42.9	32.7
Sveriges lantbruksuniversitet	Sweden	22	316	14.4	9	63.6	18.6	7.0
University of Leeds	UK	21	840	40.0	16	90.5	43.1	10.5
University of Haifa	Israel	20	363	18.2	11	55.0	25.1	9.7

*: Only sample items.
C: country; A: the annual number of total articles; TC: the annual number of citations in total articles; TC/A: number of cites by article); IC: international collaborations; NIC: no international collaborations.

Table 6. Most productive authors in EVES

Author	A	TC	TC/A	H index*	C	AF	1st A	Last A
Costanza, Robert	12	1117	93.1	9	UK	University College London	2000	2021
Dupras, Jérôme	12	179	14.9	7	Canada	Université du Québec en Outaouais	2014	2021
Ghermandi, Andrea	12	318	26.5	10	Israel	University of Haifa	2013	2021
Turner, R. Kerry	12	655	54.6	8	UK	University of East Anglia	2008	2021
Zhao, Minjuan	12	124	10.3	8	China	Northwest A&F University	2013	2021
Brouwer, Roy	11	426	38.7	10	Netherlands	Vrije Universiteit Amsterdam	2011	2019
Hanley, Nick D.	11	259	23.5	9	UK	University of Glasgow	2013	2021
Juutinen, Artti	11	128	11.6	7	Finland	Natural Resources Institute Finland Luke	2013	2021
Martín-López, Berta	11	1096	99.6	11	Germany	Leuphana Universität Lüneburg	2007	2016
Koetse, Mark J.	10	440	44.0	7	Netherlands	Vrije Universiteit Amsterdam	2011	2021
Schaafsma, Marije	10	293	29.3	7	Netherlands	Vrije Universiteit Amsterdam	2011	2021
Verburg, Peter H.	10	940	94.0	10	Netherlands	Vrije Universiteit Amsterdam	2009	2018

*: Only sample items.

A: the annual number of total articles; TC: the annual number of citations in total articles; TC/A: number of cites by article; C: country; AF: affiliation; 1^{st}A: first article of EVES research by author.

Table 7. Types of ES studied by region (%) and ecosystem (%)

Region	Provisioning	Regulating	Cultural	Mixed
Africa	59.1	66.1	49.6	47.0
Asia	66.6	81.1	64.7	63.7
Central America and Caribbean	58.1	83.9	54.8	61.3
Europe	39.1	71.9	61.1	46.5
Middle East	32.6	78.3	50.0	41.3
North America	34.5	72.9	48.9	39.3
Oceania	46.6	82.8	53.4	53.4
South America	43.9	68.3	47.6	40.2
Ecosystem	**Provisioning**	**Regulating**	**Cultural**	**Mixed**
Agriculture	56.3	83.6	56.3	57.0
Coastal	49.6	76.8	61.2	54.8
Desert	81.8	90.9	68.2	72.7
Forests	57.3	77.0	64.4	58.3
Grassland	63.9	85.1	67.9	65.9
Inland water	51.2	82.7	59.9	59.7
Island	33.3	100.0	66.7	100.0
Marine	47.7	64.8	65.9	48.9
Mountain	48.0	68.0	76.0	60.0
Polar	87.5	87.5	100.0	87.5
Urban	51.9	77.6	71.5	57.9

Table 8. Method used by region (%) and ecosystem (%) studied

	Market-based methods							Revealed preferences		Stated preferences		Value transfer methods	
Region	**MP**	**RPC**	**AC**	**RTC**	**PF**	**PC**	**SC**	**TC**	**HP**	**CV**	**CM**	**BT**	**MA**
Africa	26.1	6.1	7.8	0.0	3.5	2.6	0.0	6.1	2.6	20.0	27.8	20.0	0.0
Asia	33.4	16.7	9.8	10.5	2.1	3.1	3.3	11.0	1.7	26.7	16.0	26.5	1.0
Central America and Caribbean	22.6	9.7	9.7	3.2	3.2	3.2	3.2	6.5	0.0	32.3	25.8	19.4	0.0
Europe	17.8	8.1	6.8	3.2	2.0	3.4	2.7	10.3	0.5	25.2	35.0	15.9	0.7
Middle East	19.6	23.9	4.3	2.2	4.3	0.0	4.3	13.0	4.3	37.0	13.0	17.4	0.0
North America	14.0	7.4	8.7	3.5	4.8	1.7	0.9	7.0	4.4	17.5	27.9	16.6	3.1
Oceania	24.1	12.1	12.1	5.2	0.0	3.4	5.2	8.6	3.4	5.2	43.1	27.6	0.0
South America	23.2	6.1	8.5	6.1	4.9	6.1	0.0	2.4	1.2	30.5	23.2	19.5	1.2
Ecosystem	MP	RPC	AC	RTC	PF	PC	SC	TC	HP	CV	CM	BT	MA
Agriculture	24.0	10.7	9.0	3.8	4.6	4.1	2.3	4.3	0.0	15.6	22.5	31.5	1.0
Coastal	24.8	10.8	10.8	2.4	2.0	2.8	2.4	12.0	0.8	21.2	22.0	29.2	0.8
Desert	4.5	18.2	4.5	0.0	0.0	0.0	0.0	0.0	0.0	13.6	0.0	63.6	0.0
Forests	24.3	10.4	7.6	4.6	2.8	3.0	2.2	9.5	1.5	18.9	23.0	28.8	1.3
Grassland	21.3	12.4	6.8	4.4	1.2	3.6	2.8	6.4	0.0	13.3	18.9	45.0	1.6
Inland water	20.4	13.0	7.0	7.2	1.6	2.9	2.5	9.1	0.8	25.5	22.8	31.1	2.3
Island	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.7	33.3	0.0
Marine	25.0	5.7	4.5	1.1	4.5	2.3	4.5	6.8	0.0	29.5	28.4	22.7	1.1
Mountain	12.0	12.0	12.0	8.0	0.0	4.0	0.0	12.0	0.0	12.0	24.0	32.0	4.0
Polar	25.0	12.5	0.0	0.0	0.0	0.0	0.0	12.5	0.0	12.5	12.5	62.5	0.0
Urban	15.0	10.3	7.9	3.7	1.4	4.2	2.3	7.9	5.6	18.2	13.1	38.8	0.9

MP: direct market price; RPC: replacement cost; AC: avoided cost; RTC: restoration cost; PF: production function; PC: provision cost; SC: social cost; TC: travel cost; HP: hedonic prices; CV: contingent valuation; CM: choice modelling; BT: benefit transfer; MA: meta-analysis.

Figure 1. Components of the total economic value

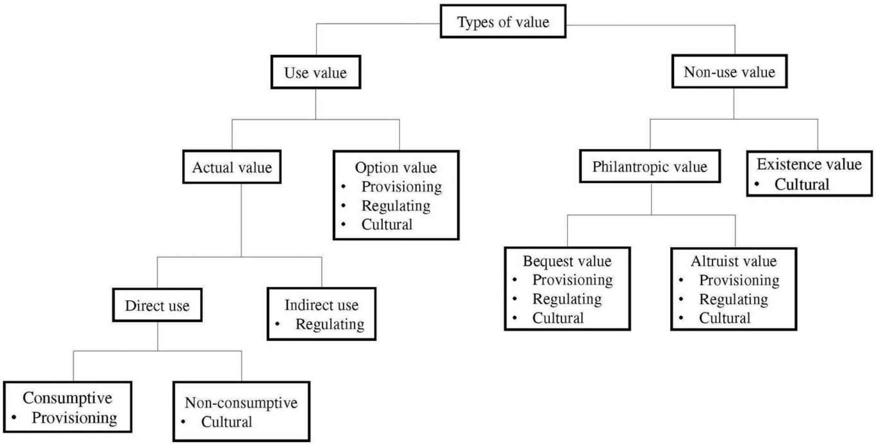

Figure 2. Summary of the methodology

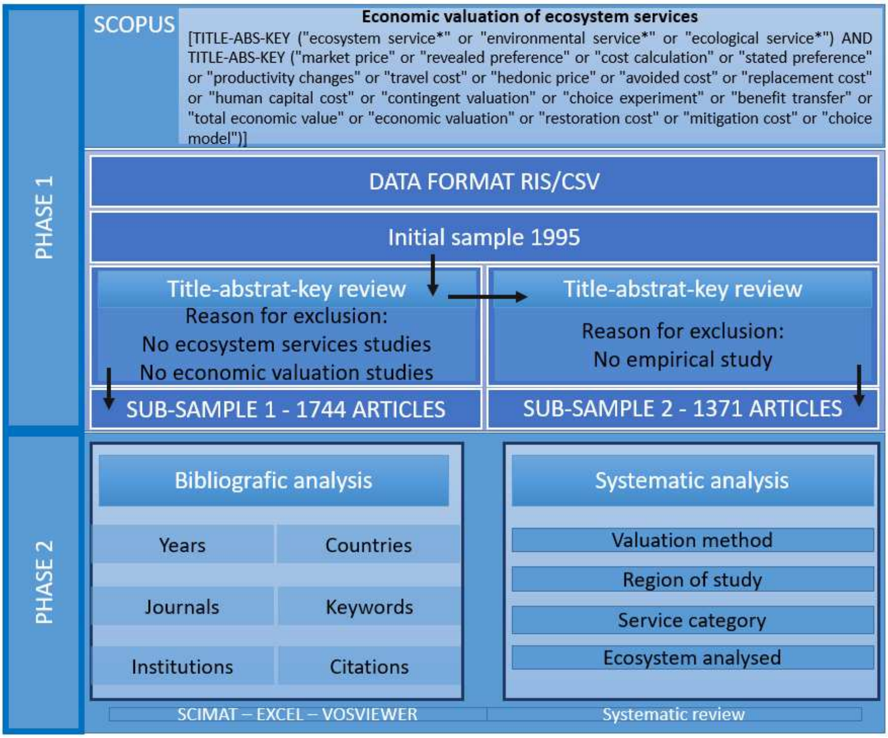

Figure 3. Network of cross-country collaborations in EVES research